Original Article

Preliminary Report of Minimally Invasive Plate Osteosynthesis with Vertical Incisions for Mid-shaft Clavicular Fractures: a Surgical Technique and its Results

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OBJECTIVE: One of the most common surgeries for mid-shaft clavicular fracture is an open reduction and internal fixation with plate and screws. When using a conventional technique of plate fixation, a long incision is used, compromising blood supply to the bone and soft tissues. This can result in delayed or nonunion, skin complications, painful scarring, infection and paraesthesia inferior to the clavicle. This study reports on a minimally invasive plate osteosynthesis with separated vertical incisions. The aim is to evaluate radiographic and clinical outcomes in mid-shaft clavicular fractures.

MATERIALS AND METHODS: From January 2011 to July 2013, eight cases were operated using the technique. Fracture reduction was arrived at by indirect manipulation with a postural reduction under fluoroscopic guidance. Vertical incisions were done proximally and distally. We evaluated the clinical and radiographic results immediately postoperation and at 2, 4, 8 weeks and thereafter every 4 weeks postoperative until union was achieved.

RESULTS: AO Type 15-B2.2 was the most common: all fractures healed within a mean period of 13.8 weeks (range 11-18 weeks). All patients showed good shoulder function, with a mean disabilities of the arm, shoulder and hand (DASH) score of 6.8 (range 4-15.3) at six months. There were no complications, except bending of an implant in one patient. However this patient achieved a bone union with good function. There was no numbness around the clavicle in this series. Average operative time was 128 minutes. Fluoroscopic exposure time was 29.5 seconds.

CONCLUSION: We propose vertical incisions as an approach for plate and screws application for this MIPO technique. This presented technique is good, not only with regards to appearance but also in avoiding any associated complications. We propose this technique as an option for minimally invasive plate osteosynthesis (MIPO) for mid-shaft clavicular fractures.

Conservative treatment of mid-shaft clavicular fracture has been a standard treatment in most cases.[1,2] However, there are many cases which need to be operated on to prevent complications of conservative treatment such as nonunion, malunion or malfunction of the shoulders.[3-7] In a systematic review of 2,144 acute mid-shaft clavicle fractures, Zlowodzki et al. found that comminuted displaced fractures had a higher rate of nonunion and longer term negative sequelae with nonsurgical management, and a relative risk reduction of 57% for nonunion when plate fixation was applied.[9]

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The most common surgery for mid-shaft clavicular fracture is open reduction and internal fixation (ORIF) with plate and screws.[3] Elastic intramedullary nailing is another common option,[5,8] however, migration of the implant, telescoping and shortening[8] are not infrequent in comminuted fractures when using this technique. The conventional technique for ORIF with plate and screws normally compromises blood supply to bone and soft tissues. This not only causes delayed union, nonunion and infection but the long horizontal skin incision can also cause skin complications such as painful surgical scarring on the prominent plate and paraesthesia of the supplied cutaneous nerve inferior to the clavicle.[3,9] Minimally invasive plate osteosynthesis (MIPO) technique for mid-shaft clavicular fractures[7,9] has become accepted and has overcome many of these complications. This is because the technique of short separated skin incisions provides good biological healing of fractures[10] and lowers the chance of injury to cutaneous nerve and results in less scarring on the prominent plate.

Comparing the type of incisions, horizontal or vertical incisions along the skin crease, some literature showed that postoperative numbness was lower in the vertical incision group.[9] Those who had undergone vertical incisions also reported a significantly reduced degree of numbness and significantly less awareness of the numbness with clothing and shoulder straps. Furthermore, a vertical incision may be substantially obscured by clothing when compared to a horizontal incision, resulting in a better cosmetic outcome.

We use MIPO technique with vertical separated incisions along the skin crease in the process of reduction and fracture stabilization to provide a good biological environment for healing and to minimize skin complications. We report the technique of minimally invasive plate osteosynthesis in mid-shaft fracture of clavicles with vertical incisions and evaluate the radiographic and clinical outcomes.

Materials and Methods

We performed percutaneous plating for displaced mid-shaft fractures of clavicles from January 2011 to July 2013. Institutional Review Board approval was obtained for a retrospective review of the medical and radiographic records of these patients.

The inclusion criteria were isolated, unilateral, displaced mid-shaft clavicular fractures with less than 25% cortical contact between the main fragments in patients aged between 18 and 65 years. The exclusion criteria were fractures of the medial or lateral third of the clavicle, former relevant injuries or previous surgical interventions of the upper extremity or additional pathological conditions affecting the limb function, pathological fractures, open fractures, fracture with associated neurovascular injury and cases with a contraindication for surgery.

Figure 1: 3.5 mm. Reconstruction LCP

Figure 2: Anatomical Superior Clavicle LCP

Surgical technique

A locking reconstruction plate or Superior Clavicle Anatomical Locking Plate (Synthes, Oberdorf, Switzerland) were chosen (Figure 1 and 2), long enough to place at least three screws on each side of the fracture fragment. Preoperative planning for plate length selection was routinely done (Figure 3). For the locking reconstruction plate, it was manually contoured preoperatively on a plastic clavicle model in order to accommodate a superior surface of the clavicle before processing for sterilization (Figure 4). General anesthesia was a standard procedure for every patient. The patient was set in a supine position on a fluoroscopic transparent operative table. A fluoroscope was positioned at the contralateral side of the injured arm, perpendicular to the longitudinal axis of the table. The C-arm of the fluoroscope was placed to obtain AP view (Figure 5), 30 to 40 degrees of cephalad tilting and 30 to 40 degrees of caudad tilting (Figure 6-9). This will provide images for the reduction and proper plate positioning before fixation. The pre-draping images were acquired for all three views before skin preparation for an adequate intraoperative assessment. Then sterile draping was administered to the whole upper limb capable of being moved freely during operation.

Anatomical landmarks, clavicle, fracture site, coracoid process, acromion and A-C joint were identified and marked (Figure 10). The selected plate was placed over the clavicle outside the skin and fluoroscopic images were taken to confirm the plate length and positioning (Figure 11). A 3 cm. vertical skin incision was made along the skin crease at the level of the second hole of the plate on the lateral fragment. A subcutaneous-supraperiosteal plane was created using a periosteal surfer along the

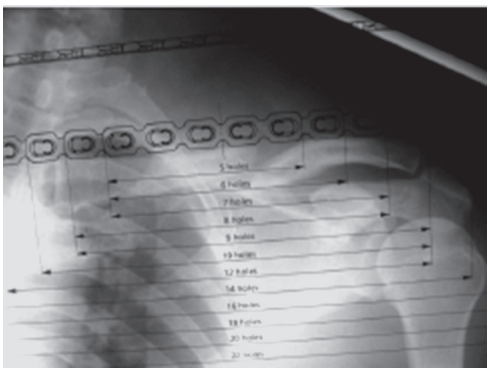

Figure 3: Preoperation template.

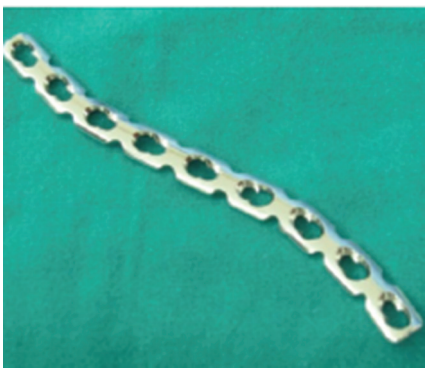

Figure 4: Preoperation contouring of 3.5 mm., reconstruction LCP.

Figure 5: Intraoperative setting of patient position and C-arm.

Figure 6: Caudad tilting of C-arm.

Figure 7: Cephalad tilting of C-arm.

Figure 8: Preoperative x-ray.

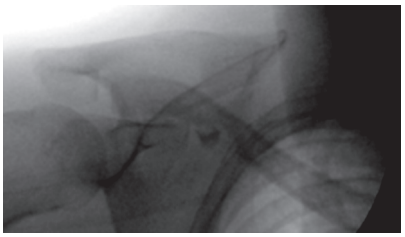

Figure 9: X-ray demonstration of Caudad tilting of C-arm.

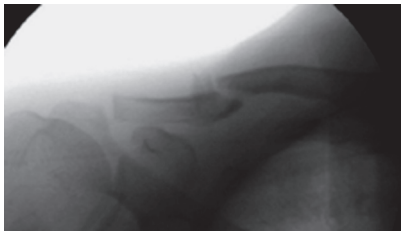

Figure 10: X-ray demonstration of Cephalad tilting of C-arm.

Figure 11: Marking of anatomical landmarks before making incisions.

Figure 12: Plate length and position identification under C-arm guidance.

Figure 13: Vertical lateral skin incision and tunnelling technique.

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Figure 14: Insert the plate, reduce the fracture and temporary fix with K wires through the medial and lateral incision.

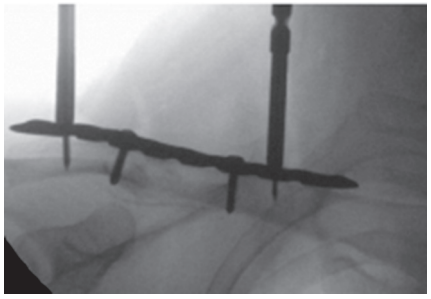

Figure 15: The 3.5 cortical screws were used to pull the main fragments to the bone, as a reduction template.

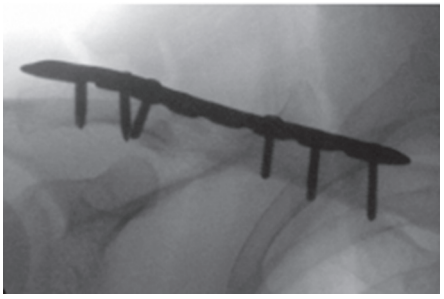

Figure 16: The amount of screws on each side is three screws.

Figure 17: X-ray of both clavicles preoperatively.

Figure 18: X-ray of both clavicles postoperatively, to compare the length of the normal and injured side.

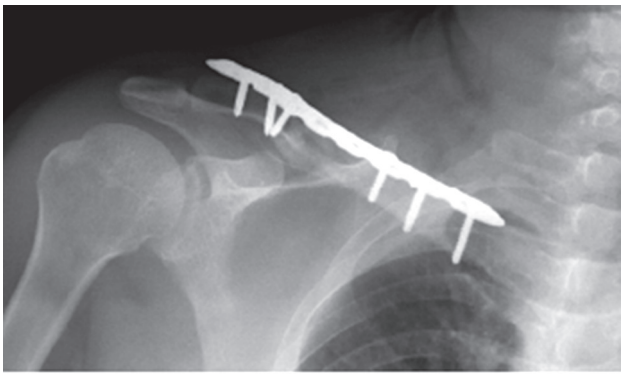

Figure 19: Postoperative x-ray in AP to monitor healing.

superior surface of the clavicle from the lateral to medial fragment; this is a tunnel for further plate insertions (Figure 12). The medial vertical skin incision along the skin crease then was opened. The plate was inserted from the lateral surgical incision to the medial side. The fracture was reduced indirectly by manipulation of the arm with fluoroscopic guidance. If necessary, a 3.5 mm. Schanz screw was fixed on each main fragment, as a joystick, to facilitate reduction of the fracture and a small external fixator was applied to maintain reduction.

When reduction was achieved with an acceptable alignment, with the correct length, angulation and rotation, the k wires were inserted for temporary stabilization through the most lateral and most medial hole of the plate (Figure 13). After the fluoroscopic images confirmed an acceptable alignment, the 3.5 mm cortical screws were inserted to pull the main fragments to the plate, using the plate as a reduction template (Figure 14). Then the 3.5 locking head screws were fixed to provide better stability. At least three screws on each side of the fragment would be fixed to ensure adequate stabilization (Figure 15). Before skin closure, three images were acquired to evaluate the bone-implant construction. No bone grafting was used in this series. Skin was closed with a subcutaneous absorbable suture following with a subcuticular skin closure to reduce any scarring complications (Figure 16).

Postoperative rehabilitation

Postoperatively, the patient's injured arm was supported in a sling to protect the load of the whole upper extremity and to increase comfort. An early range of motion of the shoulder was started with active assistance according to individual tolerance. As this was a subcutaneous suturing there was no need to remove stitches. Heavy lifting, pushing or pulling was not permitted until evidence of bone union was observed.

The follow-up period, with clinical evaluations and x-rays, was done at 2 weeks, 4 weeks, 8 weeks, 12 weeks and 24 weeks postoperatively.

Evaluation of results

Demographic data, fracture type, mechanism of injury, associated injury, fluoroscopic exposure time, time to union, skin numbness inferior to the clavicle and complications were recorded and assessed at the immediate post-operative period and during follow-up. For clinical evaluations we used the Disability of the Arm, Shoulder, and Hand (DASH) score[11,12] which was assessed at six months postoperatively. An x-ray of both clavicles (Figure 17-18) of cephalad and caudad views were taken to evaluate the degree of shortening and signs of radio-

graphic union, those defined as bridging of fracture with callus in three views. Clavicular shortening was measured[15] as the proportional difference in length between the affected and unaffected sides. Radiographs were reviewed by an independent examiner in order to verify the state of the bone union (Figure 19).

Results

There were eight patients who met the inclusion criteria and had sufficient hospital and radiographic records and were available for follow-up for at least six months after surgery. Patients included seven males, one female, with a mean age of 36.8 years (range, 20-55 years). Six out of the eight clavicles treated were right side clavicles. The most common type of fracture is AO 15 type B 2 (wedge fracture) in five patients. Six patients sustained an injury from motorcycle accidents. Four had a concomitant thoracic injury, most commonly, rib fractures. Intraoperatively, five clavicles were fixed with 3.5 mm anatomical locking plates while the other three were fixed with 3.5 mm. reconstruction locking compression plate (LCP). The average operative time was 128 minutes. Fluoroscopic exposure time was 29.5 seconds.

Postoperatively, there was no numbness of the skin inferior to the clavicle. All patients could start early range of motion exercises of the shoulder following the rehabilitation program without difficulty. The measurement of clavicular length was compared with the uninjured side. Five of the eight fractures were equal; there were three clavicles which were shorter (0.2-0.6mm). The average radiographic and clinical union was at 13.875 weeks. DASH scores were 6.7875. During history taking, no patient complained about the scar on the plate prominence and on physical examination, there were also no unsightly scars on the prominent plate (Figure 20).

There was one case which had a complication of a bent plate. This was a case which was fixed by 3.5 mm reconstruction LCP. However, the fracture healed and the patient did not complain about the angulation of the clavicle (Figure 21-22).

Figure 20: MIPO technique with vertical incisions.

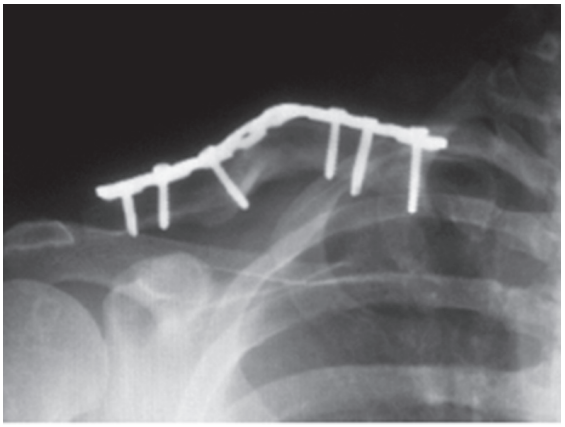

Figure 21: Reconstruction LCP is too weak to fix clavicle in some cases such as heavy arm and larger body.

Figure 22: After early ROM exercise, most of the patients had good function.

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Case	Sex	Age	Side	Fracture type (AO)	Mechanism of injury	Associated injury	Fluoroscope Time (sec)	Union time (Wk.)	DASH Score	Clavicular shortening (mm.)	Plate type
1	M	45	R	B2.2	MCA		30	13	4	0.5	LCP Superior
2	F	49	R	B1.3	MCA	Fx Right 2nd-4th rib	39	11	3.3	0.2	LCP Superior
3	M	30	L	B2.2	Fall		24	12	15.3	0.6	LCP Superior
4	M	20	R	B2.1	MCA	Right Hemopneumothorax	24	15	13.3	0	LCP Superior
5	M	28	L	B3.3	MCA	Fx Rt. 3rd rib	39	18	1.7	0	LCP Reconstruction
6	M	55	R	B2.2	MCA		24	15	6.7	0	LCP Reconstruction
7	M	24	R	B2.2	MCA	Fx Rt. 4th-5th rib	28	12	9.2	0	LCP Reconstruction
8	M	44	R	B1.3	Fall		28	15	0.8	0	LCP Superior
Mean		36.875		B2.2 (Most)	MCA (Most)	Rib fractures (Most)	29.5	13.875	6.7875	0.16	

Discussion

The operative treatment for displaced mid-shaft fractures of the clavicle has been well accepted, and has resulted in good functional recovery as well as restoration of clavicular length.[3,9] Several authors have reported favorable results with open plating.[13] However, open plating may cause considerable complications such as nonunion, delayed union or infection.[3,14,15] To avoid these complications, biological and less invasive techniques are necessary.

Good radiologic results were achieved even though the fractures were comminuted. Sohn et al. reported a high union rate after MIPO for fractures of the clavicle; their study included simple as well as comminuted fractures.[16] The same was seen by Hyun-Joo Lee et al. with favorable outcomes reported in performing MIPO with nail assistance.[7]

Wang et al. reported a comparative study between vertical incision and horizontal incision open plating techniques and showed the result of less numbness around the clavicle in the vertical incision group.[11] Thus, we use the MIPO technique with vertical separated incisions along the skin crease to provide a good biological environment for healing and to minimize any skin complications.

In our series, it was very common for injuries to be motorcycle accident-related as this is a common transportation mode in the local area. Moreover, the pattern of injuries was high energy trauma which resulted in the most common type of fractures being multi-fragmentary ones. This kind of fracture should ideally be treated with a minimally invasive technique. MIPO of the clavicle is not a very common fracture treatment, nowadays. There are a very limited number of case series reported in literature.[7,8,16] We used to perform the MIPO by separated horizontal incisions but there were still some complications of the horizontal scar lying on the prominent implants. After we developed the new vertical incision technique along the skin crease, we have not detected any numbness or scarring and hardware complications. All patients could start an early rehabilitation program as planned. This was probably due to a minimal disturbance of the muscle and soft tissue attachment around the fracture and fixation zones. The DASH scores were quite satisfactory; this might be the cause of less unfavourable factors for healing. In comparison to other MIPO studies,[7,8,17] our results seem to be the same as their results.

The only case out of eight reported with any complication was related to a bent plate which was a reconstruction LCP. This plate was not designed to be used for clavicle fixation and was quite weak. Since the thicker anatomical LCP has become available for use, we have a tendency to use this new plate to fix the clavicle in all cases.

Conclusion

MIPO may be beneficial in treating the fracture shaft of the clavicle. Changing the incision style from horizontal to vertical may reduce skin complications. Using an anatomical plate specifically designed for this area is more appropriate than using a weaker reconstruction plate. However, this study was a preliminary report of this new technique and there are a limited number of cases. We need to collect more cases to report with better statistical evidence in the future.

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