A Limited Fixation, Olecranon Sparing Approach, for Management of Geriatric Intra-Articular Distal Humerus Fractures

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Abstract
Purpose: We propose that geriatric comminuted intra-articular distal humerus fractures can be effectively treated with a limited fixation approach aimed at achieving varus/valgus stability with columnar fixation, but allowing intra-articular comminution to heal by secondary congruency against an intact olecranon, thus avoiding an olecranon osteotomy. Methods: Fifty-six elderly patients with AO 13-C type fractures, who underwent surgical fixation with ≥12-months of follow-up were retrospectively reviewed. Thirty patients were treated with intra-articular open reduction internal fixation (ORIF) with an olecranon osteotomy and 26 patients were treated with our limited fixation (L-ORIF) approach. Outcomes were range of motion (ROM), complications, additional surgery, and patient-reported outcome measures (PROMIS). Results: At final follow-up, the average elbow ROM was 97° (40°-155°) in the ORIF group and 86.5° (20°-145°) in the L-ORIF group. There was a trend toward more complications and additional surgery in the ORIF group. PROMIS scores for pain were 53.1 and 52.14, and PROMIS functional scores were 41.7 and 41.4 in the ORIF and L-ORIF group respectively. No differences in outcomes were statistically significant. Conclusion: A limited fixation technique based on achieving varus/valgus stability with columnar fixation, demonstrated equivalent outcomes in elderly patients with intra-articular distal humerus fractures when compared to intra-articular ORIF with an olecranon osteotomy

Keywords
distal humerus, fracture, elderly, osteoporosis

Introduction
Intra-articular distal humerus fractures with trochlear comminution in the elderly are disabling injuries which are commonly treated with open reduction internal fixation (ORIF) via an olecranon osteotomy. Acute total elbow replacement is also an option. Additionally, in select older patients who are medically unwell, non-operative treatment, often referred to as the “bag of bones” approach,¹ can facilitate early rehabilitation without the risks of operative intervention, though this method can be associated with poor functional outcomes, instability, pain, distorted distal humerus geometry, and joint dysfunction.²-10

ORIF and total elbow arthroplasty can achieve good results with regard to final elbow range of motion, function, and pain for elderly patients with intra-articular distal humerus fractures. Formal open reduction and internal fixation can be challenging in the geriatric population where poor bone quality and fracture comminution can make achieving and maintaining anatomical reduction of the joint surface difficult at best. An olecranon osteotomy also disrupts the extensor mechanism of the elbow and creates an iatrogenic fracture plane that can go on to delayed healing or non-union. This complication could further preclude total elbow arthroplasty as a future salvage option. Additionally, olecranon hardware has a high rate of hardware prominence and pain, often requiring a second procedure for removal.¹¹ While initially thought to be a good option for...

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Materials and Methods

Approval to conduct this study from our Institutional Review Board was obtained prior to subject enrollment. The design was a retrospective cohort study to evaluate the clinical outcomes of patients (≥ 65 years old) with humeral AO/OTA 13-C type fractures, who were treated with ORIF. Patients who underwent surgical fixation with a traditional ORIF with an olecranon osteotomy or with our limited fixation technique over a 12-year period from July 1st, 2005 to July 1st, 2017 at a single orthopaedic trauma center were eligible for enrollment. Patients had a minimum of 12-months of follow up.

Patients in the ORIF group were treated with intra-articular ORIF with an olecranon osteotomy, patients in the limited fixation (L-ORIF) group were treated with columnar plating without an olecranon osteotomy. Table 1 outlines the inclusion and exclusion criteria for the study and Table 2 summarizes the baseline demographic and injury characteristics. Within the study period, a total of 56 patients met inclusion criteria and were enrolled. Thirty patients made up the ORIF group and 26 patients were in the L-ORIF group. The 2 groups were not statistically different (p < 0.05) with respect to any demographic variables listed in Table 2.
orthopaedic patients.8,14-16 The mean score for each T score
dized to a normative US population, have been validated in
instruments, which when scored, result in T scores standar-
s) and physical function (PF) (version 1.0). PROMIS
 patient-reported pain and function, via outcome measurement
tions for the limited fixation technique can be summarized as:
a) need for ORIF as may occur secondary to an open fracture,
strong or parallel) locking plates were then applied to
secure the articular segment to the humerus and address valvar
and valgus instability. In 3 cases, sufficient fixation was
achieved with columnar screws and wires alone. Anatomic
reduction of the intra-articular comminution beyond that
allowed by this limited exposure was not attempted.
In both groups, a posterior splint was maintained for 7-14
days allowing free motion of the wrist and digits. Formal elbow
physical or occupational therapy was implemented after the
first post-operative visit at 2 weeks. At this time, the splint was
discontinued and all patients were encouraged to start passive,
active assisted, and gentle active ROM as tolerated but without
resistance. By week 4, therapists were instructed to advance
motion with gentle stretching and patients were encouraged to
use the arm for daily activities without lifting heavy objects or
pushing. By week 8, ROM stretching was unrestricted and
patients started gentle resisted active exercises. By week 12 all
restrictions were lifted.
The senior author performed the majority of procedures with
the remainder of procedures performed by 2 other trauma fel-
lowship trained orthopedic surgeons at the same institution.
Patients were not randomized and the choice of the procedure
was at the discretion of the treating surgeon. Generally, indica-
tions for the limited fixation technique can be summarized as:
a) need for ORIF as may occur secondary to an open fracture,
grossly unstable injury, injury compromising skin integrity if
left without stability, vascular injury, other acute need for open
intervention; b) presence of troclear comminution and an
intact olecranon in osteoporotic bone in addition to a); and c)
an injury in a geriatric patient with significant medical comor-
dbidities in addition to a) and b) as above.
The primary outcomes of this study were final elbow range
of motion (in the coronal plane), complications, and the need
for additional elbow surgery. Secondary outcomes included
patient-reported pain and function, via outcome measurement
tools, which were obtained in clinical or administered remotely.
The Patient-Reported Outcomes Measurement Information
System (PROMIS) were used for pain interference (PI) (ver-
sion 1.0) and physical function (PF) (version 1.0). PROMIS
instruments, which when scored, result in T scores standard-
dized to a normative US population, have been validated in
prior studies to reliably measure their intended outcomes in
orthopaedic patients.8,14-16 The mean score for each T score
distribution is 50 and the average standard deviation is 10
points. Inherent to the PROMIS measures, a higher PF score
signified increased function and a higher PI score indicated
increased pain.
All patients had at least 12 months of follow up and docu-
mented final elbow range of motion, complications, and any
additional surgeries except for 1 patient who had follow-up
care in another state where she lived. Medical record review
revealed 20 patients were deceased at the time of phone survey
and 12 patients were prohibitively demented. Seventeen
patients of a possible 24 completed the patient-reported out-
come measurement tools, leading to a response rate of 70.8%.
None of the deaths during the follow-up period were due to the
distal humerus fracture or operation.
Means were calculated for all continuous variables, and
groups were compared using 2-sided independent samples
t-tests (with \( \alpha < 0.05 \)). Calculations were performed in
REDCap (Vanderbilt University, Nashville, TN) or in Micro-
soft Excel (Microsoft Corporation, Redmond, WA).

### Results

The average patient age for the ORIF with osteotomy group
was 76.9 and for the limited fixation groups was 79.8 years.
The mean follow-up duration for the study was 15.2 months
(range 12-97 months). The average final elbow range of motion
in the coronal plane was 97° (40°-155°) in the ORIF with
osteotomy group and 86.5° (20°- 145°) (\( p = 0.231 \)) in the
limited fixation group (Table 4). The average final elbow
extension (degrees short of full extension—0°) was 22.5°
(0°-45°) in the ORIF w/ osteotomy group and 26.9° (0°- 90°)
in the limited fixation group (\( p = 0.539 \)) (Table 4).

In the ORIF w/osteotomy group, there were 11 types of
complications in the follow-up period in 11 patients (36.7%),
and 10 patients underwent additional surgery (33.3%). In
the limited fixation group, there were 2 types of complications in 4
patients (15.4%), and 4 underwent additional surgery (15.4%)
(Table 5). There was a trend to more complications (\( p = 0.073 \))
and additional surgery (\( p = 0.122 \)) in the ORIF w/ osteotomy
group compared to the limited fixation group but this did not
reach statistical significance.

PROMIS scores for pain were for 53.1 and 52.14 in the
ORIF w/osteotomy and limited fixation groups, respectively
(\( p = 0.867 \)) and PROMIS function scores were 41.7 and
41.4, respectively (\( p = 0.957 \)). The average operative time was
168 minutes in the ORIF w/ osteotomy group and 135 minutes
in the limited fixation group, a difference of 33 minutes which
was statistically significant (\( p = 0.041 \)).

### Discussion

In this retrospective study, patients over age 65 with in-
tra-articular distal humerus fractures treated with a limited fixation
technique had comparable outcomes, with regard to pain, func-
tion, and final range of motion, to patients who underwent
ORIF of the distal humerus with an olecranon osteotomy and

| Table 3. Plating Configurations and Operative Time. |
|-----------------------------------------------|
| ORIF w/ olecranon osteotomy (N = 30) | Limited fixation (N = 26) |
|-----------------------------------------------|
| Parallel | 22 (73.3%) | 7 (26.9%) |
| 90-90 | 5 (16.7%) | 12 (46.2%) |
| Single column | 3 (10%) | 4 (15.4%) |
| None | 0 (0%) | 3 (11.5%) |
| Operative time (mins) | 168 | 135 |

None = columnar screws and wires only

insertion. Single column or bicondylar (medial and lateral,
orthogonal or parallel) locking plates were then applied to
secure the articular segment to the humerus and address varus
and valgus instability. In 3 cases, sufficient fixation was
achieved with columnar screws and wires alone. Anatomic
reduction of the intra-articular comminution beyond that
allowed by this limited exposure was not attempted.
with anatomic joint reconstruction. We propose that in select geriatric patients, a limited fixation approach as described (Figure 1–3), minimizes complications and surgical time while achieving similar clinical results. While we refer to our approach as a limited fixation technique to differentiate it from an approach with an olecranon osteotomy, we believe it remains stable and appropriate fixation to provide valgus and varus stability while avoiding unnecessary disruption of trochlear comminution that may be non-reconstructable.

Geriatric intra-articular distal humerus fractures are often complex and challenging to treat, and the results can be poor. They comprise approximately 2% of fractures, often occurring in independent and active older females with an incidence that is expected to rise significantly as the population above 80 years of age increases.6,17-19 The goals of treatment for elderly patients are comfort, preservation of a functional range of motion (flexion are 30°-130°) for activities of daily living, and minimizing complications. Surgical fixation of a comminuted distal humerus fracture poses technical challenges especially in elderly patients with comminuted fractures, osteoporotic bone, poor wound-healing secondary to co-morbidities, and limited physiologic reserve.6

Non-operative management, consisting of brief elbow immobilization followed by early range of motion is an option in patients deemed too medically unwell to tolerate an operation. This “bag of bones” approach was first described in the literature by Eastwood in 1937, who reported on 14 patients with adequate elbow function, 12 of whom returned to work (or previous functional level), after non-operative treatment of a distal humerus fracture, although a closed reduction under general anesthesia was commonly performed.1 Recent studies have demonstrated mixed results with non-operative care which can result in pain, poor functional outcomes, instability, non-union, and distorted distal humerus geometry.2,3,10,20,21

There is a paucity of data comparing the results of non-operative treatment to operative treatment for intra-articular distal humerus fractures. In a retrospective review in 1986, Zagorski et al. compared the outcomes of comminuted intra-articular fractures of the distal humerus in 29 patients who were treated operatively with ORIF and 13 patients treated non-operatively.21 In this study 23 patients were treated with screw

| Table 4. Outcomes for Treatment Groups. |
|----------------------------------------|
| ORIF w/olecranon osteotomy (N = 30)     | Limited fixation (N = 26) |
| Final Extension (degrees short of 0°)   | 22.5° (0°-45°)            | 26.9° (0°-90°)  | P = 0.539 |
| Final Flexion                          | 119.5° (90°-150°)         | 113.4° (90°-150°) | P = 0.301 |
| ROM                                    | 97° (40°-155°)            | 86.5° (20°-145°) | P = 0.231 |
| Complications                          | 11 (34%)                 | 4 (15%)         | P = 0.073 |
| Additional surgery                     | 10 (31%)                 | 4 (15%)         | P = 0.122 |
| PROMIS Pain                            | 53.1                      | 52.14           | P = 0.867 |
| PROMIS Function                        | 41.7                      | 41.4            | P = 0.957 |

| Table 5. Complications and Additional Surgeries. |
|-----------------------------------------------|
| ORIF w/olecranon osteotomy (N = 30)           | Limited fixation (N = 26) |
| Complications                                 |                           |
| Hardware prominence                           |                           |
| Ulnar neuropathy                              |                           |
| Hardware loosening                            |                           |
| Olecranon bursitis with prominent K-wire      |                           |
| Deep infection                                |                           |
| Superficial Infection (treated with intravenous antibiotics) |   |
| Avascular necrosis                            |                           |
| Prolonged radial nerve palsy                  |                           |
| Advanced post-traumatic arthritis             |                           |
| Heterotopic ossification                      |                           |
| Stiffness requiring intervention              |                           |
| Complication rate                            | 36.7%                     | 15.4%           |
| Additional surgery                           | Removal of hardware (n = 3) | Removal of hardware (n = 2) |
|                                              | Total elbow arthroplasty (n = 2) | Manipulation under anesthesia |
|                                              | Operative debridement (n = 2) | Elbow contracture release |
|                                              | Cubital tunnel release      |                             |
|                                              | Ulnar nerve decompression   |                             |
|                                              | Nerve transfers             |                             |
|                                              | Manipulation under anesthesia |                         |
| Additional surgery rate                       | 33.3%                     | 15.4%           |

Geriatric Orthopaedic Surgery & Rehabilitation
fixation only, 5 patients with plates and screws, 1 patient by
multiple pin fixation, with 76\% reported to have had an excel-
lent or good result whereas only 8\% of patients treated non-
operatively achieved a similar outcome. Notably, this patient
group was substantially younger, with a mean age of 45 years
(range 17 to 82 years), compared to our present study. Higher
non-union and delayed union rates with non-operative treat-
ment were seen in an observational cohort by Robinson et al.
in a study of 320 adult patients with distal humerus fractures.\cite{18}
In a non-randomized study of 28 elderly patients (mean age of
85 years) with distal humerus fractures by Srinivasan et al. in
2005, OTA grading demonstrated favorable results (3 excel-
lent, 9 good, 7 fair, and 2 poor) in patients treated with ORIF
compared with the non-operatively treated group (zero excel-
lent, 2 good, 3 fair, and 3 poor). \cite{22} The operatively treated group
had more substantial pain relief (mild or no pain) compared to
the non-operative group (52\% v. 25\%) along with a better mean arc of motion (75.5° v. 37.5°). Similarly, John et al. reported
favorable outcomes in 49 elderly patients (mean age of 80
years) with distal humerus fractures who were treated opera-
tively. \cite{23} Eighty percent of patients assessed their result as
either very good or good and the authors noted the incidence
of implant failure, pseudarthrosis of the olecranon osteotomy,
and ulnar nerve lesions were similar to younger adult popula-
tions at the time of study. We believe our limited fixation
technique captures some of the benefits of a non-operative
approach, by minimizing surgery and potential post-operative
issues related to olecranon fixation in elderly or medically
unwell patients, while achieving similar functional and pain
relief outcomes as ORIF with intra-articular reconstruction.

Intra-articular distal humerus AO/OTA type C fractures are
challenging fractures to treat operatively given the distal frac-
ture lines of one or both columns, the osteoporotic bone in
elderly patients, the extent of comminution of the articular
surface, along with metaphyseal fragmentation of one or both
columns. Options to access the ulnohumeral joint through a
posterior approach to the distal humerus include, but are not
limited to, triceps splitting, triceps reflecting, triceps preserving
(paratricipital), and an olecranon osteotomy. \cite{7} Through a cada-
ver study, Wilkinson et al. studied the percentage of the distal
humerus exposed through the common posterior surgical
approaches,\cite{24} reporting 35\%, 46\%, and 57\%, for the triceps
splitting, triceps reflecting, and olecranon osteotomy
approaches respectively. While the triceps reflecting approach
and the olecranon osteotomy allowed the most visualization of
the distal humerus, both disrupt the extensor mechanism of the
elbow. With the triceps reflecting approach, the elbow is com-
monly immobilized for a longer period of time post-operatively
to allow the triceps tendon to heal, which may lead to loss of
range of motion and worse functional outcomes. With an

Figure 1. An 83 year-old female sustained a comminuted intra-articular distal humerus fracture after a fall from standing with an associated
radial head fracture. Initial lateral (A) and oblique (B) radiographs, and representative sagittal (C) and coronal (D) computed tomography images,
demonstrate significant intra-articular comminution of the fracture. Post-operative radiographs 3 months after surgery, utilizing a limited fixation
technique, demonstrate the preserved overall geometry of the distal humerus and ulnohumeral joint space on lateral (E) and anterior-posterior
(F) radiographs. After fracture healing, her medial plate was removed due to discomfort, and at the time of final follow up at 14 months, she was
pain free with a total-arc elbow range of motion (combined flexion-extension) of 105°. Final radiographs demonstrate preserved alignment,
fracture union, and maintained ulnohumeral joint space on lateral (G) and anterior-posterior (H) radiographs.

Kaiser et al

5
Figure 2. A 74 year-old female sustained a comminuted intra-articular distal humerus fracture after a fall from standing with an associated ipsilateral distal radius fracture. Initial lateral (A) and anterior-posterior (B) radiographs, demonstrate significant intra-articular comminution of the fracture and unstable valgus deformity. Post-operative radiographs at the time of surgery, utilizing a limited fixation technique, demonstrate joint congruency with fixation through the plates without the need of an olecranon osteotomy, lateral (C) and anterior-posterior (D) radiographs. At 9 months from surgery, she was pain free with a total-arc elbow range of motion (combined flexion-extension) of 90°. Final radiographs demonstrate preserved alignment, fracture union, and maintained ulnohumeral joint space on lateral (E) and anterior-posterior (F) radiographs.

Figure 3. A 76 year-old male hairdresser sustained a comminuted intra-articular distal humerus fracture after a fall from standing in the context of an associated prior ulnar pseudoarthrosis and dysplastic elbow changes with pre-existing limitations in pronation. He underwent fixation to preserve existing function of his elbow. Initial anterior-posterior (A) and oblique (B) films and sagittal (C) and coronal (D) CT views demonstrate significant intra-articular comminution. Post-operative radiographs at healing (E and F) demonstrate fixation with lateral plates with return to baseline function allowing the patient to return to work.
olecranon osteotomy, an intra-articular osteotomy is made which disrupts the articular cartilage of the ulnohumeral joint and makes conversion to a total elbow arthroplasty more challenging if it is ever needed. Additionally, some surgeons may delay active extension to allow healing of the osteotomy which is fixed with hardware that is often prominent and commonly removed. In contrast the triceps splitting approach leaves the extensor mechanism intact and allows for early postoperative rehabilitation, at the expense of a more limited visualization of the distal humerus articular surface. In a retrospective review of 25 patients, McKee et al. reviewed the functional results of fractures treated with ORIF through a posterior approach using the triceps splitting technique versus an olecranon osteotomy. They found no significant difference in the patients’ strength or total arc of motion, which was 108° and approximately 75% of their uninjured side, utilizing these 2 approaches. As first described by Alonso-Llame, the paratricipital (or triceps sparing) approach does not split the triceps muscle nor disrupt the extensor mechanism, but rather exposes the distal humerus by working around the medial and lateral distal triceps and the respective intermuscular septa, thus allowing early postoperative rehabilitation. While visualization for anatomic fixation of AO/OTA Type C distal humerus fractures can be challenging, elbow extension to relax the triceps muscle and tendon can help with paratricipital exposure. In a retrospective review of 67 elderly patients with AO/OTA Type C distal humerus fractures, Zhang et al. compared the results of patients who underwent ORIF using the olecranon osteotomy approach (n = 36) and the triceps-sparing approach (n = 31). For patients with type C1 and C2 fractures, they observed reductions in operative time, blood loss, complication rates, and significantly better Mayo Elbow Performance Score (MEPS) using the triceps-sparing approach compared to an osteotomy approach at final follow-up. In type C3 fractures, both approaches achieved similar elbow functional outcomes while operative time, blood loss, and complication rates was lower in the triceps-sparing approach. Similarly, our study found a shorter operative time of 135 minutes in our limited fixation group, 33 minutes shorter than the ORIF with an olecranon osteotomy group (p = 0.041).

Both the olecranon osteotomy approach and paratricipital approach allow dual plating of distal humerus. Dual plating is the established standard of care for most type C intra-articular distal humerus fractures and has been shown to be significantly stronger than other choices. While biomechanical studies have shown that parallel locked plate fixation demonstrates greater mechanical stiffness and stability compared with orthogonal locked and non-locked plating, clinically the plate orientation does not appear to affect outcomes or complications rates. Lee et al. prospectively randomized 67 patients with distal humerus fractures to fixation with orthogonal or parallel plating and found no significant differences in clinical outcomes, radiographic reductions, mean operation time, union time, or complication rates between the groups.

Limitations to the present study include its retrospective design and small sample sizes. The lack of difference between groups might have resulted from the small sample size of our cohort due to Type II error. However, the intent of the present study is to introduce a technical treatment option for a unique subgroup of patients and motivate a more rigorous future study delineating outcomes in a larger cohort. Additionally, due to the patient population, 32 patients (20 deceased, 12 prohibitively demented) were unavailable to participate in PROMIS scores, the study’s secondary outcomes. Patients were selected for treatment based on the attending surgeon’s discretion, thus inherently adding selection bias to the groups. Evidenced by a slightly higher ASA score (2.7 in limited fixation group versus 2.4 in ORIF w/olecranon osteotomy group), we believe the limited fixation group may have actually been more medically compromised, and hence selected for more limited treatment. Despite their medical condition, the limited fixation group achieved similar outcome scores. In this study we were unable to explore the effect of some covariates like patients’ demographics, BMI, and ASA, on the outcome. Further research with a prospective design and a larger sample size would be of interest to explore the effect of fracture pattern, bone density as measured quantitatively, heath status indicators (i.e., ASA, Charlson Comorbidity Index (CCI), Elixhauser Comorbidity Index), and functional level (as assessed by PROMIS, Disabilities of the Arm, Shoulder and Hand Score (DASH), Upper Extremity Functional Index (UEFI)), on the outcome of treatment with the proposed limited fixation technique.

In conclusion, we believe a technique of limited columnar fixation as described in this manuscript for intra-articular fractures in an elderly population is a valid treatment option with similar elbow motion, function, and pain relief at final follow-up when compared to ORIF with an osteotomy and an effort to anatomically reconstruct intra-articular comminution. By minimizing some of the more challenging technical issues associated with an olecranon osteotomy and open reduction of a highly comminuted trochlea with osteoporotic bone, this treatment option may allow for patients to be treated without referral to a tertiary level center. This could facilitate care within the patient’s community and provides access to family for these older patients. The limited fixation approach proposed offers valgus and varus stability which suffices to provide the patient with a stable elbow and thus allow the intra-articular comminution to heal by secondary congruency against an intact olecranon. This approach may be used selectively in geriatric patients who would benefit from surgical management, but may be lower functioning, medically unwell, or have such poor bone quality that anatomic reduction with an olecranon osteotomy would be difficult at best. Our approach also preserves olecranon integrity allowing for total elbow arthroplasty as a potential future option. While our conclusions from this limited series are suggestive of a potential benefit in terms of equivalency of outcome for this particular population when compared to results from more extensive surgery, our observations are to be interpreted in this context.
Authors’ Note
This manuscript is not based on a previous communication to a society or meeting. No benefits in any form have been received or will be received from commercial party related directly or indirectly to the subject of this article.

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