The elastic stable intramedullary nails as an alternative treatment for adult humeral shaft fractures

Yih-Wen Tarng[a,b,*], Kai-Cheng Lin[a], Cheng-Fong Chen[c,d], Meng-Yin Yang[e,f], Yueh Chien[g]

[a]Department of Orthopaedics, Kaohsiung Veterans General Hospital, Kaohsiung, Taiwan, ROC; [b]Department of Orthopaedics, National Defense Medical Center, Taipei, Taiwan, ROC; [c]Department of Orthopaedics, Taipei Veterans General Hospital, Taipei, Taiwan, ROC; [d]School of Medicine, and National Yang Ming Chao Tung University, Taipei, Taiwan, ROC; [e]Department of Neurosurgery, Neurological Institute, Taichung Veterans General Hospital, Taichung, Taiwan, ROC; [f]College of Nursing, Central Taiwan University of Science and Technology, Taichung, Taiwan, ROC; [g]Department of Medical Research, Taipei Veterans General Hospital, Taipei, Taiwan, ROC

Abstract

Background: Plate and locked intramedullary nailing for humeral fractures are golden standard procedure, but the humerus is a nonweight-bearing bone and can tolerate a larger range of acceptable alignment. We believe the elastic stable intramedullary nails (ESINs) can provide enough relative stability for humeral shaft fractures in certain adult patients.

Methods: There are four new indications for using ESINs: (1) patient could not tolerate a sugar-tong splint but was a high risk for general anesthesia, (2) intramedullary canal narrowing (<7 mm), (3) long spiral or oblique fracture over the metadiaphyseal junction, and (4) obesity. All patients received retrograde fixation with two titanium elastic nails, except for one patient with a long spiral fracture over the proximal metadiaphysis. Patients had routine follow-up plain radiographs until bone union, and we evaluated functional results of patients by Mayo Elbow Performance Score and asked to complete Quick Disabilities of the Arm, Shoulder and Hand score at the last outpatient clinic visit.

Results: A total of 16 patients with a mean age of 54.4 years were included. The mean follow-up time was 14 ± 2.5 months, and the average time to bone union was 16 ± 4.3 weeks. There were no wound infections, loss of reduction, fracture nonunion, implant failure, or skin irritation expect for one nail back-out because of osteoporosis.

Conclusion: We have reported good results using ESINs for the displaced fractures of the humerus in the four indication adults who would not be able to tolerate plate fixation or intramedullary nailing. The ESINs fixation method is a simple procedure that provides a small incision, minimal blood loss, short surgical time, and relative stability fixation.

Keywords: General anesthesia; Humeral fractures; Intramedullary nails

1. INTRODUCTION

Over the past few years, there has been a marked increase in the use of elastic stable intramedullary nails (ESINs) for management of fractures of the long bones in children.[1–5] ESINs are able to provide internal pressure in the intramedullary cannel based on the concept of three-point fixation and improve stability significantly by using two pretensioned nails inserted from opposite sides of the bone.[6,7] If ESINs are accurately contoured and properly inserted, they provide excellent axial loading and bending stability to diaphysis fractures in long bones.[6,7] Rotational stability is also better than that using Ender's nails, although this is the weakest point of the technique. ESINs avoid growth plate injury because of the small insertion site from the metaphysis of a long bone and are widely used to treat long bone fractures in children.

ESINs were initially designed to treat long bone fractures in children.[8,9] They provide excellent axial loading, and rotational and bending stability in diaphysis fractures of long bones in children because they are light weight, thicker periosteum, and rapid bone healing.[9,10] Despite the advantages of ESINs, they are seldom used in adults. Some orthopedic surgeons use ESINs to fix clavicular fractures in adults because clavicle is a nonweight-bearing bone and can tolerate less precise alignment.[11–14] Other advantages of ESINs include a small incision, minimal blood loss, short operation time, and less damage to soft-tissue and the periosteum resulting in earlier bone healing.[11–14] Plate and screw fixation for transverse fractures, and anterograde or retrograde locked intramedullary nailing for comminuted or osteoporotic fractures of humerus, however, are still the golden standard procedure of choice for treating these conditions. However, we believe that the humerus is similar to clavicle and that ESINs can provide relative stability for humeral shaft fractures in certain patients. Thus, the purpose of this study is to evaluate outcomes

*Address correspondence. Dr. Yih-Wen Tarng, Department of Orthopaedics, Kaohsiung Veterans General Hospital, 386, Da-Chung 1st Road, Kaohsiung813, Taiwan, ROC. E-mail address: qm1047@ms35.hinet.net (Y.-W. Tarng).

Conflicts of interest: The authors declare that they have no conflicts of interest related to the subject matter or materials discussed in this article.

Journal of Chinese Medical Association. (2021) 84: 644-649.

Received March 2, 2021; accepted March 23, 2021.

doi: 10.1097/JCMA.0000000000000514.

of displaced fractures of the humerus in the new indication of adults treated with ESINs.

2. METHODS

In this study, we retrospectively reviewed the records of adult patients with humeral shaft fractures treated with ESINs at our institution from January 2013 to December 2015. There are four indications for using ESINs: (1) patient could not tolerate a sugar-tong splint but was a high risk for general anesthesia (e.g., severe chronic obstructive pulmonary disease [COPD], class III-IV congestive heart failure [CHF], old age) (Fig. 1), (2) long spiral or oblique fracture over the metadiaphyseal junction (Fig. 2), (3) intramedullary canal narrowing (<7 mm) (Figs. 3, 4), and (4) obesity.

2.1. Surgical technique for intramedullary fixation using titanium elastic nails

After induction of adequate anesthesia, the patient was placed in the supine position without a tourniquet. The arm was placed on a radiolucent arm table or suspended vertically in traction. The image intensifier was positioned perpendicular and caudal to the arm. The ESINs were bent into a "C" and an "S" shape with the nail tip pointing to the concave side of the bowed nail. Bending was done by hand (≤3 mm) or with a tabletop plate-bending press (>3 mm). A 3-cm skin incision was made over the lateral condyle. The first entry point for each nail was posterolateral from the lateral condylar region, one hole above the other, angled upward. The near cortex was penetrated with the drill bit. Using a rotating awl, the awl was slowly lowered to an angle of 45° relative to the shaft axis and was advanced at this angle until it reached the medullary canal. An adequate titanium elastic nail (TEN) was then fixed in a universal chuck with a T-handle. Using oscillating hand movements, the unreamed TEN was manually gently advanced until it reached the fracture site. The nail was introduced into the proximal fragment by indirect manipulation of the fragment under fluoroscopy. The nail was carefully advanced manually throughout the entire implantation procedure to avoid penetrating the cortex, especially in osteoporotic bone, until it rested at the humeral head. The two nails should diverge in opposite directions, both medial and lateral, for optimal rotational stability. Once alignment was satisfactory, traction was released and impact the olecranon, if necessary, before cutting the nails to an appropriate length. The cut end of the nail was embedded beneath the cortex. In cases with long oblique or spiral fractures over the metadiaphysis of humerus, we first performed open reduction and fixation with two cerclage wires to avoid radial nerve injury and shortening or rotation, and then inserted the nails as described.

2.2. Postoperative care and follow-up

Elder patients (>65 years old) were immobilized with an arm sling after surgery for 3 to 4 weeks because of osteoporosis, while other patients did not receive immobilization after surgery. After discharge from the hospital, patients routine follow-up was scheduled at 2 weeks, 6 weeks, 3, 4, and 6 months after surgery, and annually thereafter. Fracture union was determined by plain radiographs taken immediately after surgery, and then at 6-week intervals until bone union was achieved.

2.3. Functional evaluation

Patients were evaluated by Mayo Elbow Performance Score (MEPS) and asked to complete the short version of the Disabilities of the Arm, Shoulder and Hand outcome questionnaire (QuickDASH) (www.orthopaedicscores.com) at the last outpatient clinic visit. The MEPS was divided into four parts (pain, arc of motion, stability, and function) and scored as excellent (score >90), good (score 75-89), fair (score 60-75), and poor (score <60). QuickDASH is a self-reported questionnaire consisting of 11 items corresponding to different activities of daily life and symptoms experienced by the patient. The QuickDASH score ranges from 0 (least disability) to 100 points (most

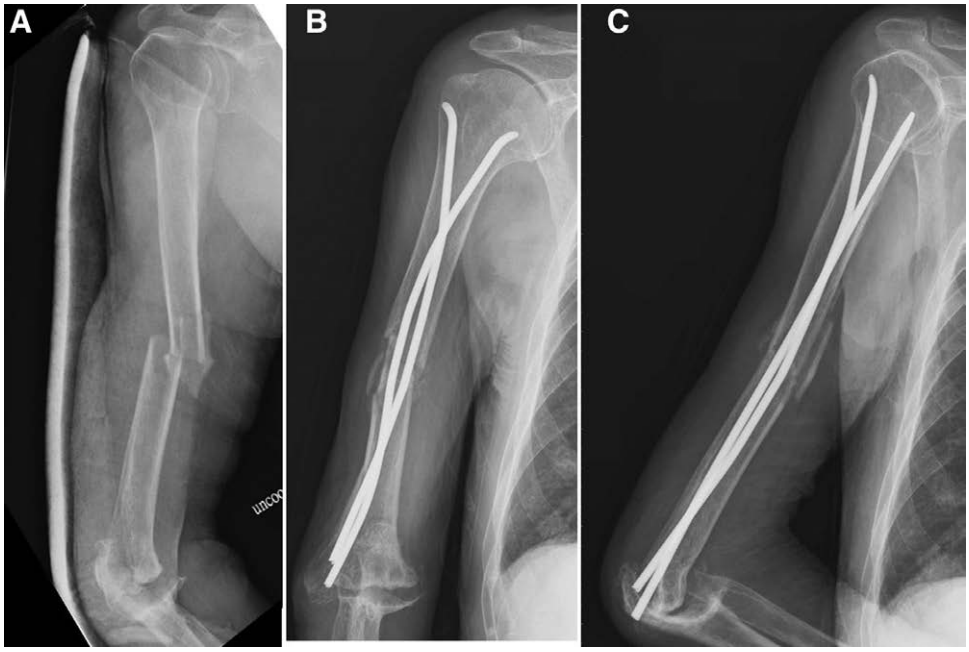

Fig. 1 An 85-y-old woman with stage III-IV congestive heart failure who could not tolerate severe pain and was at high risk for general anesthesia. A, Preoperative X-ray (B), post-operative X-ray (C) show two 4.0-mm titanium elastic nails (TENs) that were inserted in a retrograde manner and were divergent over the proximal humerus.

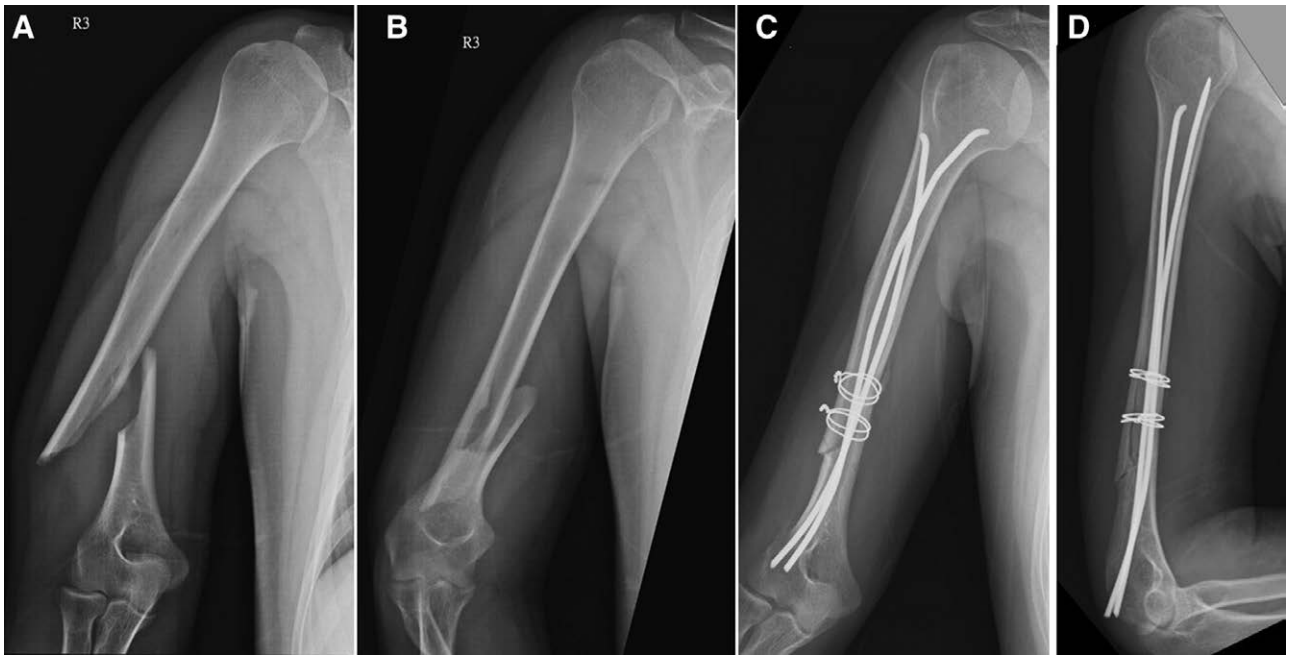

Fig. 2 A 32-y-old woman with a long oblique fracture over the metadiaphysis of the humerus with radial nerve injury. A, B, Preoperative X-ray, (C, D) postoperative X-ray show fixation with two cerclage wires and 3.0-mm titanium elastic nails that were inserted in a retrograde manner.

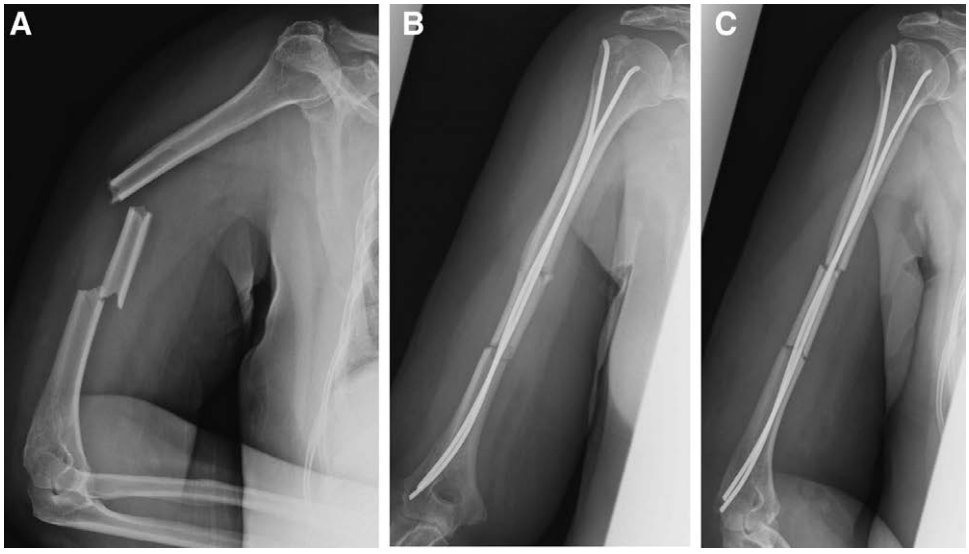

Fig. 3 A 55-y-old woman with a segmental fracture of the humerus with severe narrowing of the intramedullary cannel (<7 mm). A, Preoperative X-ray, (B, C) postoperative X-ray show two 2.5-mm titanium elastic nails that were inserted in a retrograde manner.

disability) and allows evaluation of the overall performance of the upper limb. Time to return to normal daily activities and previous work were also evaluated.

3. RESULTS

A total of 16 patients (6 males and 10 females) with a mean age of 54.4 years (range, 19-94 years) were included in the analysis (Table). Of the 16 patients, the injury was attributed to a motor vehicle accident (7 young patients), fall (7 elder patients), and exercise injury (2 patients). All patients received retrograde fixation with two TENs, except for one patient with a long spiral fracture over the proximal meta-diaphysis (Fig. 4). The mean follow-up time of the 16 patients was 14 ± 2.5 months (range, 12-18 months), and the average time to bone union was 16 ± 4.3 weeks (range, 12-25 weeks). No secondary procedures were required. There were no wound infections, loss of reduction, fracture nonunion, implant failure, or skin irritation expect for one nail back-out because of osteoporosis.

Transient radial nerve palsy occurred in three patients. The first patient had a segmental fracture with miniopen reduction of the free fragment, and drop wrist was noted after surgery. Radial nerve function recovered without any treatment 6 weeks after surgery. The second patient had a long spiral fracture over

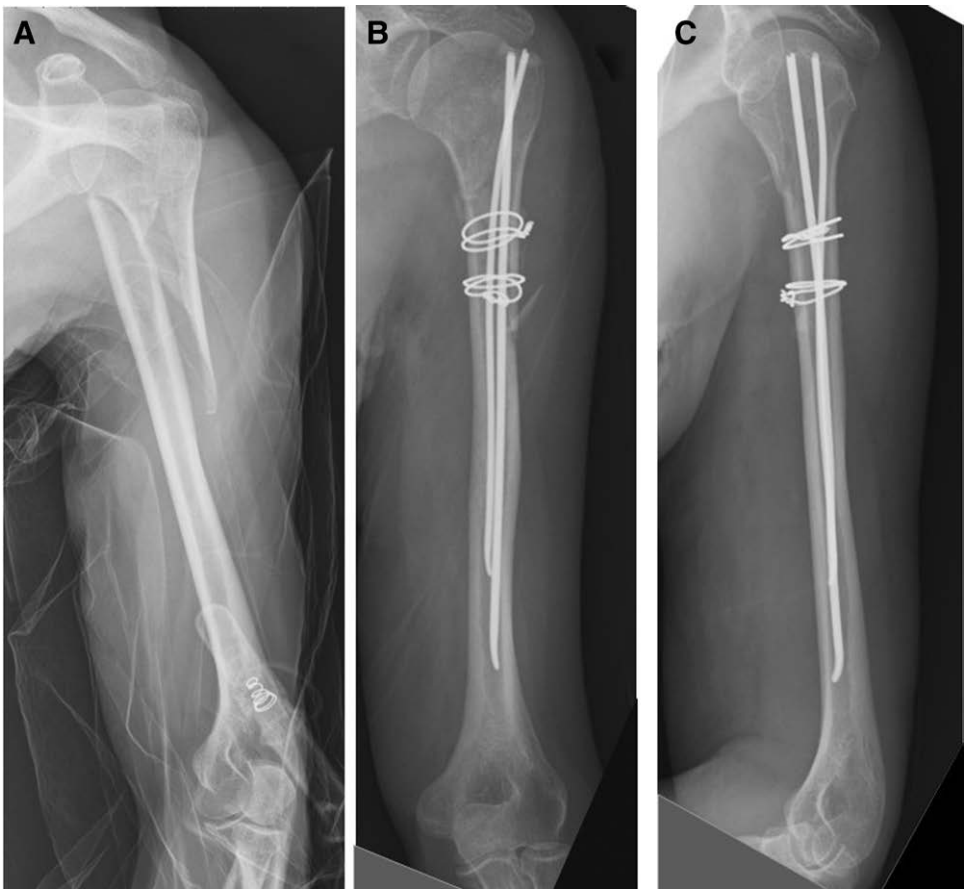

Fig. 4 A 46-y-old woman with a long oblique fracture of the proximal humerus. A, Preoperative X-ray, (B, C) post-operative X-ray showed fixation with two cerclage wires, and 3.5-mm titanium elastic nails that were inserted in an antegrade manner without rotator cuff injury.

the distal metadiaphysis region with open reduction and wire looping fixation. The radial nerve was always protected during the surgery. The transient radial nerve palsy resolved after transcutaneous electrical nerve stimulation (TENS) for 3 months. In the last patient, radial nerve palsy was found before surgery, and radial nerve was identified and protected during surgery. The radial nerve function recovered after TENS for 3.5 months.

The operative time was <45 minutes (average, 38.3 minutes; range, 35-45 minutes) in closed reduction patients, except for in two obese patients, and blood loss was also <60 mL (average, 38.3 mL; range, 20-60 ,L) because of the small incision wound and unreamed nails. Although the operative time was more than 65 minutes and blood loss >80 mL in open reduction patients, we believed radial nerve identification and protection are important, though this increases the surgical time and blood loss. Satisfaction was greater in younger patients; however, the mean MEPS was 95.0 (range, 90-100) and QuickDASH score was 0.81 (range, 0 to 6.8). In the elder patient, the mean MEPS was 82.8 (range, 75-90) and QuickDASH score was 27.4 (range, 18.6-38.2). All patients returned to normal daily activities in 3 to 4 months and to previous work within 6 months in the younger patient group.

4. DISCUSSION

Plate and screw fixation for transverse fractures, and anterograde or retrograde locked intramedullary nailing for comminuted or osteoporotic fractures remain the procedures of choice for fractures of the humeral shaft. However, there are certain patients that are not suitable for these procedures. There are many advantages of ESINs, including a small incision, minimal blood loss, short operation time, and less invasive soft-tissue dissection and periosteal stripping which contributes to faster fracture healing. ESINs were initially designed to treat long bone fractures in children. We believe they are suitable for humeral fractures in adults because the humerus is a non-weight bearing bone and can tolerate a larger range of acceptable alignment, and ESINs provide enough relative stability. The ESIN is different from traditional Ender's nails or Steinmenn pins in that they provide the internal pressure in the intramedullary cannel by three-point fixation and improve axial loading, and bending and rotational stability. Patients can engage in early rehabilitation without a splint or cast protection after surgery and return to normal daily activities and previous work sooner than with other methods.

There were seven patients that could not tolerate severe pain and sugar-tong splinting but were at high risk for general anesthesia because of severe COPD, class III-IV CHF, or old age (Table). There was concern about weaning from the ventilator after general anesthesia. We adopted closed reduction and two TENs fixation under interscalene regional block and heavy sedation because there was only going to be a small incision (3 cm) at the lateral aspect of elbow, and a short operation time (<45 minutes). This method of anesthesia is very safe, and patients are usually pain free for 12 hours after surgery and do not require an intensive care unit stay. These patients were discharged 3 to 4 days after surgery without any complications.

There were four patients with long oblique or spiral fractures over the metadiaphysis of the humerus (three distal and one

Table.

Patient characteristics

Patient	Sex	Age	Trauma mechanism	Anesthesia	ESIN indication	Closed/opened reduction	Nail diameter, mm	Blood loss, mL	Operation time, min	Complication
1	F	85	Fall	IS + HS	Old age	Closed	3.0	20	45	One nail back out
2	M	78	Fall	IS + HS	Severe COPD	Closed	3.5	35	35	
3	F	55	TA	GA	Segmental fracture Cannel narrowing (<7 mm)	Mini-opened	2.5	80	65	Temporary radial nerve injury (6-wk recovery)
4	M	94	Fall	IS	Old age	Closed	4.0	30	35	
5	F	56	TA	GA	Obesity (BMI = 42.2)	Closed	4.0	60	55	
6	F	65	Fall	IS + HS	CHF (class III-IV)	Closed	3.5	40	40	
7	M	23	Exercise	GA	Metadiaphysis long spiral fracture	Opened	3.0	100	70	Temporary radial nerve injury (3-mo recovery)
8	F	19	TA	GA	Cannel narrowing (<7 mm)	Closed	2.5	30	40	
9	F	32	TA	GA	Long oblique fracture	Opened	3.0	90	65	Preoperative radial nerve injury, (3.5-mo recovery)
10	M	74	Fall	IS + HS	Severe COPD	Closed	4.0	40	35	
11	M	25	Exercise	GA	Meta-diaphysis long spiral fracture	Opened	3.0	100	75	
12	M	38	TA	GA	Obesity (BMI = 40)	Closed	3.0	60	60	
13	F	72	Fall	IS + HS	CHF (class III-IV)	Closed	4.0	30	35	
14	F	25	TA	GA	Cannel narrowing (<7 mm)	Closed	2.5	25	40	
15	F	46	TA	GA	Meta-diaphysis long oblique fracture	Opened	3.5	90	65	
16	F	83	Fall	IS + HS	CHF (class III- IV)	Closed	4.0	30	40	

BMI = body mass index (kg/m^2); CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; F = female; GA = general anesthesia; HS = heavy sedation; IS = interscalene nerve block; M = male; TA = traffic accident.

proximal). In our prior experience, we have found it necessary to fix the fracture by a long plate, and the radial nerve usually lies on the plate. This method is associated with a larger incision, greater blood loss, and longer surgical time, as well as a high risk of radial nerve injury is a second operation is necessary to remove the implant. In these cases, we adopted open reduction and fixation with two cerclage wire after identification and protection of the radial nerve, and then inserted two TENs. Initially direct reduction and rigid fixation by two cerclage wires for primary bone healing were performed, they resisted rotation and shortening and TENs resisted bending and axial loading force. However, the composition is very rigid fixation, and patients could early active motion and return to daily activities without any immobilization. Although two transient radial nerve palsy before surgery, they were totally recovery after 3 months.

We often find intramedullary cannel narrowing (<7 mm) in Asian women. The smallest diameter of a locked intramedullary nail is 7 mm (Expert's nail, Synthesis). There were 1 patient with a segmental fracture (Fig. 3) and 2 with transverse fractures. In these patients, two 2.5-mm TENs were inserted using a 2- to 3-cm incision, which is much smaller than the 10-cm incision needed for plate fixation. We also had two patients who were obese (bosy mass index >42 kg/m^2). We believe this procedure is advantageous for obese patients because of the concern of fat necrosis and wound complication with plate or nail fixation, and it is difficult to immobilize the arm with a hanging arm cast or functional brace if nonoperative treatment. Satisfactory results were obtained in these two group patients.

All patients received retrograde nailing from the lateral condyle of the humerus, expect for initial two cases in which insertion was from the lateral and medial condyle of humerus. The suggested insertion point is at the lateral supracondylar ridge or lateral cortex below the deltoid muscle to avoid growth plate injury in children. However, we believe these insertion points are not appropriate in adults because of a thicker cortex and proximity to the radial nerve. A similar situation occurs at the medial condyle of humerus which has a narrow canal, thicker cortex, and is near the ulnar nerve. It is very difficult to position the Awl at a 45° angle relative to the shaft axis and continue to penetrate the thicker cortical bone at an upward angle after the ulnar nerve is identified and protected. Retrograde nailing to the fracture site results in compression, but not distraction. We suggest that the entry point of the two TENs be over the posterolateral condyle of the humerus in adult, and that both nails are precontoured into a "C" and an "S" shape. Alignment can be adjusted by rotating the two nails, and the nails can be fully inserted to achieve the best anchorage in the proximal metaphysis.

In conclusion, we have reported good results using ESINs for the management of displaced fractures of the humerus in adults with the four indication who would not be able to tolerate plate fixation or intramedullary nailing. The ESINs fixation method is a simple procedure that provides a small incision, minimal blood loss, short surgical time, and relative stability fixation. Bone union time and functional results are similar to those of plate fixation or intramedullary nailing. The ESINs fixation is a considerable option for treating displaced humeral fractures in adults with the four indications.

ACKNOWLEDGMENTS

Veterans Affairs Council, R.O.C – "Integrated Project: Establishment of Regenerative Medicine and Cell Therapy Platform of Veterans General Hospital System"; Ministry of Health and Welfare (MOHW108-TDU-B-211-133001 and MOHW109-TDU-B-211-114001).

REFERENCES

1. Barry M, Paterson JMH. Flexible intramedullary nails for fractures in children. *J Bone Joint Surg [Br]* 2004;**86**:947–53.
2. Kraus T, Hoermann S, Ploder G, Zoetsch S, Eberl R, Singer G. Elastic stable intramedullary nailing versus Kirschner wire pinning: outcome of severely displaced proximal humeral fractures in juvenile patients. *J Shoulder Elbow Surg* 2014;**23**:1462–7.
3. Lieber J, Schmittenbecher P. Developments in the treatment of pediatric long bone shaft fractures. *Eur J Pediatr Surg* 2013;**23**:427–33.
4. Lacher M, Schaeffer K, Boehm R, Dietz HG. The treatment of supracondylar humeral fractures with elastic stable intramedullary nailing (ESIN) in children. *J Pediatr Orthop* 2011;**31**:33–8.

5. Fernandez FF, Eberhardt O, Langendörfer M, Wirth T. Treatment of severely displaced proximal humeral fractures in children with retrograde elastic stable intramedullary nailing. *Injury* 2008;**39**:1453–9.
6. Marengo L, Canavese F, Cravino M, De Rosa V, Rousset M, Samba A, et al. Outcome of displaced fractures of the distal metaphyseal-diaphyseal junction of the humerus in children treated with elastic stable intramedullary nails. *J Pediatr Orthop* 2015;**35**:611–6.
7. Porter SE, Booker GR, Parsell DE, Weber MD, Russell GV, Woodall J Jr, et al. Biomechanical analysis comparing titanium elastic nails with locked plating in two simulated pediatric femur fracture models. *J Pediatr Orthop* 2012;**32**:587–93.
8. Garner MR, Bhat SB, Khujanazarov I, Flynn JM, Spiegel D. Fixation of length-stable femoral shaft fractures in heavier children: flexible nails vs rigid locked nails. *J Pediatr Orthop* 2011;**31**:11–6.
9. Kanlic E, Cruz M. Current concepts in pediatric femur fracture treatment. *Orthopedics* 2007;**30**:1015–9.
10. Lascombes P, Haumont T, Journeau P. Use and abuse of flexible intramedullary nailing in children and adolescents. *J Pediatr Orthop* 2006;**26**:827–34.
11. Tarng YW, Yang SW, Fang YP, Hsu CJ. Surgical management of uncomplicated midshaft clavicle fractures: a comparison between titanium elastic nails and small reconstruction plates. *J Shoulder Elbow Surg* 2012;**21**:732–40.
12. Chen YF, Wei HF, Zhang C, Zeng BF, Zhang CQ, Xue JF, et al. Retrospective comparison of titanium elastic nail (TEN) and reconstruction plate repair of displaced midshaft clavicular fractures. *J Shoulder Elbow Surg* 2012;**21**:495–501.
13. Liu PC, Chien SH, Chen JC, Hsieh CH, Chou PH, Lu CC. Minimally invasive fixation of displaced midclavicular fractures with titanium elastic nails. *J Orthop Trauma* 2010;**24**:217–23.
14. Mueller M, Rangger C, Striepens N, Burger C. Minimally invasive intramedullary nailing of midshaft clavicular fractures using titanium elastic nails. *J Trauma* 2008;**64**:1528–34.