

Clinical and radiological results of 3.5 mm locking compression plate fixation for humeral shaft fractures

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SUMMARY

Objective. This study aims to evaluate the clinical and radiological outcomes of treating 21 humeral shaft fractures using a single 3.5 mm locking compression plate (LCP). In cases where the humeral size is limited, this construct may offer a viable alternative. However, there is a scarcity of data in the literature regarding the outcomes of this technique. Traditionally, surgeons prefer using a 4.5 mm LCP or two orthogonal 3.5 mm LCPs for such fractures.

Methods. A total of 21 patients, comprising 14 men and 7 women aged 18 to 68 years (mean age: 34; median age: 29), underwent open reduction and internal fixation with a 3.5 mm LCP. The fractures were classified as 12-A, 12-B, or 12-C according to the AO classification. Patients were monitored monthly until radiological union was confirmed in at least three out of four cortices. Functional outcomes were assessed using the Disabilities of the Arm, Shoulder, and Hand (DASH) score.

Results. The mean follow-up period was 12 months (range: 7–17 months). The mean DASH score was 35.1 at 3 months and improved significantly to 8.9 by 10 months. All fractures achieved union after an average of 14 weeks, with one patient experiencing delayed union in the case of a transverse fracture. No instances of metal failure or plate breakage were observed. Radial nerve deficits were present in 5 patients due to trauma, but the structural integrity of the nerve was maintained in all cases. Full recovery of nerve function, including complete muscle strength restoration, occurred within 6 months.

Conclusions. A single 3.5 mm LCP is a viable treatment option for diaphyseal humeral fractures. This approach demonstrated a satisfactory union rate, range of motion, and a low rate of complications.

Key words: humeral shaft fracture, fracture fixation, locking compression plate, functional outcomes, radiological outcomes

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Introduction

Humeral shaft fractures account for about 3% of all long bone fractures. Of all injuries, 63% are minor fracture patterns, while 5% are open wounds ^{1,2}. In 18% of closed injuries, a broken humeral shaft can cause damage to the radial nerve and usually result from direct trauma or injuries in which important torsional forces are involved. Treatment of diaphyseal humeral fracture has evolved from a conservative cast and brace to internal fixation with plate and screws and intramedullary nailing

(IMN); each of these techniques has its own advantages and possible complications and there is no definite data that shows the superiority of one over the other ³⁻⁵. The decision to use a plate *versus* IMN for the operative treatment of a closed humeral shaft fracture remains controversial, as the current body of literature does not definitively support one method of fixation over the other. We typically prefer plate fixation in cases of radial nerve injury or when the degree of fracture displacement does not allow for a reliable closed reduction without risking further damage to the radial nerve. Furthermore, regarding the treatment with plate fixation, there are two possible treatments, using a single 4.5 mm locking compression plate (LCP) or two 3.5 mm plates in an orthogonal position. The LCP allows the plate to sit at a distance offset from the underlying bone surface providing a biologic advantage for bone fracture healing by preserving the periosteal blood supply underlying the plate ⁶. A small size of the humerus, a very narrow diaphyseal canal, and osteoporotic bone, however, limits the diaphyseal shaft length and/or diameter available for fixation, and therefore makes using a large-fragment plate difficult. Difficulties that arise include the limited number of screws that can be placed, the resulting bulky fixation with undesirable stress shielding, and the need to pre-contour the large-fragment plate to match the diverging anatomy of the humeral metaphysis. Recent literature suggests that dual small-fragment plating constructs may be mechanically superior to one large-fragment plate construct and may have a role in the fixation of certain fracture pat-

terns ^{7,8}. Furthermore, small fragment plates for humeral shaft fracture fixation have shown promising clinical results ⁹. For this reason, we prefer to treat diaphyseal fractures (12-A, 12-B, or 12-C) with a single 3.5 mm plate. It is not a biomechanical study that allows evaluation of stiffness, bone stress protection, and hardware stress, but we did consider the clinical and radiological results until the fractures healed.

Materials and methods

Our research examined the functional and radiological outcomes of managing fractures with LCP 3.5 mm osteosynthesis. All patients gave their informed consent. Using an institutional computerized database, we identified 21 patients with humeral diaphyseal fractures (Fig. 1), 12-A, 12-B, or 12-C according to AO classification. Between June 2020 and May 2023, patients aged > 18 years underwent using a 3.5 mm LCP for types 12-A, 12-B, and 12-C closed diaphyseal humeral fractures (Figs. 2-3). Patients were prospectively evaluated. Patients with multiple or open fractures, associated periarticular or intra-articular fractures of the shoulder or elbow, were excluded. In all, 14 men and 7 women aged 18 to 68 years (mean, 34; median, 29) underwent ORIF using a LCP 3.5 mm for type 12-A (n = 12), type 12-B (n = 8), and type 12-C (n = 1) humeral shaft fractures. The clinical and radiological follow-up was carried out up to one year after surgery with radiographic healing and clinical union of the fracture. Radiographic healing can be defined as visible callus bridging the fracture site of at least three out of four cortices (Fig. 4), whereas clinical union can be defined as the moment when patients can use the upper limb without feeling significant pain or weakness after radiographic healing.

All patients were treated with open reduction and LCP plate (DePuySynthes Co) fixation (ORIF) after being carefully informed about the risks of these procedures. All patients were operated by 3 surgeons. An antero-lateral surgical approach was used. In all surgical accesses the radial nerve was explored, in 5 patients due to the trauma there was a deficit of the radial nerve always with the integrity of the nerve ^{11,12}. Postoperatively, an arm pouch sling was used for support. Patients with nerve deficits undergo passive mobilization initially, avoiding overstretching the nerve, with active movement initiated as re-innervation progresses, typically after 3-6 months. In contrast, patients without nerve injury follow a careful rehabilitation protocol in which flexion and extension of the elbow, abduction of the shoulder is allowed, avoiding any twisting movement of the humerus and lifting loads for 30 days. Sutures were removed on week 2. Patients were followed up monthly until radiological union in at least 3 of the 4 cortices. Functional assessment was based on the Disabilities of Arm, Shoulder and Hand (DASH) score ¹⁰.

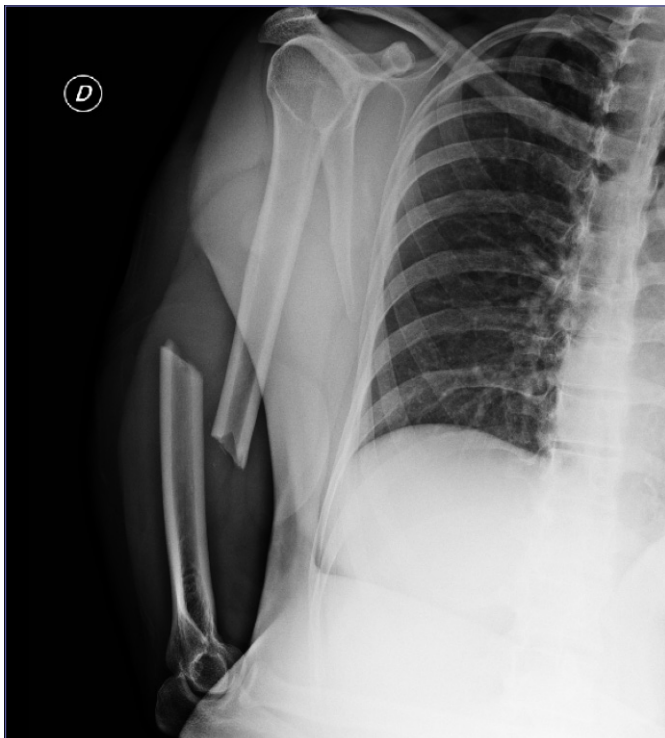


Figure 1. Pre-operative.



Figure 2. Post-operative.

Results

The mean follow-up period was 12 months (range: 7-17). The mean hospital stay was 3.8 days. The mean DASH score was 35.1 at 3 months and improved to 8.9 at 6 months, and 5.2 at 1 year (Tabs. I-II). All fractures united within a mean of 14 weeks. One patient with a transverse fracture experienced delayed union and inadequate callus formation, with pain at the fracture site and difficulty performing activities of daily living, achieving union at week 15. No bone grafting or re-fixation was undertaken.

The 5 patients who experienced radial nerve palsy all recovered after 6.69 ± 2.72 months, with full power restored in all muscle groups. No patients developed hypertrophic scars, and none were functionally dissatisfied. We used electrostimulation and a dynamic hand splint in cases of radial nerve palsy to promote recovery. Electromyography was prescribed three months



Figure 3. Post-operative.

after surgery and again at six months if paralysis persisted. No patient had a wound infection or implant failure that required re-fixation. No malunions were found; no varus, rotational, or other axis malalignment was encountered. No radial palsy due to surgery was observed. Van de Wall et al., in their meta-analysis, found that operative treatment carries an increased risk for radial nerve palsy of 3.5%, although persistent radial nerve palsies are rare and most patients recover.

Discussion

Fractures of the humeral shaft are defined as the segment distal to the surgical neck and proximal to the epicondyles and make up 5 to 8% of all fractures^{1,2}. The most common fracture type is type A (simple, including spiral, oblique, or transverse fractures), followed by type B (including intact wedge or fragmented wedge) and type C (complex, including segmental or complex). There is no single treatment option for humeral diaphyseal fractures^{6,13,14}.

Historically, nonoperative treatment with functional brace has been used, although due to the high rate of non-union, residual deformity, and joint stiffness many orthopedic surgeons tend to prefer operative treatment, particularly in severely displaced, comminute, or segmented fractures, along with demands for improved functional results and earlier rehabilitation¹⁵.



Figure 4. One year follow-up.

Operative treatment options include plate fixation or intramedullary nailing. Fixation with intramedullary nail has biomechanical advantages and good rates of bone healing, but recent studies have reported higher rates of reoperation and insertion site morbidity compared to plate fixation. Thus, plate fixation is considered the gold standard for operative treatment^{16,17}.

Plate fixation can be performed with absolute stability with anatomic reduction, interfragmentary compression, and rigid fixation¹⁸.

The smaller size of the humerus in some patients may limit application of the more commonly used large-fragment plate constructs. In such cases, large-fragment plates may limit the number of screws that can be inserted (i.e., less holes/unit length), and lead to increased stress shielding from the greater mismatch in load transfer between bone and plate.

Kosmopoulos - evaluated the mechanical performance of different dual small-fragment locking plate construct configurations for humeral mid-diaphyseal fracture fixation in terms of stiffness, stress shielding of bone, hardware stresses, and (interfragmentary strain, observing that a mechanical construct with a double 3.5 plate presented a biomechanical result comparable to a single 4.5 plate¹⁹.

The stability of the fixation system is influenced by hardware factors including the number of screws, type of screws (i.e., bicortical, unicortical), working length, plate offset from the bone cortex, and placement of the hardware. A goal of the fixation system should be to reduce and more evenly distribute the applied stress among the hardware components of the construct.

In all our patients, a cortical screw near the fracture site was used to make the plate adhere and to perform compression of the fracture to the bone and subsequently angular stability screws were used, leaving a maximum of three free holes above the fracture. To optimize stability of the fixation, each fracture was stabilized with at least 3 screws (6 cortices) on each side of the fracture.

There are no cases of malunion, delayed union, or non-union among the study participants in the current study. The study by Govindasamy et al. came to the same conclusion: there were no delayed unions or non-unions²⁰. However, in their study, Boben et al. noted a difference after 6 months; there was a union rate of nearly 97% and a non-union rate of 3%. Also, in the study by Rubel et al., almost 92% had union and 8% had delayed union²¹. Better postoperative outcomes require strict AO fixation, careful asepsis, patient education, and a well-planned rehabilitation program²². There are no biomechanical evaluations that report the use of a single 3.5 mm plate in diaphyseal fractures of the humerus, but the clinical and radiographic results of treated patients attest that even complex fractures heal, instead of two 3.5 mm plates (i.e. the 2 plates that increase the hardware are not necessary). It is important to note that the patient must carry out a careful rehabilitation protocol in which flexion and extension of the elbow, abduction of the shoulder is allowed, avoiding any twisting movement of the humerus and lifting loads for 30 days. These LCP fixing protocols for humeral shaft fractures will improve patient satisfaction and reduce sequelae.

A randomized controlled trial might produce better associations because this is an observational study. Moreover, the results cannot be compared with those of other methods because there was no control group and only a limited number of patients were involved.

Table I. Patient characteristics and treatment outcomes.

Sex/age (years)	Fracture type (AO classification)	Disabilities of Arm, Shoulder and Hand score			Range of motion of elbow at year 1	Range of motion of shoulder at year 1 *
		Month 3	Month 6	Month 12		
M/30	12-B1	32.9	6.1	3.2	0°-130°	M1
M/27	12-B1	37.0	7.3	4.8	0°-125°	M1
M/68	12-A2	33.5	6.5	5.1	5°-130°	M1
M/38	12-B1	28.1	8.9	4.6	0°-130°	M2
F/25	12-C1	33.5	5.9	4.9	0°-135°	M1
F/21	12-B3	49.2	7.2	3.9	5°-135°	M1
M/26	12-B1	39.1	6.3	4.6	0°-130°	M1
F/25	12-A2	37.1	8.0	5.1	0°-130°	M1
M/39	12-A1	32.1	8.2	5.1	0°-140°	M1
F/60	12-A2	34.3	6.5	4.0	0°-130°	M1
M/42	12-C2	49.2	7.2	3.9	5°-130°	M1
F/39	12-A2	27.1	7.2	4.3	0°-135°	M1
M/20	12-A2	42.3	8.0	4.4	5°-135°	M1
F/62	12-B1	35.3	8.0	5.0	0°-130°	M2
F/28	12/A2	42.3	8.0	4.4	0°-135°	M1
M/24	12-A2	31.9	9.1	4.8	0°-120°	M1
M/26	12-A3	37.9	6.7	4.6	0°-130°	M1
M/68	12-A2	31.9	9.1	4.8	5°-130°	M1
F/28	12-A2	37.1	3.0	5.1	0°-135°	M2
F/57	12-A1	39.1	6.1	4.7	0°-135°	M1
M/34	12-B1	28.1	8.9	4.6	5°-135°	M1

Table II. Classification of the range of motion of the shoulder.

Range of motion of the shoulder	M1	M2	M3	M4
Flexion	0°-170°/180°	0°-140°/170°	0°-120°/140°	0°-70°/120°
Extension	0°-40°/45	0°-30°/40°	0°-20°/30°	0°-10°/20°
Abduction	0°-170°/180°	0°-140°/170°	0°-120°/140°	0°-70°/120°
Internal Rotation	0°-80°/90°	0°-70°/80°	0°-60°/70°	0°-50°/60°
External Rotation	0°-80°/90°	0°-70°/80°	0°-50°/80°	0°-30°/50°

The main limitation of this study is the small number of patients, but on the other hand it offers great advantages in the observation of the results. The findings suggest that 3.5 mm LCP fixation is a reliable method for humeral shaft fractures. However, the claim that thinner plates significantly reduce surgical time and mechanical invasiveness is likely overstated. Surgical duration is influenced by multiple factors, including fracture complexity, approach, and the surgeon's experience,

rather than plate thickness alone. Additionally, mechanical invasiveness is primarily dictated by the surgical technique and implant positioning rather than hardware dimensions.

Conclusions

A randomized controlled trial could provide stronger associations, as our study is observational in nature. However, the

results of this study are noteworthy in demonstrating that even with the use of a single 3.5 mm plate, complex fractures can heal effectively. Despite the small sample size, the study highlights several key advantages: fractures united in a mean of 14 weeks, a significant improvement in functional outcomes (with a DASH score reduction from 35.1 at 3 months to 5.2 at 1 year), and the ability to achieve healing with reduced surgical time and minimal mechanical invasiveness.

The absence of a control group and the limited number of patients are the main limitations, but the findings suggest that a 3.5 mm plate can be a viable and efficient solution to treat humeral shaft fractures, even in complex cases. These results emphasize the potential of this approach to simplify treatment while maintaining good clinical outcomes.

Conflict of interest statement

The authors declare no conflict of interest

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Author contributions

All authors contributed equally to the work.

Ethical consideration

This study was approved by the Institutional Review Board of San Salvatore Academic Hospital of L'Aquila, Italy (Protocol number: 00861580/20, registered 10, 2020 Clinical Trials ID: NTC 32862830). The research was conducted ethically, with all study procedures being performed in accordance with requirements of the World Medical Association's Declaration of Helsinki.

Written informed was obtained from each participant/patient for study participation and data publication.

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