RESEARCH ARTICLE

Revision Fixation of Distal Humerus Fracture Nonunions in Older Age Patients with Poor Bone Quality or Bone Loss – Is This Viable as a Long-term Treatment Option?

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Abstract

Background: The purpose of this retrospective study was to analyze the long-term results of revision ORIF, joint contracture release, and autogenous bone-grafting in the treatment of distal humerus frac-ture nonunions in older aged patients with poor bone quality or bone loss who would have been candidates for total elbow arthroplasty.

Methods: Seven patients (average age at index procedure: 53.3 years, range: 41-75) with a distal humerus fracture nonunion treated with revision ORIF, joint contracture release and autogenous bone grafting between 1989-2000 were available for follow-up. Radiographic union and arthrosis were assessed using the most recent radiograph. Pain-related outcomes were measured using PROMIS Pain Interference scores. Functional outcomes were evaluated using the Mayo Elbow Perfor-mance Index (MEPI).

Results: After an average follow-up of 22 years (range: 19-27 years), all nonunions were healed after the index procedure and had an average arc of ulnohumeral motion of 80°, flexion of 112°, and flex-ion contracture of 32°. Average arthrosis grade was moderate joint-space narrowing with osteo-phyte formation. One patient had exertional discomfort but none required chronic pain medica-tions. PROMIS-Pain Interference scores were no different than the general population (mean [95%CI] = 49.2 [41.8, 56.6], *P=0.83*). Per the MEPI, the functional result was excellent in five patients, good in one, and poor in one.

Conclusion: Despite older age and worse bone quality, distal humerus fracture nonunions can be treated using revision ORIF, joint contracture release and autogenous bone-grafting with acceptable long-term outcomes.

Level of evidence: IV

Keywords: Humeral fractures, Osteoporotic fractures, Ununited fracture

Introduction

Distal humerus fractures are involved in approximately 2% of all skeletal fractures, however 2-10% of these injuries can be complicated by nonunion when surgically treated (1, 2). An ununited distal humerus fracture after internal fixation will often result in a painful, functionally unstable elbow that impedes completion of activities of daily living and substantially diminishes the individual's quality of life (2-4). In the older aged patient with poor bone quality or bone stock, treatment options include

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revision open reduction internal fixation (ORIF) or total elbow arthro-plasty (TEA), with soft tissue releases and nerve decompression when indicated (3, 5). The goal of treatment is a painless, functionally stable elbow that allows for completion of activities of daily living.

A number of authors have recommended revision ORIF with soft tissue release for appropriate patients, since this combination of procedures has resulted in good radiographic and functional outcomes while preserving the native elbow joint, however the long-term outcome is not clearly defined (2, 3, 6). More recent studies have advocated for treatment with TEA in older patients with underlying osteoporosis, poor bone quality or poor bone stock given good to excellent re-sults as surgeon experience and TEA implants have improved. In short- to mid-term follow-up, the clinical and functional results of TEA have been similar to revision ORIF for this subset of patients (7-10). In this setting, revision ORIF or TEA may be equally reasonable treatment options, but the longevity of TEA remains in question and the complications of TEA are recognized to be difficult to revise. The long-term radiographic and patient-reported outcomes of revision fixation are unknown (4-6, 11, 12). Thus, the purpose of this retrospective study was to analyze the long-term results of revision ORIF, joint contracture release, and autogenous bone-grafting in the treatment of distal humerus fracture nonunions in older aged patients with poor bone quality or bone loss who would have been candidates for TEA at the time of nonunion surgery.

Materials and Methods

Out of 113 nonunions of the distal humerus treated by the senior surgeon, we chose to review the long-term outcome of a subgroup of 13 patients with poor bone quality or poor bone stock and an average age of 57 years (range: 41-83 years) at the time of the index reconstruction, as a viable alternative treatment option that was considered for this cohort was a TEA. All patients were ini-tially treated operatively with ORIF (with irrigation and debridement if the fracture was open), but went on to nonunion. At the time of the index nonunion operation, all patients demonstrated poor bone stock (due to comminution or loss) on pre-operative films or were found to have poor bone quality intra-operatively. Instead of TEA, all 13 patients were treated with revision ORIF, joint contracture release and autogenous bone grafting. Patients were invited to return for a clini-cal examination or a telephone survey under a protocol approved by the IRB. Informed consent was obtained from each patient either in person or over the phone. Of the 13 eligible patients, 7 patients were available for follow-up and consented to the study [Table 1]. Of those not included, 4 patients had died by the follow-up time of this study, 1 patient was lost to follow-up with-out updated or retrievable contact information, and 1 patient did not consent.

Nonunion was defined as the persistence of a painful joint without evidence of radiographic healing on plain radiography after a minimum of 5-6 months following initial failed treatment (13). Revision open reduction

Table 1. Demographic, injury, and treatment details of patients who sustained a distal humerus fracture with subsequent non-union; ORIF = open reduction internal fixation, I&D = irrigation and debridement

Case	Gender	Age (yr, Procedure)	Age (yr, Follow-up)	Smoking	Diabetes	Injured Side	Open Injury	Intra-articular	Initial Treatment	Interval from Initial Treatment to Index Nonunion Procedure (mo)	Index Nonunion Procedure	Ancillary Procedures
1	F	46	65	No	No	Left	No	Yes	ORIF	5	ORIF, ICBG, anterior and posterior capsulectomy	
2	M	46	67	Yes	No	Left	Yes	Yes	ORIF, I&D	8	ORIF, ICBG	Removal of hardware (symptomatic screw and k-wire)
3	F	56	79	No	No	Right	No	No	ORIF	13	ORIF, ICBG, anterior capsulectomy, ulnar nerve neurolysis	
4	F	59	86	No	No	Right	No	No	ORIF	>6	ORIF, ICBG, anterior and posterior capsulectomy	
5	M	41	59	No	No	Left	No	Yes	ORIF	11	ORIF, ICBG, anterior and posterior capsulectomy	
6	M	75	99	No	No	Right	No	Yes	ORIF	24	ORIF, ICBG, anterior and posterior capsulectomy	
7	M	50	69	No	No	Right	Yes	Yes	ORIF	12	ORIF, ICBG, anterior and posterior capsulectomy	Ulnar nerve neurolysis

and internal fixation was indicated for patients with a preserved articular surface of the dis-tal part of the humerus. Excision of fibrous or synovial tissue was undertaken in all patients due to the presence of joint contracture.

The study group included 3 females and 4 males with an average age of 53.3 years at index non-union surgery (range: 41-75 years) and 74.9 years at follow-up (range: 59-99 years). At the time of index treatment, all patients were employed. The right arm was involved in 4 patients, and all patients were right hand dominant. One patient was an active smoker, and none of the patients had major medical comorbidities. Two patients had an open fracture and one had a right pilon fracture as well. The fracture was intra-articular in five patients. Two patients had ulnar nerve paresthesia and were treated with wide neurolysis (one at the time of the index nonunion proce-dure, and another subsequently). None had motor deficits. The average interval from initial treatment to the index nonunion procedure was 12.2 months (range: 5-24 months).

Operative Technique

The operative technique has been described in detail previously, but a brief summary is provided here (4, 14). The patient is placed in the lateral decubitus position with the arm draped over a bolster. A straight posterior incision incorporating prior incisions is used, with elevation of medial and lateral skin flaps. The ulnar nerve is identified and traced distally through the cubital tunnel, and mobilized at least 6 cm proximally and distally to the medial epicondyle to protect it. It is left in an anteriorly transposed position under the subcutaneous tissues at the end of the procedure. An olecranon osteotomy is used to expose the distal end of the humerus and an apex distal Chevron-shaped osteotomy is created using an oscillating saw followed by careful leverage with a small osteotome to create an irregular surface for later repositioning and repair. The olecranon fragment is elevated with the triceps muscle from the posterior aspect of the humerus and the posterior part of the capsule is excised.

Loose implants and associated tissue are removed; synovial and fibrous tissues are excised. Devi-talized bone is removed, and sclerotic fracture surfaces are perforated using a drill. The anterior part of the elbow capsule is accessed through the fracture site and released from the humeral at-tachments, while preserving the medial and lateral collateral ligaments. Articular fragments are secured provisionally to metaphyseal columns using Kirschner wires. When the distal fragment is large enough such that there is at least 2 cm of metaphyseal bone proximal to the trochlea on the medial and lateral side, two orthogonally oriented 3.5 mm pelvic reconstruction plates are used to provide adequate fixation. When the articular fragment is smaller, a third or fourth plate is some-times required to obtain rigid fixation. Autogenous cancellous bone graft is obtained from the iliac crest and applied to the fracture site.

Post-operative Management

The affected extremity is immobilized in extension using a splint overnight. On the morning of postoperative day 1, the splint is removed and gravity-assisted range of motion is initiated. The patient is encouraged to use the arm for functional activities requiring minimal force. Following healing of the fracture, the patient is allowed unrestricted use.

Evaluation

Final follow-up evaluation was performed by researchers who were not involved in the care of the patient. This evaluation consisted of a survey regarding patient-reported pain and functional outcome for all patients (15). Clinical assessment of stability and range of motion was performed for the three patients who could return for clinic evaluation.

The most recently available anteroposterior and lateral radiographs were evaluated to assess for radiographic union and arthrosis. Arthrosis of the ulnohumeral joint was rated using the system of Broberg and Morrey, as grade 0 (normal), grade 1 (slight joint-space narrowing with minimum osteophyte formation), grade 2 (moderate joint-space narrowing with moderate osteophyte formation), or grade 3 (severe degenerative changes with gross destruction of the joint) (16).

Pain was assessed using several measures, including subjective report of pain in the affected el-bow, use of pain medication, or use of narcotic pain medication. Standardized measurements of pain were assessed using PROMIS Pain Interference and Depression scores, as well as Visual Analog Scales (VAS) in four scenarios (worst pain, pain at rest, pain with lifting, and pain with repeated movements) (1, 4).

Patient-reported functional outcomes were assessed using a subjective Likert satisfaction score (graded from 0-10, with 10 being most satisfied), the Mayo Elbow Performance Index (MEPI), and the PROMIS Physical Function – Upper Extremity Score. Patients also reported their current working status and whether they had difficulty completing activities of daily living or recreation-al activities (using a 4-point Likert scale) (1).

Clinical evaluation for 3 patients who returned for in person follow-up involved assessment of mobility, strength, and stability. Muscle strength was graded per the system of the Medical Re-search Council. Instability was determined by testing for opening or toggling with varus-valgus stress at 30 and 90° of elbow flexion, and by having the patient attempt to lift their body weight from a chair using their arms. Range of motion was assessed on the affected and unaffected side in terms of terminal extension, flexion, pronation, and supination. Pinch and grip strength were also compared between the unaffected and affected sides (17).

Statistical Analysis

Survey responses were collected into a Microsoft Excel 2016 database. Descriptive statistics for demographic characteristics and patient reported outcome measures were calculated. A z-test was used to determine if the distribution of PROMIS scores for this sample was different from the general population (mean = 50, standard deviation = 10). Paired t-tests were used

to evaluate for differences in range of motion, pinch strength, and grip strength between the affected and unaf-fected side in the patients who returned for physical examination. A *P-value<0.05* was consid-ered statistically significant. Stata software, version 14 (StataCorp), or Microsoft Excel was used for all analyses.

This study was approved by our institution's internal review board.

Results

All 7 patients had demonstrated healing of the nonunion by the time of final follow-up [Table 2]. One patient required two additional operations to remove symptomatic hardware. The average arthrosis grade was 2 (moderate joint-space narrowing with moderate osteophyte formation), but the most common arthrosis grade was 1 (slight joint-space narrowing with minimum osteophyte formation; range: 1-3). None of the patients required conversion to total elbow arthroplasty. The final evaluation of these 7 patients was performed at an average follow-up of 22 years (range: 19-27 years) after the index nonunion procedure.

Pain-related outcome measures

One patient had exertional discomfort, but none required chronic pain medications [Table 2]. Four out of 7 patients used occasional over-the-counter pain medication, but none required nar-cotic or chronic pain medication. PROMIS-Pain Interference scores (mean ± SD = 49.2 ± 9.1) and PROMIS-Depression scores (mean ± SD = 49.7 ± 9.5) were no different than the general population (*P=0.83* and 0.92, respectively). VAS scores ranged from 0-6 at rest to 0-9 with activ-ity [Table 2].

Patient-reported functional outcome measures

Average ± SD subjective satisfaction score was 9.6 ± 1.1 (range 7-10). According to the MEPI, the functional outcome was rated as excellent in five patients, good in one, and poor in one [Table 3]. PROMIS Physical Function – Upper Extremity scores were worse in the affected extremi-ty compared to the general population (mean [95%CI] = 41.8 [33.8, 49.8], *P=0.045*) when includ-ing all patients; however, for patients with isolated distal humerus nonunion, PROMIS Physical Function – Upper Extremity scores following treatment were no different than the general popu-lation on average (mean [95% CI] = 49.9 [40.1, 59.7], *P=0.98*). At final follow-up, three patients continued full-time work, three were retired, and only one was unemployed due to injury.

Clinical evaluation of mobility, stability, and strength

Clinical evaluation was completed in the 3 patients who could return for in-person follow-up [Table, Supplemental Digital Content 1]. On average, the arc of ulnohumeral motion was 80°, the affected elbow had a flexion contracture of 32°, terminal flexion of 112° (range: 105-120°, *P=0.03* compared to unaffected elbow), pronation of 67° (range: 60-70°), and supination of 70° (range: 50-85°). All patients had normal power in extension, flexion, pronation, and supination. Grip strength was

Table 2. Radiographic and patient reported pain-related outcomes for 7 patients following distal humerus non-union; *None of the patients had pain in the unaffected elbow; VAS = visual analog scale (1-10)

				Radiographic Outcome				Pain-related Outcomes							
Case	Gender, Age (yr)	Other conditions	Follow-up	Follow-up Time (yr)	Union	Arthrosis	Pain*	Pain Medication	Narcotic Use	PROMIS Pain Interference	PROMIS Depression	VAS (worst)	VAS (rest)	VAS (lifting)	VAS (repeat move-ments)
1	F, 86	Knee osteoarthritis	Clinic Visit	19	Yes	2	0	Yes	No	47.7	52.3	2	0	0	1
2	M, 67	Migraines, bilateral shoulder pain	Clinic Visit	21	Yes	2	0	Yes	No	55.8	46.8	8	0	5	5
3	F, 79	Transient ulnar paresthesia	Clinic Visit	23	Yes	1	0	No	No	46.6	42	0	1	0	0
4	F, 86	Wheelchair bound secondary to recent fall	Telephone call/E-mail	27	Yes	3	0	Yes	No	44.5	63.6	2	0	0	1
5	M, 59	History of ORIF right pilon fracture, arthritis and cramping in hands	Telephone call/E-mail	19	Yes	1	1	Yes	No	66.6	60.7	9	6	9	8
6	M, 99		Telephone call/E-mail	24	Yes	1	0	No	No	41.6	41	0	0	0	0
7	M, 69		Telephone call/E-mail		Yes	1	0	No	No	41.6	41	0	0	0	0
Mean (± SD)				22 ± 3		2				49.2 ± 9.1	49.7 ± 9.5	3.0 ± 3.9	1.0 ± 2.2	2.0 ± 3.6	2.1 ± 3.1
Range				19-27		1-3				41.6-66.6	41-63.6	0-9	0-6	0-9	0-8

Table 3. Patient reported outcome measures related to function for 7 patients following distal humerus non-union

Case	Gender, Age (yr)	Other conditions causing pain or functional limitation at follow-up	Follow-up Time (yr)	Satisfaction Score (0-10)	Mayo Elbow Performance Index (MEPI)	Grade According to MEPI	PROMIS Physical Function - Upper Extremity	Working Status	Job Type	Difficulty Completing Activities of Daily Living	Difficulty Completing Recreational Activities
1	F, 86	Knee osteoarthritis	19	10	95	Excellent	45.6	Full-time	Clerical	Not difficult	Not difficult
2	M, 67	Migraines, bilateral shoulder pain	21	10	95	Excellent	39.5	Full-time	Driver	Not difficult	Unable to do
3	F, 79	Transient ulnar paresthesia	23	10	100	Excellent	56.4	Retired		Not difficult	Not difficult
4	F, 86	Wheelchair bound secondary to recent fall	27	10	80	Good	19.3	Retired		Unable to do	Unable to do
5	M, 59	History of ORIF right pilon fracture, arthritis and cramping in hands	19	7	55	Poor	31.8	Unemployed		Very difficult	Very difficult
6	M, 99		24	10	95	Excellent		Retired		Not difficult	Not difficult
7	M, 69		19	10	95	Excellent	58.2	Retired		Not difficult	Not difficult
Mean (± SD)				9.6 ± 1.1	87.9 ± 15.7		41.8 ± 14.9	Full-time	Executive	Not difficult	Not difficult
Range				7-10	55-100		19.3-58.2				

Appendix Table 1. Post-operative range of motion and strength treatment of nonunion of the distal part of the elbow in patients who returned for clinical exam

						Extension		Flexion		Pronation		Supination		Strength (Normal Power)				Grip Strength		Pinch Strength	
Case	Gender, Age (yr)	Injured Side	Follow-up Method	Follow-up Time (yr)	Stable	Unaffected Side	Affected Side	Unaffected Side	Affected Side	Unaffected Side	Affected Side	Unaffected Side	Affected Side	Extension	Flexion	Pronation	Supination	Unaffected Side	Affected Side	Unaffected Side	Affected Side
1	F, 86	Left	Clinic Visit	19	Yes	0	40	125	110	70	70	85	85	1	1	1	1	59	50.3	18.3	14.3
2	M, 67	Left	Clinic Visit	21	Yes	5	30	120	105	70	70	65	50	1	1	1	1	61.7	44.7	19	16
3	F, 79	Right	Clinic Visit	23	Yes	0	25	145	120	70	60	75	75	1	1	1	1	44.7	39.7	13.3	11.3
Mean						2	32	130	112	70	67	75	70					55.1	44.9	16.9	13.9
Range						0-5	25-40	120-145	105-120	70-70	60-70	65-85	50-85					44.7-61.7	39.7-50.3	13.3-19	11.3-16

similar between the affected and unaffected sides, but pinch strength was de-creased in the affected versus the unaffected elbow (13.9 [range: 11.3-16] versus 16.9 [range: 13.3-19], *P=0.035*).

Discussion

Distal humerus fracture nonunion is a rare but significant complication that results in a painful, functionally unstable elbow that severely impairs quality of life (1). Classically, when appropriate, the treatment for this condition is revision ORIF, joint contracture release, and autogenous bone grafting (1, 2). However, in older age patients with associated poor bone quality or stock, TEA is also a possible treatment option (3). In fact, due to advancements in TEA implant design and in-creasing surgeon experience, recent reports describing the use of TEA for distal humerus fracture nonunion treatment in older patient cohorts found similar outcomes between TEA and revision ORIF at 3-7 year follow-up (7-10). Yet, while the longevity challenges of TEA beyond 5-10 years are well described, little is known about long-term patient-reported outcomes follow-ing revision fixation for failed internal fixation (2, 3, 6, 11). This has made it challenging to guide treatment selection for older patients who are eligible for either revision ORIF or TEA. In this retrospective study of older patients with poor bone quality and a distal humerus fracture nonunion amenable to treatment by revision fixation or TEA at the time of initial nonunion surgery, we found good to excellent radiographic and patient-reported functional outcomes following revi-sion ORIF, joint contracture release, and autogenous bone-grafting at an average of 22 years of follow-up for most patients.

The development of the treatment combination of revision ORIF, joint contracture release, and autogenous bone grafting has been incremental, with changes being made based on the results of short term follow-up. Initial attempts at revision ORIF alone led to over 90% radiographic union rates, but poor functional outcomes (18). When joint contracture release was added in both younger and older patients, union rates remained similar but functional outcomes improved significantly (14, 19). This also remained true when treating severely unstable nonunions of the distal part of the humerus at average follow-up of 4 years (4). In the largest series by

Helfet et al., this combination of procedures yielded a nearly 100% union rate with significant improvement in postoperative range of motion, although 29% of patients required additional surgery (6). On the basis of this study with average follow-up of 3 years and another more recent study with average follow-up of 4 years, the combination of revision ORIF with joint contracture release and autogenous bone grafting was recommended as the preferred treatment option for most patients (2, 3, 12, 20).

However, given the technical complexity of performing revision fixation, many have explored the use of TEA to treat distal humerus fracture nonunion. While the original description of distal humerus nonunion salvage using TEA demonstrated improvement in pain and range of motion at the cost of very high complication rates, more recent reports have demonstrated significantly decreased pain, increased range of motion, and improved functional scores with lower complication rates using semiconstrained elbow replacements (7-10, 19). In fact, two studies by Pogliacomi et al. and Cil et. al. since 2008 demonstrated that use of TEA as a salvage operation for distal humerus nonunion had similar patient-reported outcomes and complication rates to revision ORIF, joint contracture release, and autogenous bone grafting over average 3-5 year follow-up in older patients (7, 8).

Based on these reports, revision ORIF or TEA would appear to be equally reasonable treatment options for distal humerus fracture nonunions in older age patients with poor bone quality or bone loss at 3-5 years of follow-up. But, the challenge with deciding between revision fixation or TEA in patients who are eligible for either option is that while the longevity of TEA and its risk of complications is known to be poor and high, the longevity of revision fixation beyond a max-imum average follow-up of 7 years is unknown (11). In addition, concern has been raised regard-ing the longevity of TEA for fracture or nonunion when both condyles are removed leading to the potential for increases torque forces on the humeral stem (11). This has made comparison of the long-term results between revision ORIF and TEA impossible in this subset of patients, and previously described factors to choose between the two modalities are of little help (2, 12). For this reason, we retrospectively analyzed the long-term results of revision ORIF, joint contracture release, and autogenous bone-grafting in the treatment of distal humerus fracture nonunions in older aged patients with poor bone quality or bone loss who were candidates for TEA at the time of nonunion surgery. We found that revision ORIF was a viable treatment option even after at least 19 years of follow-up, suggesting that its longevity is superior to that of TEA in this subset of patients.

After an average follow-up of 22 years (range: 19-27 years), all nonunions were healed after the index procedure and average radiographic arthrosis grade was 2 (moderate joint-space narrowing with moderate osteophyte formation). One patient had exertional discomfort but none required chronic pain medications. PROMIS-Pain Interference scores were no different than the general population. According to the MEPI, the functional result was excellent in five patients, good in one, and poor in one. In a selected group of patients, despite older age and poor bone quality, our data add to the literature that distal humerus fracture nonunions can be treated successfully using revision ORIF, joint contracture release and autogenous bone-grafting with good long-term patient-reported outcomes.

Limitations

This study has several limitations, many of which are inherent to all retrospective studies of in-frequent conditions. We do not have a control group of patients treated with total elbow arthro-plasty for statistical comparison, but instead compare our subset of patients to known groups of patients in previously published studies. The presentations of distal humerus nonunion were diverse and surgical constructs were unique to each patient, however the principles of treatment remained the same for all patients. We were only able to obtain data for 7 patients treated in this manner. Given that this is an uncommon condition and our inclusion criteria of long-term follow-up, many patients had died and some were not reachable. The total number of included patients was small making robust statistical comparisons to published data challenging. In addition, we could only evaluate mobility, stability and strength in three patients who could return for in-person follow-up.

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