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• Original Article •

Operative Treatment for Midshaft Clavicle Fractures in Adults: A 10-Year Study Conducted in a Korean Metropolitan Hospital

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Purpose: While all midshaft clavicle fractures have traditionally been treated with conservative measures, recent operative treatment of displaced, communited midshaft clavicle fractures has become more common. Though a recent increase in operative treatment for midshaft clavicle fractures, we have done the operative methods in limited cases. The aim of this study is to present indications, operative techniques and outcomes of the experienced cases that have applied to this limited group over the previous 10 years.

Methods: This study consists of a retrospective review of radiological and clinical data from January of 2005 to July of 2015. Operative criteria for midshaft clavicle fractures having considerable risk of bone healing process were 4 groups - a floating shoulder, an open fracture, an associated neurovascular injury, and a nonunion case after previous treatment.

Results: The study consisted of 18 patients who had operative treatment for midshaft clavicle fractures in adults. The most common surgical indication was a floating shoulder (10 cases, 55.6%), followed by nonunion (5 cases, 27.8%), an associated neurovascular injury (4 cases, 22.2%), and open fracture (3 cases, 16.7%). All cases were treated by open reduction and internal fixation in anterosuperior position with reconstruction plate or locking compression plate. Bone union was achieved in all cases except 1 case which was done bone resection due to infected nonunion. Mean bone union period was 19.5 weeks. There were no postoperative complications, but still sequelae in 4 cases of brachial plexus injury.

Conclusion: We have conducted an open reduction and internal fixation by anterosuperior position for midshaft clavicle fractures in very limited surgical indications for last 10 years. Our treatment strategy for midshaft clavicle fractures showed favorable radiological results and low postoperative complications. [J Trauma Inj 2016; 29: 105-115]

Key Words: Clavicle, Clavicle midshaft fracture, Operative treatment

I. Introduction

Clavicle fractures are one of the most common adult injuries, accounting for 5% to 12% of all fractures and representing up to 44% of injuries to the shoulder girdle.(1-3) About 80% to 85% of these fractures occur in the midshaft of the bone due to its narrow cross section and high compressive force resulting in bone failure.(4-7) While midshaft clavicle fractures have traditionally been treated with conservative measures, recent operative treatment of displaced, communited midshaft clavicle fractures has become more common.(6,8,9) However, a recent review on midshaft clavicle fracture treatment methods shows that the consensus on optimal treatment is inconclusive, due to lack of evidence. Despite a recent increase in

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operative treatment, conservative treatment remains to be the standard due to less than favorable results of a number of randomized comparative trials.(10,11) It should be stated that the standard practice for all midshaft clavicle fracture types shows strong favor for conservative treatment, as results have been favorable. Given this bias, the selection criteria for operative treatment of midshaft clavicle fractures has been highly limited. Therefore, this study presents indications, operative techniques and outcomes of the unique cases that have applied to this limited group over the previous 10 years within a particular metropolitan hospital in Korea.

II. Materials and Methods

This study consists of a retrospective review of radiological results and clinical data obtained from the medical records of a tertiary metropolitan hospital. An institutional review board was obtained for the approval of this study protocol. The criteria for inclusion in this study is limited to adult patients (age 18 or older) who visited the emergency room or outpatient clinic from January of 2005 to July of 2015 and received operative treatment for midshaft clavicle fractures. Operative criteria for midshaft clavicle fractures were: (1) a floating shoulder (i.e., a scapular neck fracture or humerus shaft fracture), (2) an open fracture, (3) an associated neurovascular injury, or (4) a nonunion case after previous treatment.

Patients included in this study maintained at least one year follow-up treatment. The follow-up protocol consists of post-operative visits at 2, 4, 8 and 12 weeks, followed by a visit at 6 and 12 months, with a final follow-up at 2 years. Patients who did not receive initial treatment within the hospital, yet received follow-up treatment only for removal of an implant, were also excluded from this study. Data from the patients included in the study is comprised of demographic information, including age at the time of injury, gender, initial injury mechanism and other associated injuries. The AO/OTA radiological classification system was applied to this study. All patients included this study were organized by operative technique, such as implant, plate position and bone graft. All cases were also categorized by operative indication. Operative results were evaluated by the rate of union and nonunion, the period of bone union and post-operative complications. Union and nonunion rate were analyzed using subsequent radiographs. Based on clavicle radiographs, radiographic union was defined as presence of complete cortical bridging between lateral and medial fragments, while nonunion was defined as no apparent radiographic union at 1 year after injury.(12)

Statistical analysis was performed with the IBM SPSS Statistics version 22 (IBM Corp., Armonk, NY, USA). The Mann-Whitney test was used to determine the difference in period of union between two groups, those with or without bone graft and nerve injury.

III. Results

From January of 2005 to July of 2015, 271 patients were seen for clavicle injuries, with 132 (48.7%) being midshaft clavicle fractures. Out of 132 patients, 19 received operative treatment. However, one patient only received treatment for implant removal and was

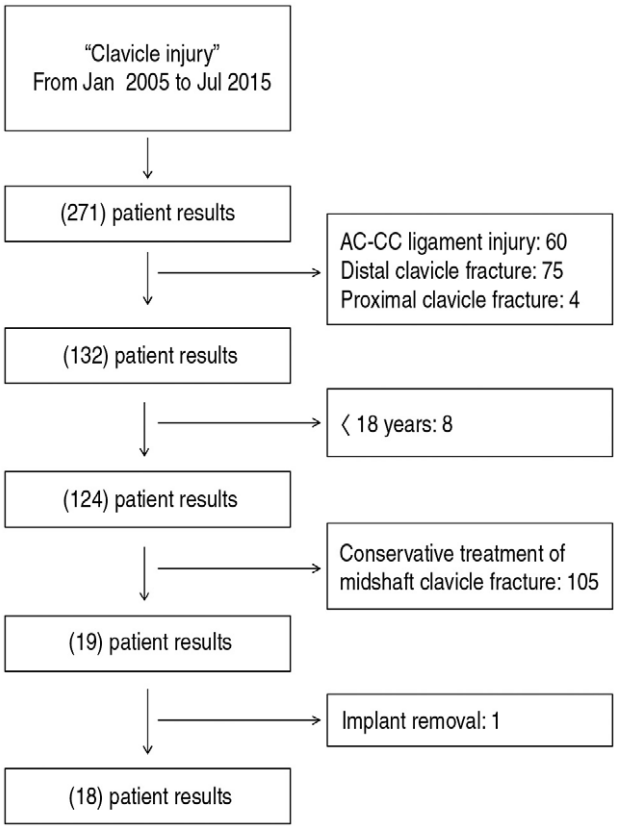

Fig. 1. Process of patient selection.

therefore excluded from the study, resulting in a total study group of 18 patients (Fig. 1).

Mean age at the time of injury was 37.2 years (range: 19–65 years). The mean follow-up period was 36.8 months (range: 12.5–96.1 months). The majority of patients were male at 15 (83.3%). The number of patients with other associated injuries unrelated to clavicle fractures were 12 (66.7%), with the most common being rib fractures, at 5 (27.8%), where hemopneumothorax occurred in 4 cases, requiring chest tube insertion. The second most common associated injuries unrelated to clavicle fractures were brain hemorrhage and intra-abdominal bleeding, with each having 4 cases. The cases of brain hemorrhage were observed to improve without treatment. Out of the 4 cases of intra-abdominal bleeding, 1 received an emergency operation with a total splenectomy, 2 received emergency embolizations and 1 recovered without treatment (Table 1).

Under radiological classification, simple fracture (15-B1) was the most common, at 9 cases, where 6 occurred as a floating shoulder and 3 occurred as a nonunion. Wedge fractures (15-B2) and complex fractures (15-B3) occurred in 3 and 6 cases, respectively.

All surgeries involved open reduction and internal fixation with a reconstruction plate or reconstruction

Table 1. Characteristics of patients

Patient no	Gender	Age	Involvement	f/u period (month)	Injury mechanism	Other associated injuries (unrelated to clavicle fracture)
1	M	26	Lt	59.3	Fall from 2nd floor	Traumatic EDH Skull fracture
2	M	28	Rt	14.2	In car TA	Contralateral humerus shaft fracture
3	M	45	Lt	28.7	In car TA	-
4	M	57	Lt	38.2	In car TA	Ipsilateral phrenic nerve palsy
5	M	48	Lt	13.4	In car TA	Traumatic SAH Splenic laceration Hemopericardium Pneumothorax with both 5-8th rib Fractures
6	M	65	Lt	96.1	Direct injury	-
7	M	40	Rt	26.8	In car TA	Ipsilateral mandible fracture
8	M	45	Rt	62.6	In car TA	Liver laceration Traumatic SDH
9	M	26	Rt	85.1	Motorcycle	-
10	F	19	Lt	41.9	Pedestrian TA	Liver, splenic laceration Scalp laceration
11	F	31	Rt	26.2	In car TA	Hemopneumothorax with ipsilateral 2-11th rib fractures
12	M	47	Rt	48	In car TA	Liver laceration Hemopneumothorax with ipsilateral 3-9th rib fractures
13	M	22	Lt	17.3	Soccer	-
14	M	39	Rt	26.5	Bicycle	Hemopneumothorax with ipsilateral 2-6th rib fractures
15	M	25	Lt	26.1	Motorcycle	Ipsilateral 2-6th rib fractures
16	F	41	Rt	18	FFSH	-
17	M	23	Rt	21.9	In car TA	-
18	M	43	Lt	12.5	Pedestrian TA	Traumatic SAH, SDH Skull fracture Ipsilateral fibular shaft fracture

TA: traffic accident, FFSH: fall from standing height, EDH: epidural hemorrhage, SAH: subarachnoid hemorrhage, SDH: subdural hemorrhage

locking compression plate in the anterosuperior position. Half of all cases received an autogenous bone graft, where inability of anatomical reduction was indicated, such as in comminuted fractures or segmental defects. These cases included both fresh fractures and postoperative complications. Aside from one case of infected nonunion, which received segmental bone resection, all cases achieved bone union.

The most common surgical indications were floating shoulder with 10 cases (55.6%) followed by nonunion with 5 cases (27.8%), associated neurovascular injury with 4 cases (22.2%) and open fracture with 3 cases (16.7%), where associated neurovascular injuries were combined with other surgical indications (Table 2).

Table 2. Surgical indications, techniques and results

Patient no	AO Classification	Surgical indication	Associated injury	Operation/ Function of plate	Bone graft	Union period (week)
1	15-B1	Floating shoulder	Ipsilateral scapular neck fracture	reconstruction plate / Neutralization	No	10.9
2	15-B1	Nonunion	-	reconstruction plate / Neutralization	Yes	30.9
3	15-B1	Nonunion	Ipsilateral winged scapula	reconstruction plate / Neutralization	No	24
4	15-B3	Nonunion	Ipsilateral BPI	reconstruction plate / Bridging	Yes	26.9
5	15-B2	Floating shoulder	Ipsilateral scapular neck fracture with BPI	reconstruction plate / Neutralization	No	13.9
6	15-B1	Nonunion	-	reconstruction plate / Bridging	Yes	28.6
7	15-B1	Floating shoulder	Ipsilateral scapular neck fracture	reconstruction plate / Neutralization	Yes	19.1
8	15-B2	Floating shoulder	Ipsilateral scapular neck fracture	reconstruction plate / Neutralization	No	12.3
9	15-B3	Nonunion (infected)	Open fracture with neurovascular injury/ Ipsilateral scapular neck fracture	Implant removal & debridement	No	-
10	15-B3	Open fracture	-	reconstruction plate / Bridging	Yes	15.7
11	15-B3	Floating shoulder	Ipsilateral humerus shaft fracture	reconstruction plate / Neutralization	Yes	28.7
12	15-B2	Open fracture	-	reconstruction plate / Neutralization	No	20.1
13	15-B3	Open fracture	-	reconstruction LCP / Neutralization	No	12.6
14	15-B1	Floating shoulder	Ipsilateral scapular neck fracture	reconstruction LCP / Neutralization	Yes	15.1
15	15-B1	Floating shoulder	Ipsilateral glenoid/ coracoid process fracture	reconstruction LCP / Compression	No	24.6
16	15-B1	Floating shoulder	Ipsilateral scapular neck fracture	reconstruction LCP / Neutralization	No	11.9
17	15-B1	Floating shoulder	Ipsilateral scapular neck fracture	reconstruction LCP / Neutralization	Yes	22.3
18	15-B3	Floating shoulder	Ipsilateral humerus shaft fracture	reconstruction LCP / Neutralization	Yes	13.9

BPI: brachial plexus injury, LCP: locking compression plate

In the various cases of floating shoulder, 7 were scapular neck fractures, 2 were humerus shaft fractures and 1 was an intra-articular glenoid fracture with a coracoid process base fracture. The 7 cases of floating shoulder with scapular neck fracture received only open reduction and internal fixation of the clavicle fracture with no treatment of the scapular neck fracture. In the 2 cases of ipsilateral humerus shaft fractures, each received open reduction and internal fixation of both clavicle and humerus (Fig. 2). In the case of intra-articular glenoid fracture with a coracoid process base fracture, the intra-articular step-off was minimally displaced and left without treatment, whereas the coracoid process base fracture was treated by screw fixation (Fig. 3).

In the 5 cases of nonunion, all were initially treated in other hospitals. Out of the 5 cases, 3 were initially treated conservatively and 2 initially received operative treatment. Of the 3 cases that received conservative treatment, 2 sustained an associated brachial plexus injury and 1 sustained an associated contralateral humerus shaft fracture that was initially treated with intramedullary nailing. Of the 2 cases that received operative treatment, 1 initially received anterosuperior plating with wiring but resulted in implant failure 3 months later (Fig. 4). The other case had an open clavicle fracture with combined neurovascular injury, which initially received 2 consecutive surgeries, resulting in an infected nonunion with active pus discharge. Our treatment of this injury consisted of implant removal, segmental bone resection and debridement without reconstruction due to a combination of permanent brachial plexus injury and extensive clavicle bone defect of approximately 15 cm (Fig. 5) (Table 3).

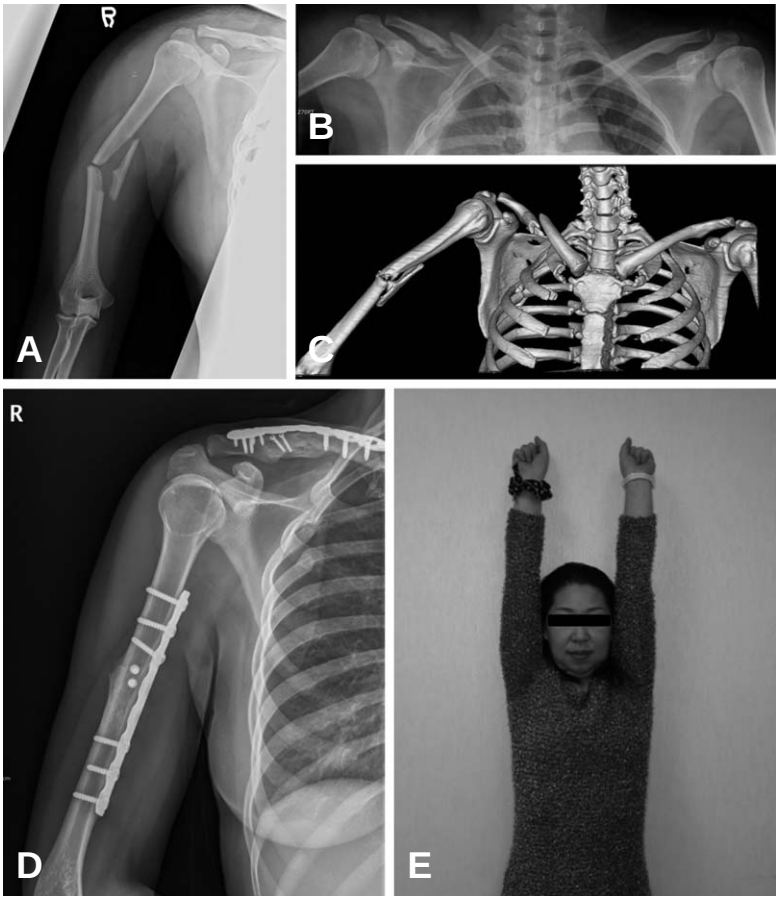

Fig. 2. A 31-year-old woman with a case of floating shoulder of the ipsilateral humerus shaft fracture type, sustained in a car accident. (**A**) Radiograph showing the humerus shaft fracture with butterfly fragments (**B**) Radiograph showing displaced midshaft clavicle fracture (**C**) CT scan showing the both fractures (total floating shoulder) (**D**) Postoperative radiograph at one year, showing pate fixation of both fractures and successful bone union (**E**) Patient at one year post operation, showing full range of shoulder motion.

A total of 17 cases achieved bone union, with one additional case of infected nonunion, where the mean period of bone union was 19.5 weeks. The longest mean bone union according to indication was nonunion at 27.6 weeks, whereas the shortest was open fractures at 16.1 weeks. The mean period of bone union according to those without bone graft was 22.4 weeks, whereas those with bone grafts achieved bone union at a mean period of an additional 4 weeks (p=0.036) (Fig. 6).

To better understand the difference of operative versus conservative treatment, the results of conservative treatment for remained 105 patients of midshaft clavicle fractures were that the average union rate was 31.4 weeks and there were only 4 nonunion cases. In all cases, there were no postoperative complications, yet sequelae remained in all 4 cases where initial indications included brachial plexus injuries. Among the cases of brachial plexus injury, 3 initially occurred as partial and 1 occurred as a complete injury. All partial cases of brachial plexus injury were not treated. In the case of complete brachial plexus injury, clavicle implant removal and shoulder fusion were performed after 14 months. In a following 15 months the same patient received a Steindler operation.

Fig. 3. A 25 year old male with a case of floating shoulder of the intra-articular glenoid fracture with coracoid process base fracture type, sustained in a motorcycle accident (**A**) Radiograph showing a minimally displaced midshaft clavicle fracture (B-1) combined with ipsilateral glenoid fracture (**B**) CT scan scan clearly showing the coracoid process base fracture and intra-articular glenoid fracture (**C**) Postoperative radiograph at one year, showing bone union by means of plate fixation of the clavicle and screw fixation of the coracoid process (**D**) Patient at one year post operation, showing full range of shoulder motion.

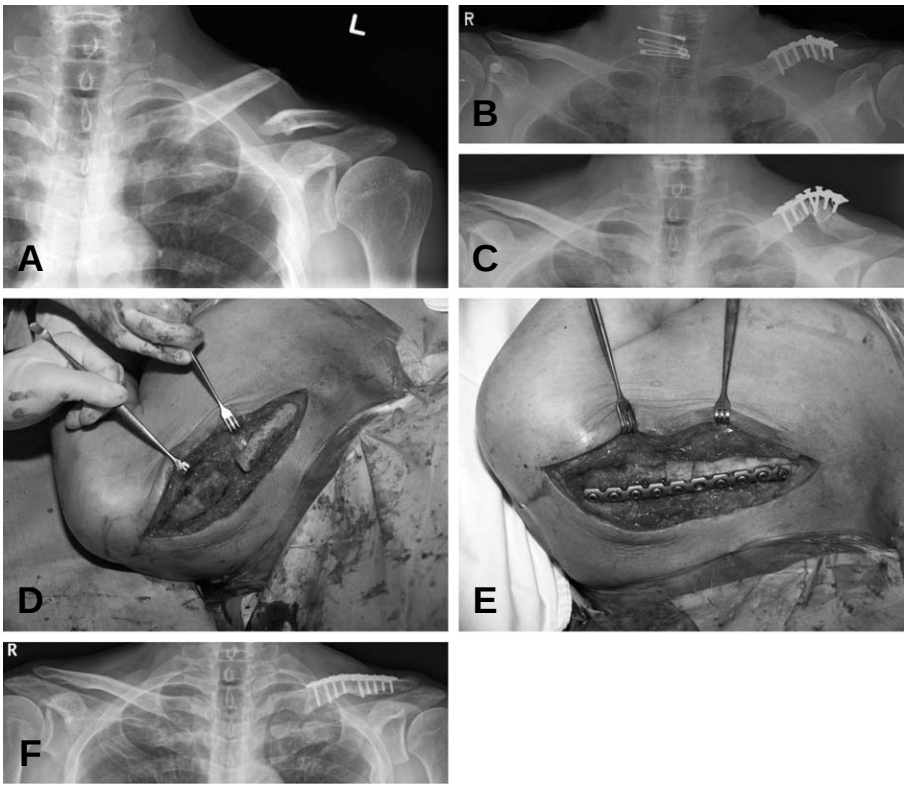

Fig. 4. A 65 year old male patient with a case of nonunion (**A**) A preoperative radiograph showing a severely displaced midshaft clavicle fracture (**B**) Immediate postoperative radiograph (previous treatment from other hospital) (**C**) Postoperative radiograph at 3 months, showing implant failure (**D**) Photo showing removal of implant and dead bone with resulting segmental bone defect (**E**) Photo showing plate fixation with autogenous strut bone graft (**F**) Postoperative radiograph at one year, showing successful bone union.

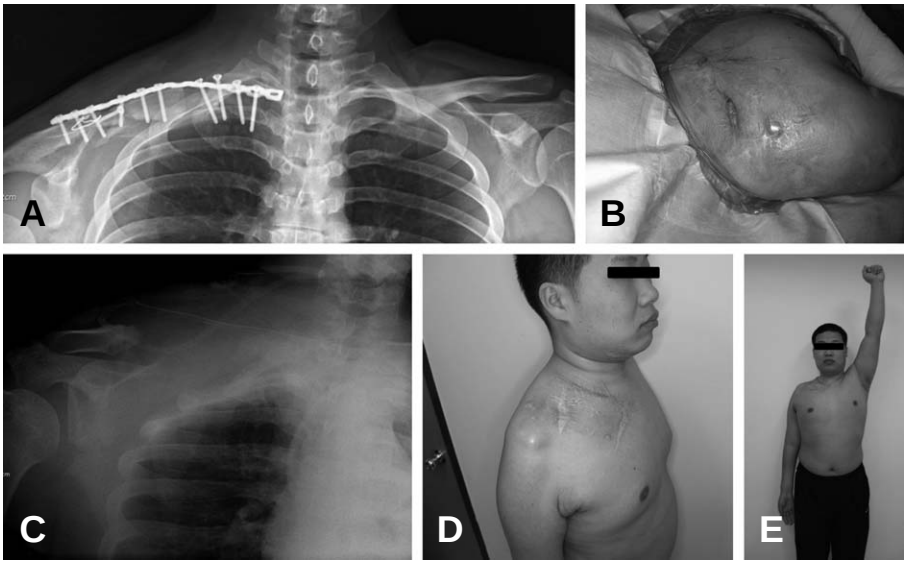

Fig. 5. A 26 year old male patient with a case of infected nonunion (**A**) The initial radiograph taken upon entry into our hospital after two prior surgeries, showing large segmental bone defect and fixation failure (**B**) Photo showing skin fistula with puss discharge (**C**) Postoperative radiograph showing removal of dead bone and failed implant (**D**) Postoperative photo at 1.5 years, showing recovery of skin wounds, resulting in infection control (**E**) Patient at 1.5 years postoperation, showing lack of shoulder motion due to associated brachial plexus injury.

Table 3. Characteristics of patients with nonunion

Patient no	Associated injury	Previous treatment	Surgical techniques	Results
2	Contralateral humerus shaft fracture	IM nailing for humerus fracture/ Conservative for clavicle fracture	Reconstruction plate with lag screw & BG	Bone union (30.9 weeks)
3	Ipsilateral winged scapula	Conservative	Reconstruction plate with lag screw	Bone union (24 weeks)
4	Ipsilateral BPI	Conservative	Reconstruction plate & BG	Bone union (26.9 weeks) Shoulder fusion d/t no recovery of BPI
6	None	Reconstruction plate with wiring	Reconstruction plate & strut BG	Bone union (28.6 weeks)
9	Open clavicle fracture Ipsilateral scapular neck fracture Partial BPI Subclavian artery thrombosis Subclavian vein branch rupture	Reconstruction plate with wiring	Incision & drainage with bone curettage	Segmental bone defect (15 cm) Partial recovery of BPI

IM: intramedullary, BPI: brachial plexus injury, BG: bone graft

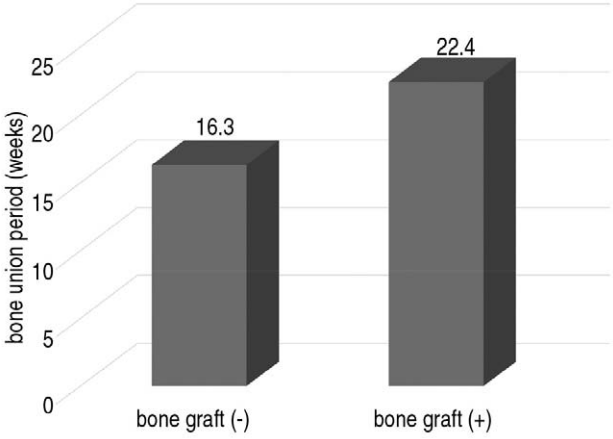

Fig. 6. Bone union period according to bone graft.

IV. Discussion

This study was conducted to provide analytical results for operative treatment of midshaft clavicle fractures over a period of 10 years. While the sample period for clavicle fractures is extensive, the number of patients who received operative treatment was small due to the limited range of indications deemed acceptable for surgical intervention. Traditionally, the standard method of treatment for midshaft clavicle fractures was conservative. However, in the 1990's several studies(18,19,20) were published showing unsatisfactory results, such as high rates of nonunion and malunion, for conservative treatment relative to operative methods. Therefore, an increase in operative treatment was observed following this period.

However, a recent randomized study concluded that evidence for routine surgical intervention was not supported.(11) In recent years, no other studies have been published showing support for operative treatment of displaced midshaft clavicle fractures as the standard method. Based on the preference for conservative treatment held by the hospital in which this study was conducted, the courses of treatment, even in cases of displaced, comminuted and shortened midshaft clavicle fractures, have avoided surgical intervention.

The limited range of indications that are deemed acceptable for operative treatment are primarily restricted to unstable fractures, such as floating shoulder, open fracture and associated neurovascular injury, where there is considerable risk of nonunion or delayed union. Where initial treatment in other hospitals, either conservative or operative, resulted in nonunion the preference of this hospital is to recommend surgery, which explains the limited numbers of cases available in operative studies.

Floating shoulder is defined as a midshaft clavicle

fracture associated with a scapular neck fracture or humerus shaft fracture. Generally, the floating shoulder is defined as a midshaft clavicle fracture with an ipsilateral scapular neck fracture.(13) However, a more accurate definition of the floating shoulder would also involve a humerus shaft fracture. In this study, we defined a floating shoulder as midshaft clavicle fracture with either or both of an ipsilateral scapular neck and humerus shaft fracture.

Out of the total 18 cases, 10 (55.6%) were classified as a floating shoulder, where all cases were sustained as high energy injuries. Some controversy remains as to whether conservative or operative treatment should be routine in cases where a floating shoulder occurs. When operative treatment has been determined necessary for a floating shoulder the clavicle fracture generally receives treatment, yet disagreement also remains as to whether scapular neck fractures should also receive surgical treatment. Recent studies(13-17) have shown favorable results with only clavicle fixation. In 7 cases of floating shoulder, patients received only clavicle fixation by anterosuperior plating and achieved bone union in all cases. After fixation of the clavicle fracture, scapular neck fractures were indirectly reduced and stabilized. This treatment has been shown to be effective in inducing indirect bone healing where scapular neck fractures are concerned. If a midshaft clavicle fracture consists of a displaced intra-articular glenoid fracture, direct reduction and fixation are called for. However, several studies(18,19) have shown, that where a minimally displaced scapular and intra-articular glenoid fracture in a floating shoulder have occurred, fixation of only the clavicle resulted in stabilization of the shoulder girdle leading to a favorable recovery. In one case of this study, where an intra-articular glenoid fracture had occurred with minimal displacement, the midshaft clavicle and coracoid process base fracture was surgically treated, which also proved to provide stability to the shoulder girdle.

In a floating shoulder, where a humurus shaft fracture has occurred, it is assumed that both humurus and clavicle fractures should receive operative treatment in order to ensure stabilization, as fixation of only the clavicle has not been shown to provide indirect stabilization to the humurus. The operative method in this case has been open reduction and internal fixation in both fractures. In the two cases, out of 10 total cases of floating shoulder, where both clavicle and humerus shaft fractures occurred, we achieved successful bone union in both.

Brachial plexus injuries in combination with clavicle fractures are uncommon and are rarely caused by fragments from clavicle fractures. Rather, the most common form of brachial plexus injuries is a result of excessive traction. Deformation of fractures along the middle third of the clavicle usually follow the pattern of downward displacement of the lateral fragment and elevation of the medial fragment due to differing forces between sternocleidomastoid tension and weight of the shoulder.(7) In combination with brachial plexus injuries the lateral fragment of a clavicle fracture is subject to greater downward force, causing displacement and increasing the chance of nonunion. Several studies (20-24) imply that clavicle fractures with associated neurovascular injuries provide an indicator for surgery. In this study, 3 out of total of 4 cases of brachial plexus injury had initially resulted in nonunion, where the patients later sought treatment in the hospital where this study was conducted. Two of the cases of nonunion related to brachial plexus injury were initially treated conservatively and one case was initially treated operatively yet resulted in an infected nonunion. Brachial plexus injuries in combination with clavicle fractures are typically a result of high energy injuries. Due to the complications discussed, operative treatment is recommended in order to insure proper bone healing when the indication of brachial plexus injury is present.

A large number of distal nonunions have been shown to appear asymptomatic,(25) yet the majority of midshaft nonunions, particularly those in young patients, have been shown to be symptomatic enough to warrant treatment.(26-29) Plate fixation and pin/IM screw fixation stand as the 2 primary methods of fixation used to achieve union under operative treatment, where standard operative treatment consists of open reduction and internal fixation. The rate of success under this method has been shown to be significantly high when plating of appropriate type and dimension is used. The recommended plate type is compression plate or lag screw with a neutralization plate, where each segment carries a minimum

of 3 bicortical screws.(4) A comparative study(30) on the use of reconstruction plates versus reconstruction locking compression plates in the treatment of midshaft clavicle fractures showed that both implants provided good stability. In this study, aside from one case of infected nonunion, the additional 4 cases of nonunion received a reconstruction plate with autogenous bone graft (one case without bone graft), where all 4 cases achieved successful bone union. Bone union period in reconstruction of initial nonunion cases took 10 to 11 weeks longer than other fracture types due to increased bone defect and/or scar tissue.

Extensive bone loss or damage, frequently associated with unsuccessful operative treatment and infection, can cause difficulty in postoperative reconstruction of the clavicle where nonunion has occurred. In cases where all reconstructive treatment methods have been exhausted, the remaining option is clavicular excision, termed claviculectomy.(4) As the clavicle plays an important role in support of the upper extremity, claviculectomy is typically only considered as a last resort. In one case of infected nonunion it was determined that reconstruction would have been beneficial, were it not for an associated brachial plexus injury and extensive bone defect that was beyond repair. Therefore, in order to control ongoing infection, a partial claviculectomy was conducted, which proved successful for such purposes.

The primary limitation for this study is related to selection bias, as the hospital in which this study was conducted is a tertiary metropolitan facility, where surgical treatment is typically only given to severe cases, such as nonunion and associated brachial plexus injuries. This condition prevents a conclusion on a generalized method of treatment as cases, by nature of selection, are an exception to the average. Secondly, further research is needed to draw conclusions on functional outcome as results in this study are limited only to radiological outcome. Another significant limitation is inherent to the retrospective nature of this study and lies in the lack of comparative results concerning conservative treatment outcomes of midshaft clavicle fractures. As bias reflected in this study favors conservative treatment in such cases, a comparative study would allow a deeper understanding of optimal treatment methods.

V. Conclusion

Of the few cases that were deemed acceptable to receive operative treatment, such as floating shoulder, open fracture, associated neurovascular injury, and nonunion after previous treatment, all posed a considerable risk of issues concerning bone healing were they to remain without surgical intervention. We are able to conclude that, within the framework of this selection group, operative treatment outcomes proved to be relatively good.

VI. Conflict of Interest

All authors have no conflict of interest in this study.

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