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Humeral shaft fractures treated by dynamic compression plates, Ender nails and interlocking nails

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Abstract Between January 1991 and December 2002, we treated 92 acute, displaced, closed humeral shaft fractures (AO classification type A). We used three fixation methods: dynamic compression plates (DCP) in 36 patients, Ender nails (EN) in 32 patients and interlocking nails (ILN) in 24 patients. The patients were followed for a minimum of 24 months. At one year, all fractures except two (one DCP/one ILN) had united. Patients treated with EN had shorter mean operation time, 51 (35–110) min; less mean blood loss, 70 (30–170) ml and shorter mean hospital stay, 5.8 (3–12) days. There were three iatrogenic radial nerve palsies: two in the DCP group and one in the ILN group. There was one wound infection. There were three cases with impingement of the shoulder but range of motion was restored after nail removal. For patients with multiple trauma or high operative risk, EN fixation served as a safer and faster procedure. ILN fixation offered a stable fixation via a smaller incision but more fracture comminution might happen.

Résumé Entre janvier 1991 et décembre 2002 nous avons traité chirurgicalement 92 fractures diaphysaires humérales fermés déplacés (classification AO type A). Nous avons utilisé trois méthodes de fixation: plaque à compression dynamique (DCP) chez 36 malades, clou de Ender (EN) chez 32 malades et clou verrouillé (ILN) chez 24 malades. Les malades ont été suivis pendant un minimum de 24 mois. Àprés un an toutes les fractures sauf deux avaient consolidé (un DCP/un ILN). Les Malades traité avec EN ont eu un temps d'opération moyen plus court, 51 (35–110) min, une perte sanguine plus faible, 70 (30–170) ml et un plus court séjour à l'hôpital, 5.8 (3–12) jours. Il y avait trois paralysies iatrogènes du nerf radial, deux dans le groupe DCP et une dans le groupe ILN. Il y avait une infection. Il y avait trois cas avec un conflit de l'épaule mais l'amplitude de mouvement a été restauré après ablation du clou. Pour les malades avec multiples traumatismes ou risque opératoire élevé, l'enclouage de Ender est une procédure plus sûre et plus rapide. L'enclouage verrouillé a permit une fixation stable par une plus petite incision, mais avec un risque plus grand de comminution de la fracture.

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Introduction

Non-operative management is a rational option for the treatment of isolated humeral shaft fractures with no or minimal displacement [18, 20]. But in some circumstances —for example, polytraumatised patients, open fractures, spiral fracture, floating elbow, segmental humeral shaft fractures, pathological fractures and patients of poor compliance for bracing—surgical management may be the better choice. However, there is still no consensus on the methods of reduction and fixation. Among those options, external fixation, compression plating and intramedullary nailing are the most common methods. In addition to traditional intramedullary nailing, interlocking intramedullary nailing has become popular [2, 15–17]. These different alternatives have their own pros and cons. For instance, in spite of a better chance to achieve anatomical reduction, open reduction with compression plates might result in increased incidence of infection, iatrogenic radial nerve injury, extensive soft tissue dissection, increased operating time and mechanical failure in osteoporotic bone [11]. However, earlier reports on intramedullary flexible nailing

have shown the problems of inadequate rotational stability. Although interlocking intramedullary nailing provides antirotation and load-sharing capabilities; the common complications of the closed technique include increased fracture comminution and injury of the rotator cuff, which subsequently limits shoulder motion [13, 19]. Consequently, we conducted this retrospective study to compare the clinical results and efficacy of dynamic compression plate (DCP), flexible intramedullary ender nails (EN) and interlocking intramedullary nail (ILN) for the treatment of acute, closed, and displaced humeral shaft fractures.

Materials and methods

From January 1991 to December 2001, 110 cases of acute displaced humeral shaft fractures treated operatively at the orthopaedic department of Kaohsiung Veterans General Hospital were reviewed retrospectively. We excluded eight cases classified as AO type B or C, four cases without adequate follow-up, four open fractures and two patients who died during the follow-up period. Thus, 92 cases (36/DCP, 32/EN, 24/ILN) classified as AO type A humeral diaphyseal fractures with at least two years' postoperative follow-up entered this study (Table 1).

All 92 patients had acute, displaced, closed humeral shaft fractures treated within two weeks after injury. All patients were skeletally mature. The mechanisms of injury were 49 traffic accidents, 34 falls, four sports injuries and five other causes.

Surgical technique and approach

In the DCP group, the anterolateral approach was used for upper-shaft and middle-shaft fractures. Posterior approach with intraoperative identification and protection of the radial nerve was performed for distal one third shaft fractures. In order to secure the fixation, at least three screws were inserted on either the proximal or distal part of the fracture site. Supplement interfragmental screws were used in spiral or oblique fractures.

EN was inserted via a modified antegrade approach in order to minimize injury to the rotator cuff. The incision was longitudinal and anterior to the acromion. The deltoid muscle was split to visualize the insertion of the rotator cuff. Nails were inserted through holes made distal to the rotator cuff and we inserted as many nails as possible.

We inserted ILN via an antegrade approach. A 4- to 5-cm incision lateral to the acromion was made to facilitate the splitting of the deltoid muscle. The posterior margin of the greater tuberosity was exposed by retracting the supraspinatus tendon. The entry hole was made with an awl. The canal was gradually enlarged by reaming after insertion of a guide pin. The proximal screw was fixed by the target device and the distal screw by freehand technique using an image intensifier.

All 92 fractures showed good or acceptable alignment on intraoperative and immediate postoperative radiographs. The patients used arm slings postoperatively and pendulum and elbow movement were allowed immediately. Patients were encouraged to start active shoulder exercises 3 weeks postoperatively.

We followed the patients at 2-week intervals in the first month and then every month thereafter till 12 months postoperatively. Plain radiographs were taken to evaluate union. Successful union was defined as the appearance of bridge callus or bridging of the cortex with at least partial obliteration of the fracture site observed on anteroposterior and lateral view radiographs. We defined delayed union as union occurring 6–12 months postoperatively and nonunion as no evidence of union after 12 months. Malunion was defined as varus or valgus deformity equal to or more than 20° compared with the contra-lateral limb. We compared blood loss, operative time, hospital stay, incidence of complications, the need for further operation and the cumulative union rate at different time frames among these three groups.

Results

In Table 1, we compare the perioperative courses for patients using DCP, EN, and ILN to treat humeral shaft fractures. With respect to operative time (from incision to complete wound closure) and intraoperative blood loss, the EN group presented significantly better results than the two other groups ($p<0.005$ compared with either the DCP group

Table 1 Demographics of the three groups and their perioperative parameters. *DCP* Dynamic compression plate, *EN* ender nail, *ILN* interlocking intramedullary nail

Implant type	DCP	EN	ILN
Patient number	36	32	24
Gender, male/female	20/16	18/14	15/9
Mean age: years (range)	53 (19–85)	51 (19–88)	47 (20–72)
Operation time: min (range)	110 (55–160)	52 (35–110)	102 (53–170)
Blood loss: ml (range)	320 (150–920)	70 (30–170)	210 (80–450)
Hospital stay: days (range)	8.1 (4–16)	5.8 (3–12)	7.5 (5–12)
Mean follow-up: months (range)	92 (12–130)	88 (14–128)	20 (12–44)
Cumulative union rate			
3 months postoperatively	24	25	18
6 months postoperatively	32	29	20
1 year postoperatively	35	32	23

Table 2 Comparison of perioperative condition by Student's *t* test among the three groups. *EN* ender nail, *ILN* interlocking intramedullary nail

	EN versus DCP	EN versus ILN	ILN versus DCP
Blood loss	$p<0.001$	$p<0.001$	$p<0.001$
Operation time	$p<0.001$	$p<0.001$	n.s
Hospital stay	n.s.	n.s.	n.s.

Table 3 Number of secondary operations/number of complications. *EN* ender nail, *ILN* interlocking intramedullary nail

Implant type	DCP	EN	ILN	Total
Iatrogenic radial nerve palsy	0/2	0/0	0/1	0/3
Intraoperative comminution	0/0	0/0	0/2	0/2
Infection	1/1	0/0	0/0	1/1
Protrusion of implant	0/0	2/3	3/3	5/6
Nonunion	3/4	3/3	3/4	9/11
Total	5/7	4/6	6/10	14/23

or the ILN group; Student's *t* test). However, the ILN group showed less blood loss than the DCP group ($p<0.005$; Student's *t* test) despite no significant difference in operation time. Patients in the EN group had shorter hospital stay than patients in the DCP group and the ILN group ($p<0.005$; Student's *t* test). But there was no significant difference between the DCP group and the ILN group (Table 2). Six patients had preoperative radial nerve palsy with fully spontaneous recovery within 4 months. Three patients had iatrogenic radial nerve injury—two in the DCP group and one in the ILN group—but nerve function recovered within 5 months.

The overall postoperative complications and secondary surgery required in our study are listed in Table 3. Nine of the 11 patients without solid union had secondary surgical treatment including autografting six months after the primary operation. Two nonunion patients refused further surgical treatment. One patient in the EN group and three in the ILN group were found to have soft tissue interposition at the fracture sites. Three patients in the DCP group and two in the EN group had fixation failure. All patients had secondary surgical treatment including autogenous bone grafting and all fractures united within one year. Two patients encountered iatrogenic comminution at the fracture site during antegrade insertion of the ILN but this did not affect the final outcome. There was only one infection in a patient treated with DCP fixation. Six patients had impingement due to proximal protrusion of the nail: three in the EN and three in the ILN group. Normal motion was attained in five patients following implant removal. There was no malunion.

Discussion

Several studies reported less than 10% fracture complications and a union rate of more than 90% in humeral shaft fractures treated conservatively [18, 20]. However, due to the longer time to solid union and the late restoration of daily activities, nonoperative treatment has become less popular. The results of compression plate fixation for humeral shaft fractures have been reported to be quite good [2, 11, 15]. The rate of non-union or delayed union and hardware failure needing reoperation ranged from 0 to 7%. In cases of non-union, revision fixation with DCP or ILN and autogenous bone grafting usually achieves satisfactory results [9, 14, 15]. In this study, the rate of delayed union in the DCP group was 11% (4/36). Three patients achieved solid union one year after revision with ILN and autogenous bone grafting. Apart from infection, iatrogenic radial nerve palsy is another common complication after DCP fixation. Most iatrogenic radial nerve palsies were transient and required no further surgical treatment. In our study, we saw two cases in the DCP group (5%) but both recovered spontaneously within five months.

EN can be used in marrow canals narrower than eight mm and need no reaming thereby avoiding such complications as increased bleeding, iatrogenic fractures and destruction of endosteal blood supply [3, 5]. Previous studies have indicated poor shoulder motion resulting from impingement by the nail or damage of the rotator cuff when using the antegrade approach [7, 8, 10]. We avoided damage to the shoulder capsule by visualizing the insertion of the rotator cuff during surgery and we achieved almost full range of motion of the shoulder via a modified antegrade approach. In our study, we achieved a union rate of 91% in the EN group without persistent limitation of shoulder motion. Additionally, we saw less blood loss, shorter operative time and shorter hospital stay in the EN group. The ease of application of the EN offers a quicker and safer fixation alternative for some kinds of humeral shaft fractures. For patients with multiple trauma or high operative risk, it seems thus more appropriate to use EN because of the diminished blood loss and the shorter operation time. But EN was not recommended in cases with floating elbow or in severely comminuted fractures.

In some ways, an antegrade insertion of rigid interlocking intramedullary nails may encounter similar problems. Partial loss of shoulder motion has been reported in several studies [1, 2, 13, 15, 20]. Even though the effect of reaming might facilitate bone healing, non-union has been reported in 0–9% of cases [6, 12, 17]. Either replacement of the ILN or revision internal fixation with DCP was a rational alternative for the treatment of delayed union and nonunion [9, 14, 21]. However, in our study, there were four cases with delayed union in the ILN group: Three patients were treated with open reduction and revision by DCP including autogenous bone grafting and solid union was obtained in all within 6 months. Three patients treated with ILN had impingement symptoms due to proximal protrusion of the nail. It is evident that this rate is higher than in the other two groups of our study. In three patients, normal shoulder function returned after nail removal. In the ILN group, we found no loss of fixation even in the four patients with nonunion. In our study, ILN offered a satisfactory stable fixation [4].

The most important factors in obtaining fracture healing are anatomical reduction, stable fixation and adequate blood supply. Although internal fixation with DCP may result in a better reduction, it also carries a more extensive soft tissue dissection with risk of radial nerve lesion and infection. In multiple trauma or high operative risk patients, EN may offer the ideal choice of fixation for humeral shaft fracture, especially if the nail is inserted through a modified antegrade approach thereby avoiding damage to the shoulder capsule. ILNs provide secure and rigid fixation with limited surgical exposure and are suitable for segmental or comminuted fractures of the humeral shaft. The disadvantages include a relative high incidence of shoulder problems, high technical skills and additional fracture comminution. The method should be used with caution only by experienced surgeons.

References

1. Ajmal M, O'Sullivan M, McCabe J, Curtin W (2001) Antegrade locked intramedullary nailing in humeral shaft fractures. Injury 32:692–694
2. Chapman JR, Henley MB, Agel J, Benca PJ (2000) Randomized prospective study of humeral shaft fracture fixation: intramedullary nails versus plates. J Orthop Trauma 14:162–166
3. Chen CM, Chiu FY, Lo WH (2000) Treatment of acute closed humeral shaft fractures with ender nails. Injury 31:683–685
4. Chen AL, Joseph TN, Wolinksy PR, Tejwani NC, Kummer FJ, Egol KA, Koval KJ (2002) Fixation stability of comminuted humeral shaft fractures: locked intramedullary nailing versus plate fixation. J Trauma 53:733–737
5. Chiu FY, Chen CM, Lin CFJ, Lo WH, Huang YL, Chen TH (1997) Closed humeral shaft fractures: a prospective evaluation of surgical treatment. J Trauma 43:947–951
6. Fernandez FF, Matschke S, Hulsenbeck A, Egenolf M, Wentzensen A (2004) Five years' clinical experience with the undreamed humeral nail in the treatment of humeral shaft fractures. Injury 35:264–271
7. Flinkkila T, Hyvonen P, Lakovaara M, Linden T, Ristiniemi J, Hamalainen M (1999) Intramedullary nailing of humeral shaft fractures. A retrospective study of 126 cases. Acta Orthop Scand 70:133–136
8. Hall RF, Pankovich AM (1987) Ender nailing of acute fractures of the humerus. J Bone Joint Surg Am 69:558–567
9. Kumar A, Sadiq SA (2002) Non-union of the humeral shaft treated by internal fixation. Int Orthop 26:214–216
10. Liebergall M, Jaber S, Laster M, Abu-Snieneh K, Mattan Y, Segal D (1997) Ender nailing of acute humeral shaft fractures in multiple injuries. Injury 28:577–580
11. Lin J (1998) Treatment of humeral shaft fractures with humeral locked nail and comparison with plate fixation. J Trauma 44:859–864
12. Lin J, Hou SM (2003) Locked nailing of severely comminuted or segmental humeral fractures. Clin Orthop 406:195–204
13. Lin J, Shen PW, Hou SM (2003) Complications of locked nailing in humeral shaft fractures. J Trauma 54:943–949
14. Martinez AA, Cuenca J, Herrera A (2004) Treatment of humeral shaft nonunions: nailing versus plating. Arch Orthop Trauma Surg 124:92–95
15. McCormack RG, Brien D, Buckley RE, Mckee MD, Powell J, Schemitsch EH (2000) Fixation of fractures of the shaft of the humerus by dynamic compression plate or intramedullary nail: a prospective, randomized trial. J Bone Joint Surg Br 82:336–339
16. Rodriguez-Merchan EC (1996) Hackethal nailing in closed transverse humeral shaft fractures after failed manipulation. Int Orthop 20:134–136
17. Sanzana ES, Dümmer RE, Castro JP, Díaz EA (2002) Intramedullary nailing of humeral shaft fractures. Int Orthop 26: 211–213
18. Sarmiento A, Zagorski JB, Zych GA, Latta LL, Capps CA (2000) Functional bracing for the treatment of fractures of the humeral diaphysis. J Bone Joint Surg Am 82:478–486
19. Simon P, Jobard D, Bistour L, Babin SR (1999) Complications of Marchetti locked nailing for humeral shaft fractures. Int Orthop 23:320–324
20. Wallny T, Sagebiel C, Westerman K, Wagner UA, Reimer M (1997) Comparative results of bracing and interlocking nailing in the treatment of humeral shaft fractures. Int Orthop 21:374–379
21. Wenzl ME, Porte T, Fuchs S, Faschingbauer M, Jurgens C (2004) Delayed union and non-union of the humeral diaphysis —compression plate or internal plate fixation. Injury 35:55–60