Surgical treatment of displaced mid-shaft clavicular fractures with precontoured anatomical locked plates

Abdel Sattar Abdel Hay El Gendy[1], MBBCh; Mahmoud Mohamed Hadhoud[2], MD; Mohamed Ahmed Fayek Samy[3], MD and Osama Abdel Mohsen Sherif[4], MD

1- Resident of Orthopaedic Surgery, New Cairo hospital
2- Professor of Orthopaedic Surgery, Faculty of Medicine - Menofia University, Menofia, Egypt
3- Assistant Professor of Orthopaedic Surgery, Faculty of Medicine - Menofia University, Menofia, Egypt
4- Lecturer of Orthopaedic Surgery, Faculty of Medicine - Menofia University, Menofia, Egypt

Corresponding author: Abdel Sattar Abdel Hay Elgendy, MBBCh
Work: New Cairo hospital
Address: Madinet Nasr - Cairo
Email: abdogendi1@gmail.com
Tel: 01008738386 - 01158581919

The Egyptian Orthopedic Journal; 2021 supplement (2), December, 56: 135-141

ABSTRACT

Background:
Fractures of the clavicle are classified by Allman according to its localization as middle, lateral and medial third fractures. The Middle third being the first in the frequency of occurrence of approximately 80% of clavicle fractures.
Objective:
This work aimed to study the results of open reduction and internal fixation of displaced fractures of the mid-shaft of the clavicle by precontoured anatomical locked plate.
Patients & Methods:
This study was carried out on thirty patients, the cases have been operated on in the orthopedic department of Menofia university hospital and New Cairo hospital, and informed consent was obtained from all patients in the research.
Results:
Time of union in the studied patients ranged from 8 weeks to 12 weeks with a mean of 10.0 ± 1.33 weeks except for one case which presented with infected non-union. There was a statistically significant relationship between age and final score. The mean age for the excellent results was 33.63 ± 11.74 years and that for good results was 53.33 ± 4.16 years. The test of significance was the t-test where the p-value was <0.001.
Conclusion:
Open reduction and internal fixation of displaced fractures of the middle third of the clavicle using a precontoured clavicular locked plate is an effective method of treatment in selected patients. The procedure has low morbidity and good overall results and low complications rate.
Keywords:
clavicle, fracture, reduction, fixation, precontoured, locked plate.

INTRODUCTION

Fractures of the clavicle can occur at any part of the clavicle. However, the vast majority (69-82%) occurs in the midshaft, at or near the junction of the middle and outer third. This is due to two factors: firstly this is the thinnest part of the bone, and secondly, it is the only part of the bone not reinforced by attached musculature and ligaments. [1]

Typically, fractured clavicles occur as the result of a fall onto an outstretched arm or at the point of the shoulder. They are common in very young and very old patients. Traditionally midshaft fractures of the clavicle have been treated with immobilization and a sling or figure-of-8 dressing, and in most cases, results are said to be excellent with low non-union rates and minimal functional impairment. [1]

Open reduction and internal fixation by plate or intramedullary fixation are two of the most commonly used surgical techniques for treating displaced midshaft clavicular fractures. [2]

Typical complications of plate fixation include infection, implant loosening, nonunion, and refracture after implant removal. [3]

A precontoured clavicle plate is a plating system that is anatomically precontoured which assists in restoring the original structure of the patient's anatomy with little or no bending of the plate by the surgeon at the time of surgery. Avoiding the need to bend a precontoured clavicle plate saves valuable operating room time. [4]

The recent introduction of anatomically contoured clavicle plates may reduce the need for hardware removal. [5]

PATIENTS AND METHODS:

This study was carried out on thirty patients, the cases have been operated on in the orthopedic department of Menofia university hospital and New Cairo hospital, and informed

consent was obtained from all patients in the research.
All data were collected about the studied patient as follow:

Methods of examination: Data have been collected according to the following sheet.

A) History: Personal data: Name, age, sex, occupation, and time lag before presentation to hospital. **History of the present symptoms:** Mechanism of injury and presence of pain and swelling.

B) Clinical examination: Side affected, dominant or non-dominant side, presence of tenderness, skin condition overlying the fracture, tenting of skin overlying the fracture, presence or absence of associated vascular or neurological injuries, and other associated injuries.

C) Radiological evaluation: An Anteroposterior radiograph view of the clavicle was obtained for every patient to assess the fracture type according to Robinson's classification. [6]

Inclusion criteria:

Recent fractures, patients older than 16 years old and younger than 65 years old, patients with at least post-operative 6 months follow up. patients indicated for surgical treatment: Severe displacement causing tenting of the skin with the risk of puncture; this is often seen with type 2 fractures of the distal clavicle, complete fracture displacement, fractures with 2 cm of shortening, comminuted fractures with a displaced transverse "zed" (or z-shaped) fragment, neurovascular compromise, polytrauma (with multiple fractures); to expedite rehabilitation, open fractures and an inability to tolerate closed treatment.

Methods of treatment

All patients were treated by open reduction and internal fixation using a precontoured stainless steel locking plate.

Anesthesia and positioning:

Surgery was performed with the patient under general anesthesia. Cefuroxime 1.5 g was administered intravenously 30 to 60 minutes before induction of anesthesia. The patient was placed in semi setting (beach-chair) position with a small pad placed under the shoulder blade and the involved upper extremity tucked into the side and square draped (Fig 1).

Figure (1): Position of the patient.

Procedure: The following reduction, the appropriately sized left or right clavicle plate was selected from the different lengths the two middle slots may be placed over the fracture, ideally leaving two to three locking and/or non-locking holes both proximal and distal to the fracture fragments; however, the plate can be slid medially or laterally for the most ideal location. Once the plate's ideal positioning has been selected, it was provisionally stabilized to the clavicle with bone clamps, the non-locking screws may be placed either unicortical or bicortical. If bicortical screws are used, it is important to not over-penetrate the distal cortex and potentially risk neurovascular injury. A curved retractor or other means of protection should be placed under the inferior surface of the clavicle to protect the neurovascular structures from over-penetration of the drill bit. For early stability, the first two screws should be placed medial and lateral to the fracture site. Using the appropriate drill pot size and the offset drill guide, drill measure for depth and place the screws into the slots with the assembled driver. Once the two screws are installed, the bone clamps holding the plate to the clavicle may be removed. Using the locking drill guide and place the 3.5 mm locking screws into the threaded holes so that there are at least three screws (if possible) on each side of the fracture (Fig 2).

Figure (2): Precontoured locking plate applied to the fracture.

Closure: Once all screws were inserted and the stability of the construct insured, the field was copiously irrigated with normal saline. A standard closure was then performed in layers using no. 1 absorbable sutures for the myofascial, no. 2-0 absorbable sutures for the subcutaneous tissue, and clips or subcuticular stitch for the skin.

Methods of follow-up: The patient was placed in an arm sling and cefuroxime 1.5 g was administered every 8 hours for 24 hours (duration of antibiotic therapy extended to 48 hours or 72 hours in some selected patients at risk). The patients started pendulum range of motion exercises at the first post-operative week. Passive motion exercises were initiated for the first four weeks, active assisted from four to six weeks, and active strengthening was initiated at six weeks postoperatively once healing was seen radiographically. The radiological follow-up period was six months for all patients with follow-up plain x-ray every 2 weeks at the first two months and one plain x-ray for each month later. Results were assessed at the end of this period according to **Constant and Murley Score (CMS).** [7] The CMS system is used internationally as a means of establishing normal levels of shoulder function appropriate for different age groups and to establish what constitutes a disability in normal individuals. It has also been used to establish differential rates of progress after injury or treatment. The CMS is a 100-point functional shoulder assessment tool in which higher scores reflect increased function. It combines four separate subscales: subjective pain (15 points), ADL; Activity of Daily Living (20 points), objective clinical assessment of the range of motion (40 points), and strength (25 points).

1. **Pain:** The first subjective parameter assesses the most severe degree of pain experienced during activities of normal daily living.
2. **The activity of Daily Living (ADL):** The other subjective parameter assessed is the ability of the individual to carry out daily activities concerning work, recreation, and the ability to sleep.
3. **Range of motion:** The Objective assessment rates the patient on painless active motion in the plane of pure forward and lateral elevation (Table XIV), as well as composite functional external and internal rotation.
4. **Strength:** Scoring is based on resistance against abduction to a maximum of 25 points.

Statistical analysis of the data: Qualitative data were described using numbers and percentages. Quantitative data were described using range (minimum and maximum), mean, standard deviation, and median. The significance of the obtained results was judged at the 5% level.

RESULTS:

At the end of the follow-up period (6 months), the mean score was 94.30 ± 12.81 ranging from 46 – 100 according to the Constant and Murley shoulder score. Twenty-four patients (80%) had excellent results, five patients (16.67%) had good results, and one patient (3.33%) had poor results (Table 1).

At the end of the follow-up period, the mean final Constant score for pain was 14.0 ± 2.62 ranging from 5 to 15 (Table 2).

At the end of the follow-up period, the mean final Constant score for the activity of daily living was 18.80 ± 3.38 ranging from 6 to 20 (Table 3).

At the end of the follow-up period, the mean final Constant score for active forward flexion was 9.20 ± 1.20 ranging from 6 to 10 (Table 4).

Time of union in the studied patients ranged from 8 weeks to 12 weeks with a mean of 10.0 ± 1.33 weeks except for one case which presented with infected non-union (Table 5).

There was a statistically significant relationship between age and final score. The mean age for the excellent results was 33.63 ± 11.74 years and that for good results was 53.33 ± 4.16 years. The test of significance was a t-test where the p-value was 0.001 (Table 6).

There was no statistically significant relationship between time-lapse before surgery and final score. The mean for excellent was 4.58 days and that for good was 4.2 days, while that for poor was 1 day. The p-value was 0.603 (Table 7).

Table (1): Distribution of the studied patients regarding the final score according to Constant and Murley score

Final score	No.	%
Excellent (91 – 100)	24	80.0
Good (81 - 90)	5	16.67
Fair (71 – 80)	0	0.0
Adequate (61 - 70)	0	0.0
Poor (< 60)	1	3.33
Total	**30**	**100.0**
Min. – Max.	46.0 – 100.0	
Mean ± SD.	94.30 ± 12.81	
Median	100.0	

Table (2): Distribution of the studied patients regarding pain

Pain	No.	%
None	24	80.0
Mild	5	16.67
Moderate	1	3.33
Total	**30**	**100.0**
Min. – Max.	5.0 – 15.0	
Mean ± SD.	14.0 ± 2.62	
Median	15.0	

Table (3): Distribution of the studied patients regarding Activity of daily living

Activity of daily living	No.	%
Activity level		
Full work	28	93.33
Full recreation/sport	1	3.33
Unaffected sleep	1	3.33
Total	**30**	**100.0**
Positioning		
Up to neck	1	3.33
Above head	29	96.67
Total	**30**	**100.0**
Min. – Max.	6.0 – 20.0	
Mean ± SD.	18.80 ± 3.38	
Median	20.0	

Table (4): Distribution of the studied patients regarding active forward flexion

Active external rotation	No.	%
61-90°	1	3.33
121-150°	1	3.33
151-180°	28	93.33
Total	**30**	**100.0**
Min. – Max.	6.0 – 10.0	
Mean ± SD.	9.20 ± 1.20	
Median	10.0	

Table (5): Distribution of the studied patients regarding the union

Union (weeks)	No.	%
Non-union	1	3.33
Union	29	96.67
Total	**30**	**100.0**
Min. – Max. (n=29)	8.0 – 12.0	
Mean ± SD.	10.0 ± 1.33	
Median	10.0	

Table (6): Relation between the final score and the age of the patient

Age (years)	Final score						Test of sig.	P
	Excellent (n = 24)		Good (n = 5)		Poor (n = 1)			
	No.	%	No.	%	No.	%		
≤21	5	20.83	0	0.0	1	100.0	$\chi 2$=5.26	^{MC}p=0.072
>21	19	79.16	5	100.0	0	0.0		
Total	**24**	**100**	**5**	**100**	**1**	**100**		
Min. – Max.	20.0 – 56.0		50.0 – 58.0					
Mean ± SD.	33.63 ± 11.74		53.33 ± 4.16		27.0#		t=3.66	0.001*
Median	31.0		52.0					

*$\chi 2$: value for chi-square test MC: Monte Carlo t, p: t and p values for Student t-test for *: Statistically significant at $p \leq 0.05$*
#: excluded from the comparison

Table (7): Relation between final score and time-lapse before surgery

Time-lapse before surgery (days)	Final score			Z	P
	Excellent (n = 24)	Good (n = 5)	Poor (n = 1)		
Min. – Max.	1.0 – 13.0	1.0 – 12.0			
Mean ± SD.	4.58 ±3.61	4.2 ± 4.54	1.0	0.519	0.603
Median	3.5	3.0			
Total	**24**	**5**	**1**		

Z, p: Z and p values for Mann Whitney test for comparing between the two groups

DISCUSSION:

Fractures of the clavicle are classified by Allman according to its localization as middle, lateral and medial third fractures. The Middle third being the first in the frequency of occurrence of approximately 80% of clavicle fractures. Weight of the arm, pectoralis major, pectoralis minor, latissimus dorsi, trapezius, and scapular motions act on the fracture site to impair union in displaced fractures. Non-operative treatment results in delayed or non-union. [8]

The design features of precontoured plates may afford potential benefits. Firstly, they have the anatomic shape of the natural clavicle and large modularity with available right and left clavicle fittings. This allows facing all types of mid-shaft fractures and may facilitate surgical technique. Secondly, the low profile and rounded edges could reduce the risk of postoperative hardware intolerance. [9]

The rehabilitation protocol in our study was that the patients were placed in an arm sling and start pendulum range of motion exercises at the first postoperative week. Passive motion exercises were initiated from the first four weeks, active assisted from four to six weeks, and active strengthening was initiated at six weeks postoperatively once healing was seen radiographically.

The present study on surgical management of clavicular mid-shaft fractures by locking plate is compared with other studies such as Böstman et al study and VanBeek et al study.

Böstman et al study treated only middle third clavicle fractures; in this study 103 patients were treated by early open reduction and internal fixation with plate and screws. The major complications included deep infection, plate breakage, nonunion, and refracture after plate removal. The most common of the minor complications was plate loosening resulting in malunion. The infection rate was 7.8%, plate prominence occurred in 3 patients (15%), delayed union occurred in 3 patients (2.91%), permanent nonunion ensued in two patients, a total of 14 reoperations were performed because of the complications. The total complication rate was 23%. Patient noncompliance with the postoperative regimen was the major cause of the failures. [4]

VanBeek et al retrospectively compared the outcomes of 24 patients treated with precontoured plates and 14 treated with non-contoured plates. Even though the study population size was limited, they showed higher hardware removal using non-contoured plates (21.4%) than using precontoured plates (10.7%). Plate prominence was reported postoperatively in 9 of 14 patients (64.3%) of the non-contoured group and 9 of 28 patients (32.1%) of the precontoured group. Non-union occurred in one patient with revision surgery with bone grafting was done. The total complication rate in Vanbeek et al study was 64.3% in the non-contoured group and 39.3% in the precontoured group. [10]

Chandrasenan, et al study treated 30 patients with plating for displaced mid-shaft clavicle fractures, 15 with non-contoured plating, and 15 with precontoured plating. At a mean of 18 months postoperatively, no patients in the precontoured group had undergone removal of hardware. In the non-contoured group, nine patients (60%) had removal of their plate: two for plate breakage, five for soft tissue irritation, and two for painful non-union. [11]

Houwert et al analyzed retrospectively 90 patients with displaced midshaft clavicle fractures treated with plate fixation or intramedullary nails. Complications were evaluated in both treatment groups and subsequently compared. Three re-fractures (7 %) were observed in the plate group after removal of the implant against none in the EIN group. All re-fractures occurred within 2 months after the removal of the implant. However, implant removal was less often required in patients treated with plates than EIN patients. [12]

Poigenfurst et al followed 122 patients after plating of displaced clavicle fractures. There were four refractures after plate removal. The reason behind this higher refracture rate after implant removal in the plating group is that plate fixation provides a rigid fixation leading to primary bone healing: that's why, after plate removal, the mechanical strength of the healed fracture site is reduced, explaining higher refracture rates. [13]

Ferran et al compared Rockwood pin fixation (17 cases) and non-contoured low contact dynamic compression plate (LCDCP; 15 cases) in displaced mid-shaft clavicle fractures and found no significant difference after 12 months in functional outcome. All cases treated with either Rockwood Pin or plating achieved a 100% union rate, with no major complications, but 53% of plates had to be removed due to soft tissue irritation. [14]

Tarng et al compared 25 patients treated by EIN and 32 patients treated by 3.5-mm reconstruction plate. The study showed that the application of intramedullary nails can provide sufficient stability, release pain quickly, and obtain functional recovery of the affected limb compared with fixation by reconstruction plates. A similar complication rate was reported for both

techniques. It also showed that 16% of cases treated by EIN requested the removal of the implant, as compared with 37.5% in the plate group. [15]

Liu et al compared 51 patients treated by EIN and 59 patients treated by reconstruction locking compression plates and reported no significant difference between plate and intramedullary fixation in operation time, fracture healing time, recovery, non-union, malunion, infection, rate of fixation removal, failure of early fixation, the time taken to return to work, Constant score of the shoulder, and disabilities of the arm, shoulder and hand score. Duan et al also reported similar results. [16,17]

Campochiaro et al retrospectively evaluated 68 patients treated with precontoured plates and showed excellent functional results, with only 14.3% plate removal after fracture consolidation. [18]

Kalamares, et al immobilized the patients in a sling for 6 weeks and after that, he initiated gradual physiotherapy. The mean Constant score was 96, and the range was 96-100 despite the long period of immobilization and the delay in return to full activities in contrast to this study as we started pendulum exercises immediately in the first post-operative week as our fixation was secured by locked screws. [19]

Case presentation:

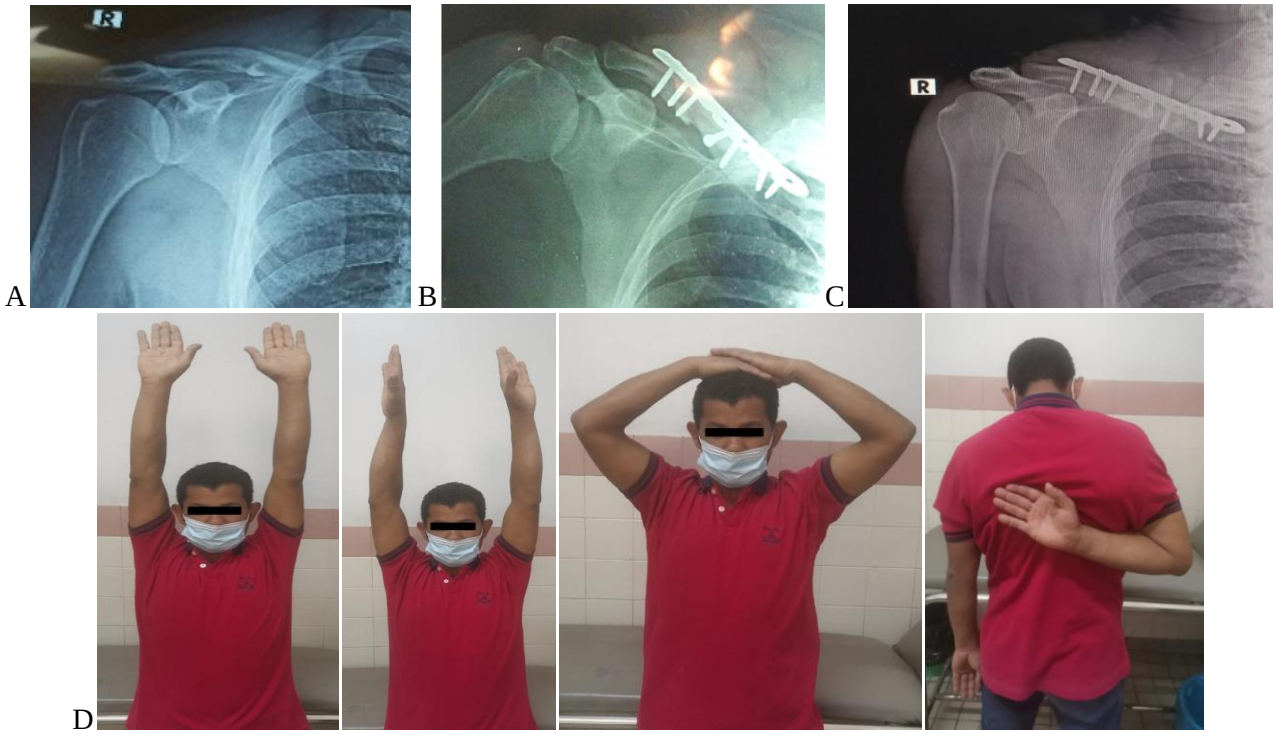

Figure (3): A thirty-three years old male, his occupation is a manual worker, has a fracture of the middle third of the right clavicle (Robinson type 2 B1) due to a direct fall on his right shoulder. Fixation with a precontoured locked plate was done after one day. A: preoperative X-ray. B: Immediate postoperative. C: X-ray after six months shows complete union. D: full active forward elevation, abduction, external rotation and internal rotation. The final score was 100 and the grade was excellent.

CONCLUSION:

Open reduction and internal fixation of displaced fractures of the middle third of the clavicle using a precontoured clavicular locked plate is an effective method of treatment in selected patients. The procedure has low morbidity and good overall results and low complications rate.

Conflict of interest:
The authors declared that there were no conflicts of interest and no financial support for this work.

REFERENCES:

1. Jeray K. Acute Midshaft Clavicular Fracture. Journal of the American Academy of Orthopaedic Surgeons. 2007; 15:239-48.
2. Smekal V, Oberladstaetter J, Struve P, Krappinger D. Shaft Fractures of the Clavicle: Current Concepts. Archives of Orthopaedic and Trauma Surgery. 2008; 129:807-15.

3. Bostman O, Manninen M, Pihlajamaki H. Complications of Plate Fixation in Fresh Displaced Midclavicular Fractures. The Journal of Trauma: Injury, Infection, and Critical Care. 1997; 43:778-83.
4. Altamimi S, McKee M. Nonoperative Treatment Compared with Plate Fixation of Displaced Midshaft Clavicular Fractures. Journal of Bone and Joint Surgery. 2008; 90:1-8.
5. Nonoperative Treatment Compared with Plate Fixation of Displaced Midshaft Clavicular Fractures. The Journal of Bone & Joint Surgery. 2007; 89:1-10.
6. Robinson C. Fractures of the Clavicle in the Adult. The Journal of Bone and Joint Surgery British Volume. 1998; 80:476-84.
7. Constant C, G. Murley A. A Clinical Method of Functional Assessment of the Shoulder. Clinical Orthopaedics and Related Research. 1987; 214:160-4.
8. Collinge C, Devinney S, Herscovici D, DiPasquale T, Sanders R. Anterior-inferior Plate Fixation of Middle-third Fractures and Nonunions of the Clavicle. Journal of Orthopaedic Trauma. 2006; 20:680-6.
9. Goswami T, Markert R, Anderson C, Sundaram S, Crosby L. Biomechanical Evaluation of a Pre-contoured Clavicle Plate. Journal of Shoulder and Elbow Surgery. 2008; 17:815-8.
10. VanBeek C, Boselli K, Cadet E, Ahmad C, Levine W. Precontoured Plating of Clavicle Fractures: Decreased Hardware-related Complications. Clinical Orthopaedics & Related Research. 2011; 469:3337-43.
11. Chandrasenan J, Espag M, Dias R, Clark D. The Use of Anatomic Pre-contoured Plates in the Treatment of Mid-shaft Clavicle Fractures. Injury Extra. 2008; 39:171.
12. Houwert R, Wijdicks F, Steins Bisschop C, Verleisdonk E, Kruyt M. Plate Fixation versus Intramedullary Fixation for Displaced Mid-shaft Clavicle Fractures: A Systematic Review. International Orthopaedics. 2011; 36:579-85.
13. Poigenfürst J, Rappold G, Fischer W. Plating of Fresh Clavicular Fractures: Results of 122 Operations. Injury. 1992; 23:237-41.
14. Ferran N, Hodgson P, Vannet N, Williams R, Evans R. Locked Intramedullary Fixation vs Plating for Displaced and Shortened Mid-shaft Clavicle Fractures: A Randomized Clinical Trial. Journal of Shoulder and Elbow Surgery. 2010; 19:783-9.
15. Tarng Y, Yang S, Fang Y, Hsu C. Surgical Management of Uncomplicated Midshaft Clavicle Fractures: A Comparison between Titanium Elastic Nails and Small Reconstruction Plates. Journal of Shoulder and Elbow Surgery. 2012; 21:732-40.
16. Liu H, Chang C, Chia W, Chen C, Tarng Y et al. Comparison of Plates versus Intramedullary Nails for Fixation of Displaced Midshaft Clavicular Fractures. Journal of Trauma: Injury, Infection & Critical Care. 2010;69:82-7.
17. Duan X, Zhong G, Cen S, Huang F, Xiang Z. Plating versus Intramedullary Pin or Conservative Treatment for Midshaft Fracture of Clavicle: A Meta-analysis of Randomized Controlled Trials. Journal of Shoulder and Elbow Surgery. 2011;20:1008-15.
18. Campochiaro G, Tsatsis C, Gazzotti G, Rebuzzi M, Catani F. Displaced Mid-shaft Clavicular Fractures: Surgical Treatment with a Pre-contoured Angular Stability Plate. Musculoskeletal Surgery. 2012; 96:21-6.
19. Kalamaras M, Cutbush K, Robinson M. A Method for Internal Fixation of Unstable Distal Clavicle Fractures: Early Observations Using a New Technique. Journal of Shoulder and Elbow Surgery. 2008; 17:60-2.