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ORIGINAL STUDY

LCP metaphyseal plate fixation for fractures of the distal third humeral shaft using brachialis splitting approach

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The authors retrospectively studied the clinical and radiographic outcomes of locking compressive plate (LCP) metaphyseal plate fixation through the anterolateral approach in patients treated surgically for unstable distal third humeral shaft fractures.

Twenty seven patients were treated surgically with LCP metaphyseal plate using brachialis splitting methods through the anterolateral approach. The mean arc of elbow motion was 132.4° with a mean flexion of 133.5° and mean flexion contracture of 1.1°. Three patients had a slight elbow flexion contracture with loss of 5° (n = 1), 10° (n = 1), and 15° (n = 1) of extension. The mean American Shoulder and Elbow Surgeons score was 92.6 points, which corresponded to excellent results in 26 shoulders and a good result in one. The mean Mayo Elbow Performance Score was 90.7 points, which corresponded to excellent results in 24 elbows, a good result in 2, and a fair result in 1. Treatment of distal third humeral shaft fracture using LCP metaphyseal plate through the anterolateral approach is an acceptable and alternative method that can provide good results.

Keywords : humerus ; distal one third humerus shaft fracture ; LCP metaphyseal plate ; anterolateral approach.

INTRODUCTION

Treatment of extra-articular distal third fractures of the humerus is contentious, because of the osteopenic quality of the metaphyseal bone and complex peri-articular anatomy, and because small fragment size fractures make stable fixation difficult (*18,19*). Some authors recommend conservative management of distal third humeral shaft fractures with a functional brace because of the possibility that patients could experience an unnecessary risk for infection and neurovascular injury (*7,20*). However, many surgeons continue to favor operative treatment, citing as possible reasons radial nerve injury (during either closed reduction or movement of the fracture ends during bracing) (*6,15*), difficulty controlling fracture alignment, and elbow stiffness after conservative treatment (*1,5*). Internal fixation treatments are becoming more accepted as implants and procedures continue to improve.

Placing dynamic compression plates posteriorly in the humerus was once favored. However, for the fracture of the distal shaft portion, the distal fragment can be too small to obtain six-to-eight cortices

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of purchase. On the other hand, impingement on the olecranon fossa may occur if the plate is placed at the far distal portion. To reduce the issues, Levy *et al* reported the use of precontoured plates centrally placed on the posterior humerus to provide a flare extending distally for added fixation (*9*). Prasarn *et al* proposed the use of precontoured plate in conjunction with a second lateral plate that serves as a reduction tool in addition to offering enhanced structural support (*16*). Although, postoperative radial nerve palsy was not evident in these two studies, this method has risk of radial nerve injury due to the nerve manipulation that is essential on the posterior approach (*4*). Also, adhesion caused by the previous surgery can increase the risk of radial nerve injury during subsequent implant removal. However, the anterolateral approach does not require radial nerve manipulation and may allow radial nerve exploration as it approaches the fracture site by a split of the brachialis after reflection of the biceps.

Among the variously shaped plates, the locking compressive plate (LCP®) metaphyseal plate (Synthes, Oberdorf, Switzerland) which has 5.0 mm locking and standard combination holes at one end and a cluster of 3.5 mm combination holes at the other end allows placement of a greater number of screws within a relatively small segment of bone. Therefore, it enables stable angular fixation of a relatively small fragment for distal humeral shaft fractures that occur at the junction of the metaphysis.

The purpose of the present study was to determine the clinical outcome and radiologic outcome after applying the LCP metaphyseal plate after the anterolateral approach in patients who had sustained distal third humeral shaft fractures.

MATERIALS AND METHODS

Our Institutional Review Board approved this retrospective study. All patients who had been treated with the procedure between March 2008 and January 2012 were available for review. Thirty one consecutive patients with distal third humeral shaft fracture were treated surgically using the LCP metaphyseal plate. Inclusion criteria were as follows : (1) distal humeral shaft fractures that occurred at the junction of the metaphysis ; (2) more than 2 years of follow-up after surgery ; and (3) normal elbow and shoulder function before injury. The exclusion criteria included the following : degenerative disease of the elbow and shoulder joint ; pathologic fracture ; combined elbow and shoulder fractures ; Gustilo grade III open fracture ; previous surgery on the affected elbow and shoulder joint ; and hemiparesis. All procedures were performed by a single surgeon.

Of the total 31 patients in the study, 4 were lost to follow-up. Thus, a total of 11 men and 16 women, with a mean age of 41.0 years (range 23-75 years) were included in this study. The dominant arm was involved in 17 of the 27 cases. The mechanism of injury was a simple fall in 13 cases, traffic accident in 8 cases, sports activity in 5 cases, and arm wrestling injury in 1 case. As a combined injury, 1 patient had ipsilateral 4th metacarpal shaft fracture and 1 patient had biceps partial rupture (Gustilo grade II open fracture). The location and patterns of the fractures as determined by the American Orthopedic/Orthopedic Trauma Association classification (*13*) are listed in Table I.

Three patients were noted to have radial nerve palsy before surgical intervention. All patients were treated within 1 to 14 days (mean 3 days) with open reduction and internal fixation using the LCP metaphyseal plate after their injuries. Radiologic indications for surgical treatment was ≥ 15° varus/valgus angulation or ≥ 3 cm of shortening (*16*).

Specifics of implant design

The LCP metaphyseal plate has combi-holes allowing an internal plate fixation using standard screws and/or angular stable locking screws. This provides the flexibility of conventional screw fixation (such as axial compression) or locking fixation for fixed-angle constructs. The LCP metaphyseal plate in this study consisted of 5.0 mm locking and standard combination holes at one end and five 3.5 mm combination holes at the other end. The staggered pattern of the latter allows insertion of more screws within a small segment of bone (Fig. 1). The two distal 3.5 mm holes are angled at 11° towards the center, which allows optimal application of locking screws in the epiphyseal area with low-impact on the elbow joint. This plate has a limited-contact design, which reduces the plate-to bone contact and a resulting adverse impact on the periosteum. The distal portion of this plate is designed with a thinner profile, permitting easier application of the plate in the confined space of the anterior surface of the distal humerus.

Table I. — Patient Demographics

Case No.	Gender/ Age	AO/OTA classification	No. of Lag screw	No. of proximal screws	No. of distal screws	Bone graft	Follow-up (weeks)	Time to union (weeks)	Complication	Radial nerve injury
1	M 33	12-A1.3	3	5	5	None	60	16	None	N
2	F 28	12-A1.3	4	4	4	None	54	16	None	Preoperative
3	M 37	12-B1.3	4	4	4	None	53	12	None	N
4	F 39	12-B1.3	4	3	5	None	52	16	None	N
5	M 36	12-A1.3	4	4	4	None	51	20	None	N
6	F 26	12-B2.3	3	3	5	DBM	43	12	None	N
7	F 51	12-B2.3	3	4	4	Auto	42	8	None	N
8	F 23	12-B1.3	4	4	5	DBM	42	8	None	N
9	M 30	12-B1.3	4	4	4	None	39	8	None	N
10	F 50	12-A1.3	3	6	5	None	38	20	None	N
11	F 23	12-A1.3	3	5	4	None	38	8	None	N
12	F 39	12-A1.3	3	4	5	None	33	12	None	N
13	M 33	12-A1.3	4	5	5	None	36	8	None	Preoperative (Sensory only)
14	F 52	12-B1.3	4	5	4	None	31	16	None	N
15	F 40	12-A1.3	3	5	4	None	26	16	None	Preoperative
16	M 31	12-A1.3	4	3	5	None	26	20	None	N
17	M 26	12-C1.1	3	5	5	DBM	28	12	None	N
18	M 48	12-B2.3	4	4	5	None	35	16	None	N
19	M 64	12-A1.3	2	4	4	None	34	12	None	N
20	F 73	12-C1.1	3	5	5	DMB	36	14	None	N
21	F 56	12-A1.3	4	4	4	None	41	16	None	N
22	F 75	12-B1.3	3	3	4	DBM	56	12	None	N
23	F 43	12-B1.3	3	5	5	None	52	10	None	N
24	M 28	12-A1.3	2	4	5	None	40	12	None	N
25	F 36	12-B1.3	3	3	4	None	36	16	None	N
26	F 52	12-C1.1	3	4	5	Auto	32	16	None	N
27	M 36	12-A1.3	2	4	4	None	33	20	None	N

M = male ; F = female ; No. = number ; Y = yes ; N = no ; Auto = autologous iliac crest bone ; DMB = demineralized bone matrix.

Surgical technique

Under general or regional anesthesia, the patient was placed in the supine position on a radiolucent operation table. If the anterior iliac crest bone was to be taken for grafting, the area was also draped. The anterolateral approach method using the brachialis-splitting was done routinely. The elbow was flexed slightly to decrease the tension of the biceps brachii and brachialis. A curvilinear incision was made over the lateral aspect of the biceps, beginning proximally at the deltoid tubercle and terminating just proximal to the antecubital crease. When the incision went over the distal side of the antecubital crease, a curvilinear incision was used to prevent elbow contracture (Fig. 2). During the subcutaneous dissection, the lateral antebrachial cutaneous nerve was identified and preserved. The deep fascia of the arm was incised to identify the brachialis muscle that innervated dual innervation from the radial and musculocutaneous nerves, The brachialis muscle was split parallel with its fiber along

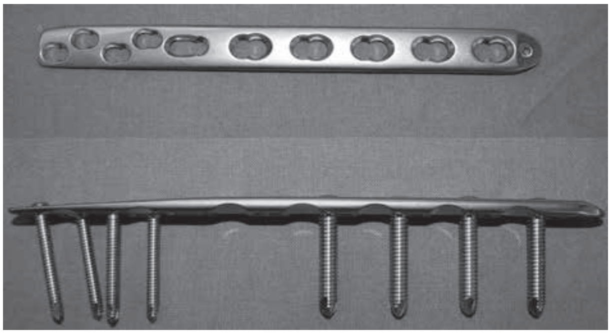

Fig. 1. — Photographs of LCP metaphyseal plate. (Top) Anteroposterior photograph of the plate showing 5.0 mm combination holes at one end and a staggered cluster of 3.5 mm combination holes at the other end. (Bottom) Lateral photograph of the plate with screw inserted showing two distal holes angled at 11° towards the center and thinned plate profile.

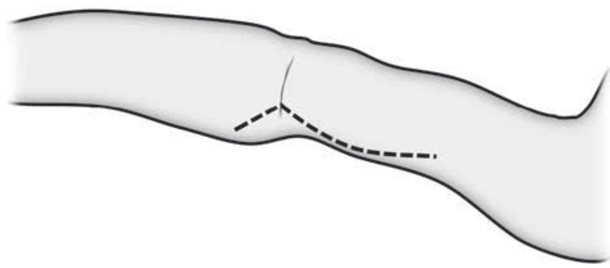

Fig. 2. — An illustration of the patient's left arm showing the anterolateral approach over the anterolateral aspect of the arm

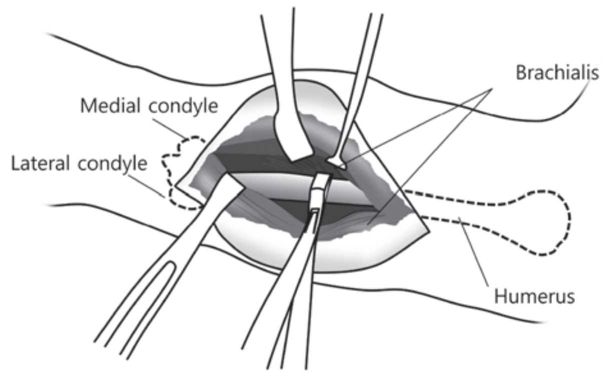

Fig. 3. — A diagram viewing anterolateral aspect of a left humerus illustrates the exposure and reduction of fracture site after splitting the brachialis muscle in a patient with a distal third humeral shaft fracture.

the middle two-thirds and the lateral one-third to avoid damage to either nerve because this is an internervous plane between the musculocutaneous nerve medially and the radial nerve laterally (Fig. 3). If the patient had intact radial nerve function, we did not explore the radial nerve, because the lateral portion of the brachialis protects the radial nerve from retractors placed within the split. However, if the patient had preoperative radial nerve palsy, we dissected the interval between the brachialis and brachioradialis to explore radial nerve because radial nerve palsy at this level is due to contusion or entrapment of the radial nerve (*28*). It is an advantage of this approach that the radial nerve was either explored or not explored according to the presence or absence of radial nerve injury, since there is a possibility of radial nerve palsy merely from nerve manipulation (*4*). After the brachialis was split, the fracture site was identified and defined. The fracture was provisionally reduced and interfragmentary lag screws were used initially in all cases depending on the type of fracture, because initial fracture fixation with a lag screw can affect bone healing by compressing the fractured segments of bone together (*25*). No wiring or Kirschner wires were used. The LCP metaphyseal plate was applied on the anterior humerus using proximally minimum four 5.0 mm locking screws and distally minimum four 3.5 mm locking screws after the plate was bent to the anterior contour of the distal humerus (Fig. 4). While fixing the screws on the distal portion, the near and far cortices were predrilled for stable fixation because of the softness of the distal metaphyseal bone. A locking screw whose length was identical to that of both cortices was inserted. Five-millimeter locking and cortical screws were placed in the holes in the proximal portion. Depending on the type of fracture, an additional interfragmentary screw could be used.

If the fracture was comminuted or the bone was osteoporotic, the bone defect was filled with autologous iliac crest bone or allogeneic bone graft substitute. Under fluoroscopic guidance, successful fracture reduction and proper positioning of the plate and length of the screw were confirmed. Unrestricted elbow flexion-extension without mechanical block or catching was confirmed intraoperatively. The wound was closed in standard fashion over a suction drain. No external immobilization was used.

Postoperative care

On the first day after surgery, gentle passive and active assisted range of motion (ROM) of the elbow and shoulder was initiated and continued under the supervision of a physiotherapist. ROM exercise of elbow and shoulder was continued until radiographic union was achieved, at

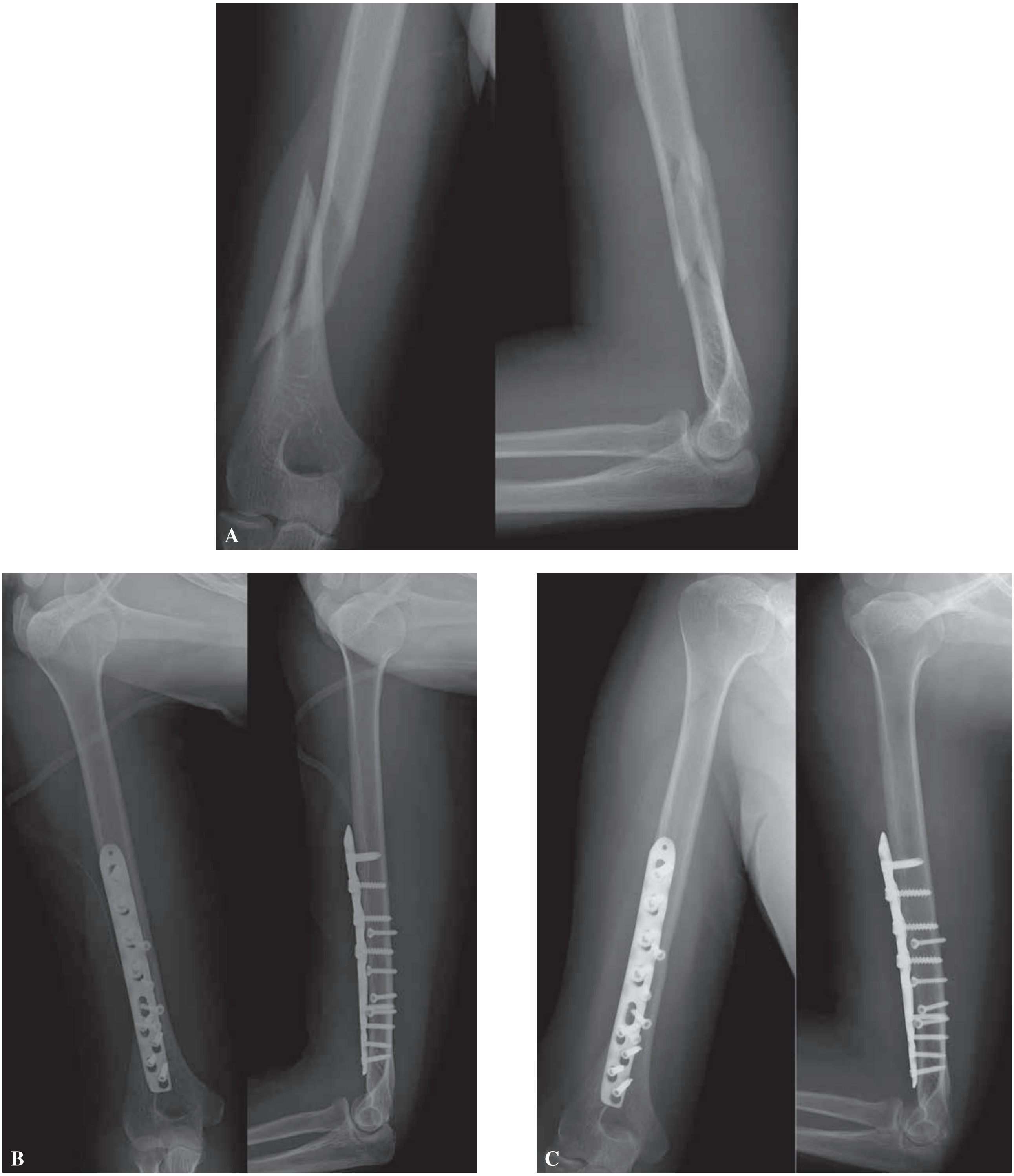

Fig. 4. — (A) Preoperative anteroposterior and lateral radiographs of an AO/OTA classification type 12-B1.3 fracture in the dominant arm of a 30-year-old man that occurred during sports activity. (B) Postoperative anteroposterior and lateral radiographs after fixation with LCP metaphyseal plate and additional interfragmentary lag screws. (C) Anteroposterior and lateral radiograph at 1-year show solid bony union with restoration of alignment.

which point strengthening and unrestricted active elbow and shoulder motion were encouraged. Patients were followed-up in the outpatient clinic every 4 weeks until radiographic and clinical evidence of union. Afterward, postoperative radiographs were scheduled at 6-month intervals, as needed until the final follow-up.

Postoperative assessment

The patients were evaluated radiographically based on the time to union and alignment of the humerus. Fracture union was judged to have occurred when a bridging callus was evident on three of the four cortices seen on the anteroposterior and lateral radiographs of the humerus. Alignment (including varus-valgus alignment and apex anterior-posterior alignment) was assessed on the final anteroposterior and lateral radiographs of the humerus as the angle between lines bisecting the humeral diaphysis proximal and distal to the fracture. The radiographs were examined for any evidence of fracture healing, implant failure, and plate migration at each follow-up period. The clinical outcomes were assessed using the ROM of elbow and shoulder, the American Shoulder and Elbow Surgeons (ASES) score *(17)*, and Mayo Elbow Performance Score (MEPS) *(12)*. The ASES score is a sum of functional and pain subscores, with a maximum of 100 points. The functional subscore equals the sum of 10 functional questions (responses graded 0-3 points), multiplied by a factor of 5/3, for a maximum of 50 points. The pain subscore equals a visual analog score (0-10) subtracted from 10 and multiplied by 5, for a maximum of 50 points. The categorical rating was 76-100 points, excellent result ; 60-75 points, good result ; and < 50 points, poor result. In the MEPS system, both the subjective and objective clinical data were included, with a maximum score of 100 points. Pain (45 points), motion (20 points), stability (10 points), and function (25 points) were evaluated. The categorical rating was 90-100 points, excellent result ; 75-89 points, good result ; 60-74 points, fair result ; and < 60 points, poor result. To reduce measurement errors, measurements were obtained twice by each author and the average values calculated. Intraobserver reliability was considered according to the criteria of Winer (degree of bias and mean squared error) *(29)*. Reliability was classified, according to the intraclass correlation coefficient, as absent to poor (0-0.24), low (0.25-0.49), fair to moderate (0.50-0.69), good (0.70-0.89), or excellent (0.90-1.0). Interobserver reliability was 0.94, 0.90, 0.91, and 0.92 for ROM of elbow and shoulder, ASES, and MEPS, respectively.

RESULTS

All fractures united uneventfully. The mean time to radiographic union was 13.8 weeks (range 8-20 weeks). The average patient follow-up was 40.3 months (range 26-60 months). An average of 3 lag screws (range 2-4 screws) was used in all cases depending on the type of fracture. All fractures were fixed with a LCP metaphyseal plate of varying length with a minimum of three 5.0 mm screws (range 3-6 screws) on the proximal fragment of the fracture. The small sized distal fragment of the fracture was fixed using a minimum of four 3.5 mm screws (range 4-5 screws) to maximize rotational stability and torsional strength, and to obtain firm fixation (Fig. 2). Bone graft with autologous iliac crest bone or allogeneic bone graft substitute was performed in 7 of 27 patients. Autologous iliac crest bone in 2 patients and allogeneic bone substitute in 5 patients were used for fracture comminution or bone loss. All patients had ≤ 5° of angulation in all planes and no appreciable shortening or rotation. There were 2 complete radial nerve palsies and 1 partial (radial sensory only) palsy identified preoperatively. The radial nerve of these patients was explored during the operation and confirmed to be only neuropraxia. All achieved complete recovery by 6 months postoperative without any further treatment. There were no intraoperative problems associated with use of the implant and anterolateral approach, and no patient had loss of fixation, postoperative infection, iatrogenic radial nerve palsy, heterotophic ossification or delayed union.

All patients regained shoulder motion similar to the uninjured side. The mean arc of elbow motion was 132.4° (range 115°-145°) with a mean flexion of 133.5° (range 130°-145°) and mean flexion contracture of 1.1° (range 0°-15°). Three patients had a slight elbow flexion contracture : 1 patient lost 5°, 1 lost 10°, and 1 lost 15° of extension. The functional arc of motion, as determined according to criteria of Morrey *et al* *(11)* (flexion-extension arc of 30°-130° and 100° of forearm rotation), was achieved in all 27 patients.

The mean ASES score was 92.6 points (range 61-100 points), which corresponded to an excellent results in 26 shoulders and, a good result in one. The mean MEPS was 90.7 points (range 70-100 points), which corresponded to an excellent result in 24 elbows, good result in 2 and a fair result in 1. One patient with unsatisfactory functional scores with a good result of ASES score and a fair result of MEPS had combined injury, which was Gustilo grade II open fracture with biceps partial rupture.

Implant removal was conducted in response to request from 4 patients and 1 at the suggestion of one of the author at an average of 28 months (range 18-37 months). The latter patient had to hardware removed to alleviate elbow stiffness elbow flexion of 130° and flexion contracture of 15°. The hardware was removed surgically 18 months after the original operation and was combined with open arthrolysis. Full elbow ROM resulted without any complications.

DISCUSSION

The optimal treatment of distal third humeral shaft fracture has not been clearly defined (*1-7,9,10, 14-16,18-21,24,31*). Among several surgical options including intramedullary devices (*2,3,14*) and plate fixation with open reduction (*9,16,24*), internal fixation with plate demonstrated firm fixation resulting in union compared with intramedullary devices (*9*). When a distal third humeral shaft fracture is treated using a plate, several points need to be considered including the shape of the plate and surgical approaches.

The torsional strength of a plate is dependent on the number of screws used to secure the plate, with torsional strength increasing with the number of screws used per segment (*26,27*). However, a traditional LCP plate, which has uniformly sized screw holes throughout the length of the plate, can be difficult to use in the treatment of fractures of the distal third humeral shaft because the small sized distal fragment for screws and the restricted space for instrumentation at the distal segment make it more difficult to obtain six-to-eight cortices of purchase in the distal fragment of this fracture. Therefore, we thought the LCP metaphyseal plate, which features both larger and wider-spaced screw holes for fixation in the diaphysis as well as smaller, clustered screw holes for enhanced fixation in the short bony segments and poor quality bone of the metaphysis, was well designed for fractures of the distal third humeral shaft. The clustered distal screw concept proposed in this plate aims to reinforce and support the distal fragment of the humerus discharging the stress forces on the plate onto the bone. Moreover the two most distal holes among five 3.5 mm screw combination holes have an 11° angle towards the center of the plate, which does not influence the elbow joint at all. The 3.5 mm clustered distal screw concept of the LCP metaphyseal plate allows the placement of many screws to fix small sized distal fragment of humerus, which maximizes rotational stability and torsional strength, leading to good clinical results (*24,30*). The LCP technology should facilitate the forceful stability in treating fractures in osteoporotic or otherwise poor-quality bone (*8,23*). In the present study, we used LCP metaphyseal plate to insert at least four 3.5 mm screws in the distal fragment, which allows us to obtain at least eight cortices. Consistent with our hypothesis concerning the utility of the plate, we had excellent restoration and maintenance of reduction and alignment in all patients treated with this technique, even in elderly patients.

Initial fracture fixation with a lag screw compresses the fractured segments of bone together, and changes in compression due to plate application, such as realignment of the bone, may also affect healing (*25*). We initially fixed initially the fracture site using an average of 3 lag screws (range, 2-4 screws) in all cases before applying the plate. This fixation technique with plate and lag screws reportedly produces rapid bone healing (*25*). We achieved the anatomical reduction and bony union in all cases.

Schatzker and Tile documented 4 reasons for plating the distal humerus posteriorly (*22*) : the posterior surface of the distal humerus provides a flat surface suitable for plating, placement of the most distal screws from a posterior approach allows direct visualization and avoids the antecubital fossa, posterior placement allows for the plate to extend distally permitting additional screw placement, and a posterior approach provides the option of double plating. For these reasons, many surgeons use the posterior approach in the treatment of distal third humeral fractures (*4,9,16,24*). In addition, some authors reported contoured locking plate with a "hockey stick" distal configuration (*9,16*). The plate is positioned distally at the juncture of the posterior condyle cortex and capitellum through the posterior approach. This is sufficient for distal fragment to obtain 6 to 8 cortices of purchase. Excellent restoration and maintenance of reduction and alignment of humerus was reported (*4,9,16*). However, use of the plate through the posterior approach can cause skin irritation or pain due to the positioning of the plate on the posterior aspect of the capitellum (*16*). Additionally, open reduction and internal fixation through the posterior approach has been associated with postoperative radial nerve injury in 12%-16% of cases (*4,7*). As Eglseder et al reported, we also thought that postoperative radial nerve injury might be experienced merely from nerve manipulation which is essential on posterior approach (*4*).

We used the anterolateral approach. This approach has several advantages. There is a choice of whether to explore the radial nerve or not. If there is no need to manipulate the radial nerve in a patient who has intact radial nerve function preoperatively, we ignored the radial nerve to prevent postoperative radial nerve injury by manipulation. Even this approach allows the exploration of the radial nerve as necessary for patients with radial nerve palsy preoperatively. In addition, there is no plate-related skin irritation because of the bulky muscle on the anterior surface of the distal humerus. Paradoxically, insertion of a plate and screw on the distal fragment may be difficult because of these bulky muscles and sharp anterior border of distal humerus. However, a bullet nose tip, thinned plate profile, and fracture stabilization by lag screws allow an easier application of plate.

There were some limitations in this study. It was a retrospective review and lacked comparative groups. Also, the number of patients was relatively small. It was difficult to obtain a sufficient number of patients because this fracture is not a common injury. Future studies are warranted for detailed comparisons with groups that use other treatment methods. However, the fact that the surgeries were done by one surgeon with extensive experience in trauma of upper extremities, minimized the confounding factors. Although the sample size was relatively small, it may be possible to compare with other reported series dealing specifically with operative treatment of fractures in the particular anatomic site.

The LCP metaphyseal plate has 5.0 mm locking and standard combination holes at one end and five 3.5 mm combination holes at the other end. This plate design allows a minimum four distal screw holes for the distal fragment of distal third humeral shaft fracture. The current results on the use of this plate are encouraging because this technique has the advantage of achieving a stable fracture fixation using the staggered cluster of five 3.5 mm combination holes that allows insertion of more screws within a small segment of bone. Additionally, the anterolateral approach is advantageous in allowing the exploration of the radial nerve as circumstances demand with protection of the iatrogenic radial nerve from injury. The LCP metaphyseal plate through an anterolateral approach provides an acceptable alternative surgical method for the internal fixation of distal third humeral shaft fracture and will provide satisfactory results in these difficult-to-treat fractures.

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