Int J Clin Exp Med 2018;11(2):870-876
www.ijcem.com /ISSN:1940-5901/IJCEM0062101

Original Article

A retrospective comparison of minimally invasive percutaneous plate osteosynthesis (MIPPO) and minimally invasive percutaneous titanium elastic nail osteosynthesis (MIPTENO) for midshaft clavicle fracture

Long Chen[1], Hui Chen[2], Majid Nisar[1], Hua Chen[1], Jun Pan[1], Lei Peng[3], Qingyu Chen[1], Dongsheng Zhou[4], Jianjun Hong[1]

[1]Department of Orthopedics Surgery, The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, Wenzhou 325027, Zhejiang, China; [2]Departments of Surgery, The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, Wenzhou 325027, Zhejiang, China; [3]Department of Orthopedics Surgery, The Affiliated Hospital of Hainan Medical College, Haikou 570102, Hainan, China; [4]Department of Orthopedics Surgery, Shandong Provincial Hospital of Shandong University, Jinan 250014, Shandong, China

Received July 23, 2017; Accepted November 17, 2017; Epub February 15, 2018; Published February 28, 2018

Abstract: Minimally invasive percutaneous plate osteosynthesis (MIPPO) and minimally invasive percutaneous titanium elastic nail osteosynthesis (MIPTENO) are used for midshaft clavicle fracture, but there is no study directly comparing the two methods. We aim to compare MIPPO and MIPTENO of the treatment of midshaft clavicle fracture in adults. This was a prospective study of patients with midshaft clavicle fracture treated at the Departments of Orthopedics Surgery of our hospital from January 2007 to October 2013. Patients were randomized to MIPPO and MIPTENO (n=27/group). Union time, mean time of operation, mean time of fluoroscopy, time of hospital stay, implant failure, cosmetic dissatisfaction and complications were evaluated. The primary endpoints were the constant shoulder score and DASH score were used to analyze the functional outcomes. Bone union was achieved in all cases after 12.2±1.2 weeks in the MIPPO group and 13.1±1.9 weeks in the MIPTENO group (P=0.049), especially in wedge (P=0.003) and comminuted (P=0.02) fractures. There were no significant difference in constant shoulder scores (P=0.521) or DASH scores (P=0.158) between the two groups. There were two patients with dysesthesia and two patients with painful local irritation in the MIPPO group. There were three patients with telescoping and four patients with painful local irritation in the MIPTENO group. MIPPO showed fast bone union and lower complications than MIPTENO, especially in wedge and comminuted fractures. However, MIPPO was not superior to MIPTENO in terms of shoulder score at final follow-up.

Keywords: Midshaft clavicle fracture, fracture fixation, minimally invasive percutaneous plate osteosynthesis, minimally invasive percutaneous titanium elastic nail osteosynthesis

Introduction

Traditional treatment of midshaft clavicle fractures is nonsurgical, and the nonunion rate with conservative treatment is low (<1%) [1, 2], but recent studies revealed a nonunion rate of 14.3-24% in patients with displaced midshaft clavicle fractures [3, 4].

Minimally invasive surgery is increasingly being used for the treatment of midshaft clavicle fracture. The two most commonly used implant are titanium elastic nail (TEN) and locking compression plate (LCP) [5, 6]. Minimally invasive percutaneous plate osteosynthesis (MIPPO) is widely used for long bone fracture [7-9]. The plate is inserted percutaneously using two small incisions, causing less disruption of soft tissues and preserving the blood supply to the bone fragments [10]. MIPPO of the clavicle results in lower rates of dysesthesia and hypertrophic scarring, and better cosmetic results than open reduction [6]. Minimally invasive percutaneous titanium elastic nail osteosynthesis

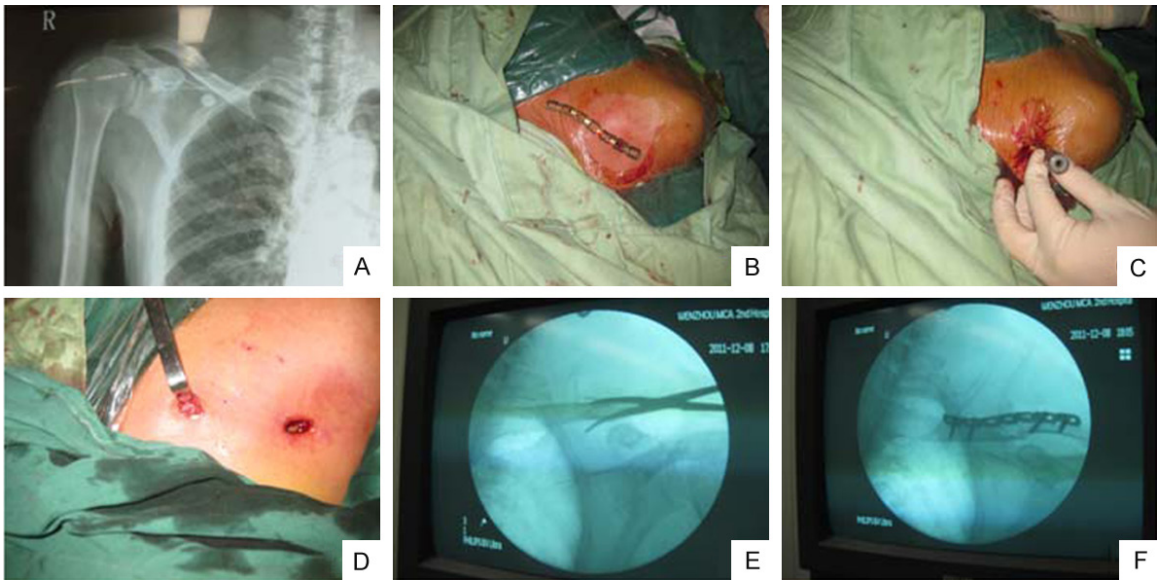

Figure 1. Minimally invasive percutaneous plate osteosynthesis (MIPPO) procedure. A. Anteroposterior view of the clavicle fracture. B. Shape of the locking plate. C. Insertion of the locking plate. D. Locking plate shown in the wound. E. Reduction of fracture. F. Postoperative X-ray.

(MIPTENO) of midshaft clavicle fractures has been shown to achieve good outcomes [11], but it is technically challenging and various complications may occur [12].

No previous study directly compared MIPPO and MIPTENO. The present study aimed to compare MIPPO and MIPTENO of the treatment of midshaft clavicle fracture in adults.

Material and methods

Study design and patients

This was a prospective study of patients with midshaft clavicle fracture treated at the Departments of Orthopedics Surgery of our hospital from January 2007 to October 2013. The study was approved by the ethics committee. The patients signed an informed consent form.

The inclusion criteria were: 1) midshaft clavicle fracture (Robinson Type 2 B1 or B2 clavicle fractures); 2) eligible to MIPPO or MIPTECO; 3) followed up for at least 6 months; 4) age 18-60 years; and 5) operated by traumatic orthopedic surgeons. The exclusion criteria were: 1) old fractures; 2) pathological fractures; 3) fracture combined with nerve or vascular injury, 4) history of ipsilateral congenital malformation; 5) vital organs trauma; or 6) associated with fractures of other parts of the ipsilateral limb.

Fractures were classified according to the Orthopedic Trauma Association (OTA) Classification System [13]. All surgeries were performed by the trauma orthopedic surgeon (10 years of experience).

Grouping and randomization

Based on the inclusion and exclusion criteria, 54 patients were identified. The patients were randomized to MIPPO and MIPTENO (n=27/group). Randomization was carried out using sequential sealed envelopes prepared by a statistician using a random number table.

Surgical technique

The patients were placed in the beach chair position on a radiolucent operating table under general anesthesia, brachial plexus block or both. MIPPO was performed as previously described [6, 10]. Two small bilateral incisions (approximately 2.0-3.0 cm) were made 2.0 cm from the fracture site. The locking plate (Synthes-Stratec Inc., West Chester, PA, USA) was contoured to the shape of the clavicle and placed in the anterosuperior position. Closed reduction was performed with a periosteal dissector, a reduction clamp, or a towel clamp percutaneously. To avoid injury to the underlying neurovascular structures, the towel clamp was not clamped until the tips were confirmed to be

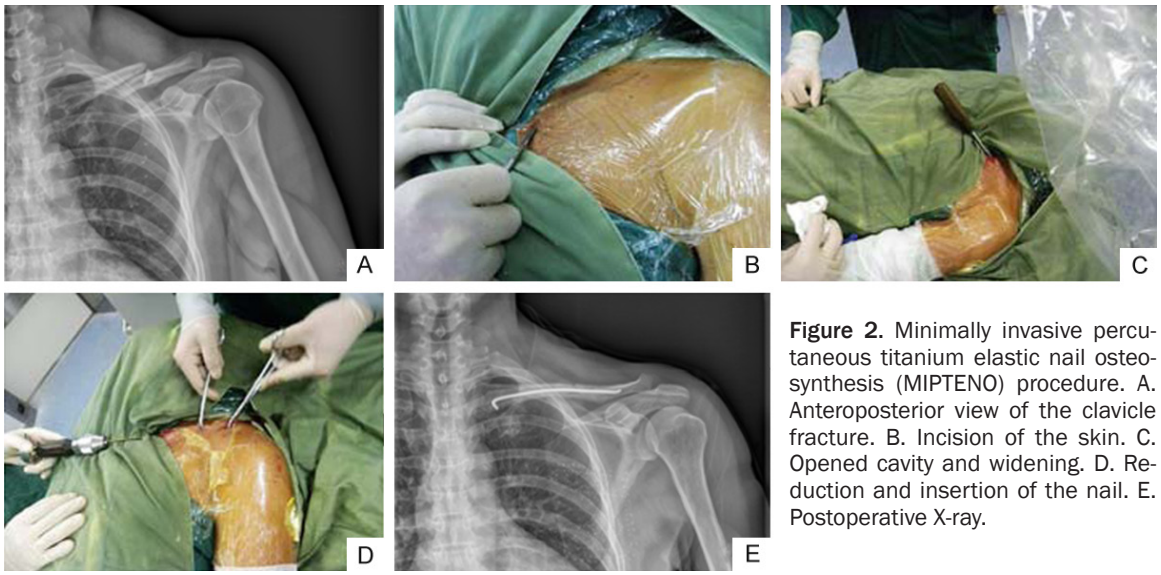

Figure 2. Minimally invasive percutaneous titanium elastic nail osteosynthesis (MIPTENO) procedure. A. Anteroposterior view of the clavicle fracture. B. Incision of the skin. C. Opened cavity and widening. D. Reduction and insertion of the nail. E. Postoperative X-ray.

secured on the bone. If close reduction could be achieved, a small incision (approximately 2.0 cm) was centered over the fracture site to reduce it, then the plate was inserted through the distal incision. Two or three screws were inserted in the plate through the distal incision and the proximal incision, alternatively (**Figure 1**).

MIPTENO was performed as previously described [5, 11, 12, 14]. A 1-cm skin incision was made on the medial end of the clavicle about 1.0-2.0 cm lateral to the sternoclavicular joint. A cavity in the lower border of the medial clavicle was opened using a 2.5-mm drill and widened with an awl. Under anteroposterior fluoroscopy, the TEN (Synthes-Stratec Inc., West Chester, PA, USA) with a diameter between 2.0 and 3.0 mm, fixed in a chuck with a T-handle, was advanced laterally up to the fracture with oscillating movements. Closed reduction and advancement into the lateral fragment were attempted in every case, which was performed by manipulating the fracture while moving the free-draped arm. If necessary, the medial fragment was reduced using a towel clamp percutaneously. If closed reduction failed, direct manipulation of the fragments was enabled by an additional skin incision of 2.0-3.0 cm in length, parallel to the Langers lines at the fracture site. Single displaced fragments were left in situ. After open reduction, the TEN was then advanced under visual control into the lateral fragment 2.0-3.0 cm medial to the acromioclavicular joint. After that, the medial protruding end of the nail was cut as short as possible (**Figure 2**).

Postoperative care

No supplementary support such as a sling was used. The patients were asked to exercise with a motion range <90° during the first three weeks, and then to go full range thereafter. Since rotation forces of the clavicle could promote implant dislocation, the elevation of the arm was limited to 90° until the end of the third postoperative week.

Follow-up

Following hospital discharge, the patients underwent clinical and radiological evaluations every 4 week to assess fracture healing, function of the arm, cosmetic results, and any complications such as nonunion, delayed union, symptomatic malunion, implant failure, telescoping, transient plexus irritation, etc. [14, 15]. Five patients (three with MIPTENO and two with MIPPO) were lost to follow-up.

Outcomes

The functional outcomes was measured by the surgeon after implant removal according to the Constant and Murley Shoulder Score (range: 0-100 points, best: 100) [12]. Usage of the upper extremity was evaluated using the disabilities of the arm, shoulder, and hand (DASH) questionnaire score (range: 0-100 points, ideal: 0) [16].

Table 1. Baseline and operative characteristics of the patients

Parameter	MIPPO	MIPTENO	P
Age (years)	37.8±10.6	39.1±11.4	0.675
Gender (M/F)	16/11	15/12	0.788
Fracture type			0.392
Simple	14	17	
Wedge	7	6	
Comminuted	6	4	
Mechanism of injury			0.758
Traffic accident	14	17	
Fall	7	6	
Sports injury	6	4	
Interval from injury to operation (h)	24.6±20.0	22.2±18.4	0.794
X-ray time (s)	11.2±1.5	10.3±1.5	0.037
Length of hospital stay (days)	7.48±2.42	7.63±2.48	0.825
Operation time (min)	53.5±13.1	51.5±10.4	0.53

Table 2. Time to union

Type of fracture	MIPPO	MIPTENO	P
Simple	11.6±0.9	12.0±1.3	0.295
Wedge	12.1±1.1	14.2±0.8	0.003
Comminuted	13.7±0.8	16.0±1.7	0.018
All types	12.2±1.2	13.1±1.9	0.049

Results are presented as the number of weeks (mean ± SD).

Table 3. Constant shoulder and DASH score sat final follow-up

Fracture type	MIPPO	MIPTENO	P
Constant shoulder score			
Simple	96.9±2.2	96.6±2.6	0.762
Wedge	96.3±3.2	97.3±3.7	0.593
Comminuted	96.3±3.4	96.5±3.4	0.942
All types	96.6±2.7	96.7±2.9	0.845
DASH score			
Simple	2.06±1.29	2.31±0.99	0.550
Wedge	3.50±2.43	3.43±2.09	0.959
Comminuted	3.98±2.19	6.93±2.55	0.087
All types	2.86±1.96	3.24±2.21	0.505

Results are presented as mean ± SD.

Statistical analysis

This was a preliminary study and no power analysis was performed. Continuous data was presented as mean ± standard deviation (SD) and analyzed using the Student's t test. Categorical data was presented as proportions and analyzed using the Fisher's exact test. Statistical analysis was performed using SPSS 19.0 (IBM, Armonk, NY, USA). Two-sided *P*-values <0.05 were considered significant.

Results

Characteristics of the patients

Twenty-seven patients were randomized to each group. In the MIPPO group, 23 patients were treated by closed reduction. An accessory incision had to be made centered over the fracture site in four patients. In the MIPTENO group, 25 patients were treated by closed reduction. An accessory incision had to be made above the fracture in two patients.

Age, gender, fracture type, mechanism of injury, and interval from injury to operation were similar between the two group (**Table 1**). Length of hospital stay and operation time were also similar between the two groups. The fluoroscopy time was slightly shorter in the MIPTENO group (10.3±1.5 vs. 11.2±1.5 s, P=0.04).

Follow-up

All patients were followed up for a mean of 15 months (range, 12-24 months). The MIPPO group need more X-ray time (P=0.037). Bony union was achieved in all cases after an average of 12.2 weeks in the MIPPO group and 13.1 weeks in the MIPTENO group (P=0.049), especially in wedge (P=0.003) and comminuted fractures (P=0.02) (**Table 2**). In the MIPPO group, the shoulder activities reached the normal range 7-14 days after operation. In the MIPTENO group, the shoulder activities reached the normal range 10-20 days after operation. The MIPPO group had no significantly superior constant shoulder scores or DASH scores (**Table 3**) (all P > 0.05).

Complications

The complications in the MIPPO group included dysesthesia (n=2) and painful local irritation (n=2). The complications in the MIPTENO group included telescoping (n=2 patients with

comminuted fractures and n=1 patient with a wedge-type fracture). All patients with telescoping suffered from painful prominence of the medial protruding nail. Implant failure was observed in one patient. There was one case of infection. There was no fracture recurrence.

Discussion

A meta-analysis by McKee et al. [17] revealed that primary operative fixation does provide more rapid return of function and minimizes early residual disability following fracture. In addition, the prevalence of symptomatic malunion and nonunion is significantly lower [17]. The ideal goal for the treatment of midshaft clavicle fracture is to relieve pain, achieve a complete restoration of shoulder function, fracture coalescence, fast return to daily activities, cosmetic appearance, and no symptomatic malunion. Surgery is usually indicated for completely displaced fractures, potential skin perforation, shortening of the clavicle by > 2 cm, neurovascular injury, floating shoulder, open fracture, and the patient's request [3, 4, 12, 17, 18].

Several options are available for the surgical treatment of clavicle midshaft fractures, including intramedullary K-wire fixation, Steinmann pin fixation, and TEN and plate fixation [3, 4, 15, 18-20]. Minimally invasive surgical techniques can achieve the goals described above and the most common techniques are MIPPO and MIPTENO. Jiang et al. [6] showed that surgery with a LCP for clavicle shaft fractures can be used to obtain stable fixation. Particularly, MIPPO of displaced midshaft clavicle fractures resulted in a lower rate of dysesthesia, hypertrophic scarring, and a better cosmetic than conventional open reduction, although the functional outcomes (Constant and DASH) were not significantly different between the two groups. Overall satisfaction was higher in the MIPPO group than conventional open reduction group [6]. Chen et al. [5, 14] showed that limited open reduction and internal fixation with TEN in the treatment of midclavicular fractures in adults resulted in a high fracture healing rate, rapid functional recovery and minimal complications. The procedure is minimally invasive and achieved high patient satisfaction [5, 14, 21].

The present study directly compared MIPPO and MIPTENO. The results revealed that minimally invasive surgical had a low rate of complications when treating displaced midshaft clavicle fractures. For simple midshaft clavicle fractures, the MIPPO and MIPTENO groups showed no significant difference in osseous healing. MIPPO could be more suitable for wedge type comminuted midshaft clavicle fractures, maybe leading to faster osseous healing, possibly because the plate is more stable than TEN. Finally, both approaches led to good functional outcomes at the last follow-up.

As for complications, the MIPPO group showed two patients with dysesthesia. Therefore, larger branches of the identifiable supraclavicular nerves should be identified and protected throughout the procedure, especially among patients who have to undergo open reduction. Another two patients had painful local irritation. Fixation with anterior-inferior plating could overcome some of these complications [16], but it has to be confirmed in MIPPO. In the MIPTENO group telescoping occurred in two patients with comminuted fractures and in one patient with a wedge-type fracture. For these cases, the TEN cannot provide enough stability and a limited range of motion of 90° for 3 weeks was recommended. A return to full activity after consolidation of the fracture or use of the plate could be a better choice. Four patients suffered from painful local irritation. As a mean to reduce irritation, Frigg et al. [12] used an end cap to successfully reduce medial migration and pain; however, additional fixation of the TEN inside the end cap is required to avoid lateral penetration. There was one case of superficial skin infection in the MIPTENO group, but early removal of the TEN was not necessary. Zehir et al. [21] also reported that complications were rare in similar patients.

Some means could be used to reduce the rate of complications. LCP have been preferred for plate osteosynthesis of the clavicle in MIPPO. It is easy to shape but not easy to dislocate. In addition, blood supply preservation can be achieved due to minimal contact between the plate and cortical bone [5, 22]. Locking screws should be inserted before shaping the plate in order to avoid damaging the threads in the plate. If the length of the drill bit can be controlled within approximately 2.0 cm after passing through the guide, the risks of injury to the subclavicular artery or brachial plexus could potentially be reduced. To reduce fluoroscopy

time as well as operating time, limited open reduction should be performed after a maximum of two attempts at closed reduction. A percutaneously applied towel clip or reduction forceps could help to accomplish this procedure successfully. The TEN should not be advanced too far toward the lateral end of the clavicle but only as far as necessary to bridge the fracture. The oscillating drill can be used to bridge the fracture; then, the TEN should be advanced manually with a T-handle into the lateral fragment. Intraoperatively, an axillary view of the clavicle should be obtained to visualize a laterodorsal penetration of the cortex. For the simple type of fracture, MIPPO and MIPTENO could be appropriate, but MIPPO seems to be more suitable for wedge and comminuted fractures, as observed Arno Frigg et al. [12]. Caution should be paid in order not to damage the vital structures and the medial protruding end of the nail should be shortened to the point where it just exceeds the bone. Finally, the whole operation should be done under the centre of the C-arm X-ray machine.

There are some limitations of this study that should be considered. The sample size was relatively small and the follow-up time was short. Secondly, accurate fracture healing time is difficult to judge, and had to be based on the X-ray taken 2-4 weeks after surgery. This study was preliminary and additional trials are necessary to assess superiority or non-inferiority of MIPPO and MIPTENO for midshaft clavicle fractures in adults.

In conclusion, MIPPO showed fast bone union and lower complications than MIPTENO, especially in wedge and comminuted fractures. However, MIPPO was not superior to MIPTENO in terms of shoulder score at final follow-up.

Acknowledgements

This study was funded by Zhejiang Province Health Department (No. 2016KYB196) and Zhejiang Province Bureau of Traditional Chinese Medicine (No. 2016ZA140).

Disclosure of conflict of interest

None.

Address correspondence to: Jianjun Hong, Department of Orthopedics Surgery, The Second Affiliated Hospital and Yuying Children's Hospital of Wenzhou Medical University, 109 Western Xueyuan Road, Wenzhou 325027, Zhejiang, China. Tel: +86-13867704583; Fax: +86-577-88832693; E-mail: surgerycl@163.com; Dongsheng Zhou, Department of Orthopedics Surgery, Shandong Provincial Hospital of Shandong University, 324 Jingwueriqi Road, Jinan 250014, Shandong, China. Tel: +86-531-87938911; Fax: +86-531-87938911; E-mail: cl@wzhealth.com

References

[1] Neer CS. Nonunion of the clavicle. J Am Med Assoc 1960; 172: 1006-1011.
[2] Rowe CR. An atlas of anatomy and treatment of midclavicular fractures. Clin Orthop Relat Res 1968; 58: 29-42.
[3] Canadian Orthopaedic Trauma Society. Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. A multicenter, randomized clinical trial. J Bone Joint Surg Am 2007; 89: 1-10.
[4] Virtanen KJ, Paavola MP and Remes VM. Nonoperative versus operative treatment of midshaft clavicle fractures: a randomized controlled trial. 75th Annual Meeting of the AAOS; March 9; New Orleans 2010.
[5] Chen QY, Kou DQ, Cheng XJ, Zhang W, Wang W, Lin ZQ, Cheng SW, Shen Y, Ying XZ, Peng L and Lv CZ. Intramedullary nailing of clavicular midshaft fractures in adults using titanium elastic nail. Chin J Traumatol 2011; 14: 269-276.
[6] Jiang H and Qu W. Operative treatment of clavicle midshaft fractures using a locking compression plate: comparison between mini-invasive plate osteosynthesis (MIPPO) technique and conventional open reduction. Orthop Traumatol Surg Res 2012; 98: 666-671.
[7] Zhiquan A, Bingfang Z, Yeming W, Chi Z and Peiyan H. Minimally invasive plating osteosynthesis (MIPO) of middle and distal third humeral shaft fractures. J Orthop Trauma 2007; 21: 628-633.
[8] Lau TW, Leung F, Chan CF and Chow SP. Minimally invasive plate osteosynthesis in the treatment of proximal humeral fracture. Int Orthop 2007; 31: 657-664.
[9] Fernández Dell'Oca AA. The principle of helical implants. Unusual ideas worth considering. Injury 2002; 33 Suppl 1: SA1-27.
[10] Ji F, Tong D, Tang H, Cai X, Zhang Q, Li J and Wang Q. Minimally invasive percutaneous plate osteosynthesis (MIPPO) technique applied in the treatment of humeral shaft distal fractures through a lateral approach. Int Orthop 2009; 33: 543-547.
[11] Kettler M, Schieker M, Braunstein V, Konig M and Mutschler W. Flexible intramedullary nail-

ing for stabilization of displaced midshaft clavicle fractures: technique and results in 87 patients. Acta Orthop 2007; 78: 424-429.
[12] Frigg A, Rillmann P, Perren T, Gerber M and Ryf C. Intramedullary nailing of clavicular midshaft fractures with the titanium elastic nail: problems and complications. Am J Sports Med 2009; 37: 352-359.
[13] Fracture and dislocation compendium. Orthopaedic trauma association committee for coding and classification. J Orthop Trauma 1996; 10 Suppl 1: v-ix, 1-154.
[14] Chen YF, Zeng BF, Chen YJ, Wang HM, Xue JF, Chai YM, Xie XT and Zhang C. Clinical outcomes of midclavicular fractures treated with titanium elastic nails. Can J Surg 2010; 53: 379-384.
[15] Smekal V, Irenberger A, Struve P, Wambacher M, Krappinger D and Kralinger FS. Elastic stable intramedullary nailing versus nonoperative treatment of displaced midshaft clavicular fractures-a randomized, controlled, clinical trial. J Orthop Trauma 2009; 23: 106-112.
[16] Chen CE, Juhn RJ and Ko JY. Anterior-inferior plating of middle-third fractures of the clavicle. Arch Orthop Trauma Surg 2010; 130: 507-511.
[17] McKee RC, Whelan DB, Schemitsch EH and McKee MD. Operative versus nonoperative care of displaced midshaft clavicular fractures: a meta-analysis of randomized clinical trials. J Bone Joint Surg Am 2012; 94: 675-684.
[18] Altamimi SA, McKee MD; Canadian Orthopaedic Trauma Society. Nonoperative treatment compared with plate fixation of displaced midshaft clavicular fractures. Surgical technique. J Bone Joint Surg Am 2008; 90 Suppl 2 Pt 1: 1-8.
[19] Chu CM, Wang SJ and Lin LC. Fixation of mid-third clavicular fractures with knowles pins: 78 patients followed for 2-7 years. Acta Orthop Scand 2002; 73: 134-139.
[20] Chuang TY, Ho WP, Hsieh PH, Lee PC, Chen CH and Chen YJ. Closed reduction and internal fixation for acute midshaft clavicular fractures using cannulated screws. J Trauma 2006; 60: 1315-1320; discussion 1320-1311.
[21] Zehir S, Zehir R, Sahin E and Calbiyik M. Comparison of novel intramedullary nailing with mini-invasive plating in surgical fixation of displaced midshaft clavicle fractures. Arch Orthop Trauma Surg 2015; 135: 339-344.
[22] Haidukewych GJ. Innovations in locking plate technology. J Am Acad Orthop Surg 2004; 12: 205-212.