ORIGINAL ARTICLE

Minimally invasive plate osteosynthesis of clavicular midshaft fractures under insertion guide

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ABSTRACT

BACKGROUND: The less invasive stabilization systems for the distal femur and proximal lateral tibia have been developed to simplify the surgical technique of minimally invasive plate osteosynthesis (MIPO). MIPO, however, has simply been introduced into clavicular midshaft fixation without the aid of insertion guide though the procedure for midshaft clavicular fractures was found to produce satisfactory clinical and radiologic outcomes without serious complications. The purpose of this study was to determine the outcome of MIPO of clavicular midshaft fractures using an insertion guide.

METHODS: A total of 15 patients with clavicular midshaft fractures treated by MIPO using insertion guide between September 2016 and September 2018 were included. We assessed bony union, shoulder function by the Constant score, and complications at a mean follow-up of 15.4 months (ranged from 12 to 24 months).

RESULTS: The mean surgical time 55.9±9.4 min (ranged from 50 to 70 min) and the fluoroscopic time was 146.5±29.0 s (ranged from 110 to 190 s). In all patients, the bony union was achieved at 8.8±1.0 weeks (ranged from 8 to 10 weeks) with no delayed unions or nonunions. The average Constant score was 99.1±1.2 (ranged from 96 to 100) at follow-up. Postoperative complications including infections, screw pull-out, hardware prominence, and neurovascular injury were not observed, however, one patient complained of mild plate discomfort.

CONCLUSION: MIPO using insertion guide is believed to be an acceptable and effective choice in the operative treatment of clavicular midshaft fractures.

Keywords: Clavicle; fixation; fracture; insertion guide; minimally invasive plate osteosynthesis.

INTRODUCTION

Clavicular fractures can be said to be one of the most commonly encountered in traumatology and orthopedic practice. Fractures of the clavicle account for between 2.9% and 5% of adult fractures, of them, 69–82% occur in the middle third.[1,2]

Although it has been believed since the time of Hippocrates that clavicle fractures require little more than benign neglect by clinicians,[3] in recent studies, owing to higher rates of nonunion, malunion, and shortening with conservative treatment compared with surgical management, open reduction and internal fixation (ORIF) is preferred by more and more surgeons.[4–8]

ORIF, however, comprises several complications including wound infection, infraclavicular numbness, refracture, nonunion, and so on. The authors mentioned that these complications can be reduced by careful soft-tissue handling including layered closure over the implant, setting optimal timing of surgery, and use of appropriate size and length plates.[8–11]

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More recently, as in the other long bones, minimally invasive plate osteosynthesis (MIPO) has been developed to minimize soft-tissue dissection and to reduce the incidence of aseptic healing disturbances, and introduced into orthopedic clinical practices by several authors and proved to be a procedure to produce satisfactory results without serious complications for clavicular midshaft fractures.[12–18] However, closed reduction of the clavicle is technically demanding due to the curved shape of the clavicle and the risk of iatrogenic neurovascular injury; thus, these MIPO procedures have not been frequently performed for midshaft clavicular fractures.[13] The less invasive stabilization system, which was initially developed for the distal femur and for the proximal tibia, simplifies the surgical technique for percutaneous plate osteosynthesis, thanks to its insertion handle or guide.[12]

The aim of the present study was to prospectively evaluate determine the outcome of MIPO of clavicular midshaft fractures under insertion guide.

MATERIALS AND METHODS

This study was approved by the Hospital Ethics Review Committee. Between September 2016 and September 2018, 15 patients with clavicular midshaft fractures were treated by MIPO technique using Clavicular Midshaft MIPO System (Myohyangsan, DPR Korea).

The Clavicular Midshaft MIPO Systems (left and right) consist of a new concept of implant and instruments for the treatment of the clavicular midshaft fractures (Fig. 1). The implant includes a plate-like device with combination holes and locking head screws which together act as an internal fixator. The plates, which are pre-contoured and low profile, make them ideal for the subcutaneous clavicle and easy to insert through its surface and cause little hardware discomfort. Other complications have not been identified. The instruments for the insertion of the implant have insertion guide, drill sleeves, and guide sleeves. There are 9 holes in the insertion guide, which have been designed to allow insertion of drill and guide sleeves. The plate can be inserted in combination with the insertion guide by two guide sleeves tighten in the lateral end of the plate and insertion guide along the superior border of the clavicle.

The Clavicular Midshaft MIPO System was indicated for the clavicular midshaft fractures with gross displacement, shortening >20 mm, and comminution (Type 2B1, 2B2 by the Robinson classification). Patients with ages ranged from 18 to 65 were involved in the study. Individuals who were skeletally immature and had other serious medical conditions were excluded. Fractures, associated with neurovascular injury, of more than 2 weeks, pathologic or open fractures were also excluded. The fractures were classified by the Robinson classification system (Fig. 2).

All patients were given intravenous antibiotics according to the usual prophylactic protocol. With the patient in the beach-chair position on a radiolucent table, surgery was conducted under general anesthesia. The shoulder on the affected side was stretched into the abduction to restore the shortening. Using towel clips inserted percutaneously and maneuvers under fluoroscopy, an accurate closed reduction was done. The reduction was checked with anteroposterior and 45° oblique radiographs before the fixation.

A 2-cm skin incision was made in the lateral side along the superior border of the clavicle to expose the lateral end. Us-

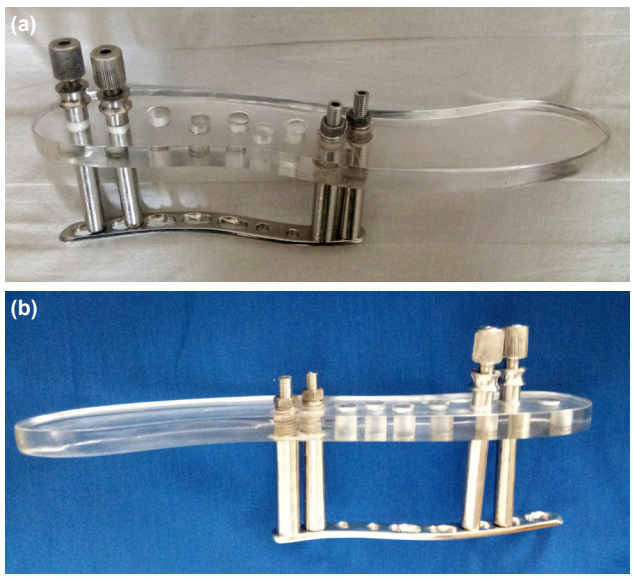

Figure 1. Clavicular Midshaft MIPO Systems, **(a)** Left one, **(b)** Right one. MIPO: Minimally invasive plate osteosynthesis.

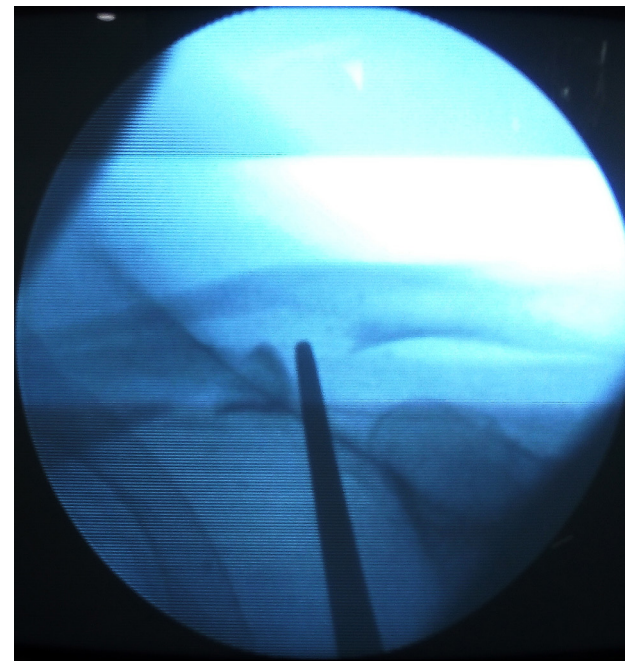

Figure 2. Clavicular midshaft fracture in a 47-year-old man on anteroposterior plain X-ray. Type 2B2 by Robinson classification.

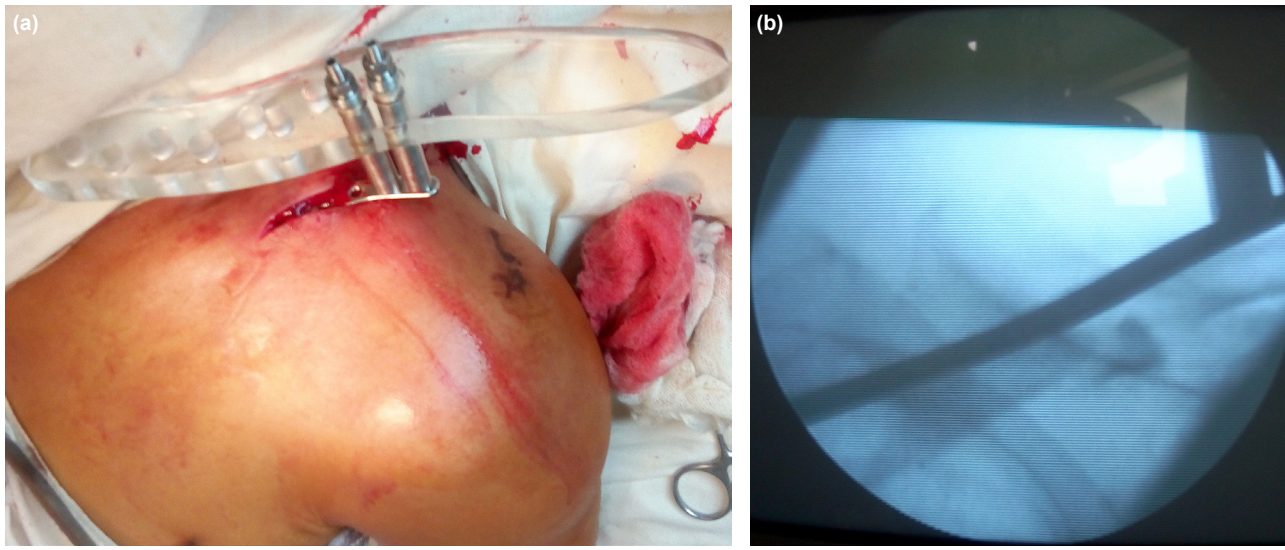

Figure 3. (a) Insertion of the plate assembled with insertion guide by the guide sleeves. **(b)** Insertion of the plate along the superior border of the clavicle.

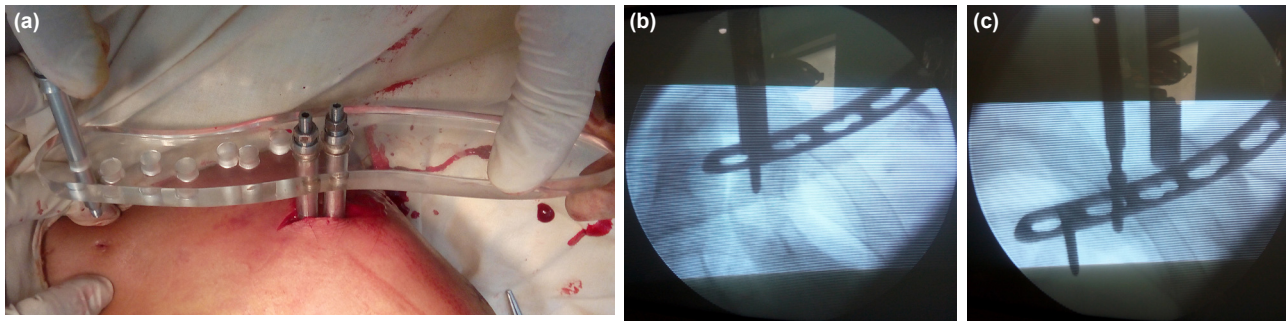

Figure 4. (a) Insertion of a drill sleeve through the guide sleeve in the medial clavicle. **(b)** Insertion of a locking head screw. **(c)** Insertion of locking head screws.

ing a periosteal elevator, a submuscular plane was developed and the plate assembled with the insertion guide by the guide sleeves was inserted along the superior border of the clavicle under fluoroscopy (Figs. 3a and b).

A stab incision was made in accordance with a guide sleeve inserted to the medical end of the insertion guide. A drill sleeve was inserted through the guide sleeve in the medial end to make an entry point of the locking head screw (Figs. 4a and b). If needed to compress the fracture ends, a cortical screw was inserted into a dynamic hole of the plate. After removal of the guide hole, the second screw was inserted into the lateral hole of the plate. Reduction and the position of the plate and screws were checked again radiographically. 3–4 locking head screws were inserted to ensure secure fixation (Figs. 4c and 5). The cortical screw used to compress the fracture ends was replaced with a locking head screw. The incisions were closed (Fig. 6).

Postoperatively, patients were placed in a sling for 2 weeks, allowing pendulum mobilization of the shoulder. A graduated physiotherapy regimen including range-of-motion exercises

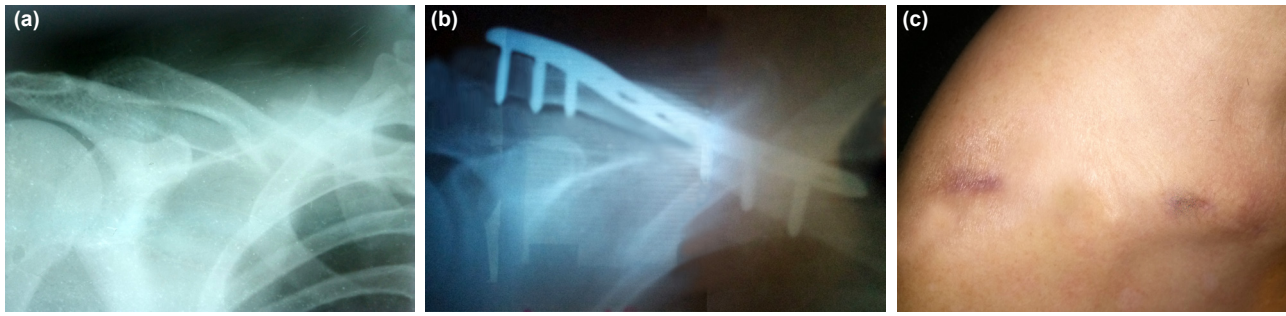

Figure 5. Clavicular midshaft fracture in a 38-year-old man on anteroposterior plain X-ray. Type 2B2 by Robinson classification, **(a)** preoperative radiograph, **(b)** postoperative radiograph at the 8 weeks follow-up, **(c)** postoperative scar.

Figure 6. Skin closure.

and daily activities was then commenced after the sling was removed. The patients were followed by the physiotherapy protocol unless complications such as infection, hardware breakage, or screw pullout, developed.

We assessed bony union on anteroposterior plain X-rays, shoulder function by the Constant score, and complications including infections, delayed union, nonunion, screw pull-out, hardware prominence, and neurovascular injury regularly at 4, 8, 12 weeks, and every 6 months.

RESULTS

A total of 15 patients were involved; 12 patients (80.0%) were men. 11 patients (73.3%) were Type 2B1 and 4 (26.7%) were Type 2B2 by the Robinson classification system. The mean age was 44.9 years (ranged from 23 to 60) and the duration of follow-up was 15.4 months (ranged from 12 to 24 months). The mean time from trauma to surgery was 5.7 days (ranged from 3 to 12 days). None of the patients were lost to the follow-up.

The mean surgical time 55.9±9.4 min (ranged from 50 to 70 min) and the fluoroscopic time was 146.5±29.0 s (ranged from 110 to 190 s). In all the patients, fracture union was achieved at a mean of 8.8±1.0 weeks (ranged from 8 to 10 weeks). Delayed unions or nonunions were not observed. We assessed the shoulder function at the last visit (deleted). The average Constant score was 99.1±1.2 (ranged from 96 to 100) at the final follow-up.

Postoperative complications including infections, screw pull-out, hardware prominence, and neurovascular injury were not observed, however, one patient complained of mild plate discomfort. The plate removal resolved that symptom.

DISCUSSION

The goal of clavicle fracture treatment is to reconstitute the clavicle as a rigid strut for the shoulder girdle to allow painless motion and strength around the shoulder while avoiding symptomatic nonunion or malunion.[19] To meet this goal, countless studies have been performed. Outcomes following conservative treatment of displaced clavicular midshaft fractures are far less favorable than was once perceived, with several studies demonstrating an increased rate of nonunion and symptomatic malunion.[8,20–22] There has gradually been a growing body of evidence supporting the primary fixation of displaced midshaft clavicle fractures, in particular, in those in whom altered shoulder function would have an impact on sport or occupation.[19,23–27] Postoperative complications by ORIF including mainly plating and good outcomes following biological osteosynthesis concept, however, encouraged the surgeons to introduce MIPO techniques even into the clavicle with complicated shapes and lack of muscular or ligamentous reinforcement.[28–32]

Zhang et al.[13] introduced MIPO for midshaft clavicular fracture using superior anatomic locking plates and concluded that it is a reproducible procedure and alternative to conventional operative methods.[12] Other authors have also compared different MIPO techniques with conventional ORIF with a locking compression plate and a reconstruction ribbon plate[15,18] and observed satisfactory outcomes with the MIPO procedures. However, they applied the MIPO techniques without insertion handle or guide.

In our study, we used Clavicular Midshaft MIPO System to fertilize the insertion of the plate and screws. The insertion guide can be assembled with the plate by the guide sleeves and aids the insertion of the plate and screws. The surgeons made stab incisions for the screw insertion through the guide sleeves and drilling by the drill sleeves, with which the fixation procedures have been followed easily and correctly. The mean surgical time 55.9±9.4 min using the Clavicular Midshaft MIPO System in our study, which was slightly shorter than it reported by Zhang et al.[13] We believe that the operative time could be decreased, because, once the plate had been inserted following the fracture reduction, drilling and insertion of screws were performed correctly under the insertion guide without fluoroscopic control. As a result, we would also reduce the fluoroscopic time during the MIPO using insertion guide.

In all the clavicular midshaft fractures treated with MIPO using insertion guide, the bony union was observed at a mean of 8.8±1.0 weeks, without delayed unions or nonunions. In literature, MIPO shortened the union time after surgery and the period of rehabilitation.[33,34] The result of our study in regard to the bony union also demonstrated the advantage of the MIPO. In our experience, a small degree of movement at the fracture site provided by bridge plating and preservation of periosteal blood supply may promote bone healing in this MIPO technique.

In patients with clavicle fractures, postoperative discomfort may be caused by plate, which requires hardware removal resulting in possible refracture after the plate removal.[19]

Meanwhile, the middle third of the clavicle is the thinnest segment of the bone and is devoid of any protective muscular or ligamentous attachment.[19,35] All of these explain the reason why plating in clavicle fractures causes postoperative hardware discomfort. To decrease the pain, the authors recommended using precontoured plates with a low profile.[19,36,37] We have also used pre-contoured plates which are low profile, making them ideal for the subcutaneous clavicle and causing little hardware discomfort. Other complications have not been identified.

The clavicle has several important functions, which is an important element in the integral functional mobility of the shoulder.[38–40] The average Constant score was 99.1±1.2, indicating that the MIPO technique using the insertion guide supports excellent recovery of the shoulder function after surgery. This is similar to the score provided by Zhang et al.,[13] 99.1±1.2, which means that MIPO techniques might produce good outcomes.

The shortcomings of our study are that the number of subjects is relatively small and it is a prospective case series. Other large scale of investigations to determine indications peculiar to MIPO under insertion guide for the treatment of clavicular midshaft fractures and assess patient satisfaction questionnaires during long-term follow-up could be performed in the future.

Conclusion

As internal fixation devices and techniques advance, MIPO will achieve more brilliant successes, seasoning and perfecting their features. The present study shows MIPO using insertion guide is an acceptable and effective choice in the operative treatment of clavicular midshaft fractures.

Ethics Committee Approval: The study was approved by Pyongyang Medical College Hospital Ethical Review Committee and was done in accordance with Declaration of Helsinki (Date: 21.3.2018, Decision No: 698513).

Peer-review: Internally peer-reviewed.

Authorship Contributions: Concept: M.S.K.; Design: M.S.K., K.I.R.; Supervision: T.W.M.; Resource: K.I.S.; Materials: M.S.K., T.W.M.; Data: M.S.K., K.I.C.; Analysis: K.I.R.; Literature search: K.I.C; Writing: M.S.J.; Critical revision: T.W.M.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZET*

Klavikula orta şaft kırıklarının giriş kılavuzu ile minimal invaziv plak osteosentezi

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AMAÇ: Minimal invaziv plak osteosentez (MIPO) cerrahi tekniğini basitleştirmek üzere distal femur ve proksimal lateral tibia için daha az invaziv stabilizasyon sistemleri geliştirilmiştir. Bununla birlikte MIPO, klavikula orta şaft kırıklarında giriş kılavuzunun yardımı olmadan fiksasyonda kullanıma sunulmuştur ve ciddi komplikasyonlar olmaksızın tatmin edici klinik ve radyolojik sonuçlar görülmüştür. Bu çalışmanın amacı, giriş kılavuzunu kullanarak klaviküler orta şaft kırıklarında MIPO sonuçlarını belirlemekti.

GEREÇ VE YÖNTEM: Eylül 2016 ile Eylül 2018 arasında MIPO ile giriş kılavuzu kullanılarak tedavi edilen klaviküler orta şaft kırığı olan 15 hasta dahil edildi. Ortalama 15.4 aylık takipte (aralık: 12–24 ay) kemik kaynaması, Constant skor ile omuz fonksiyonu ve komplikasyonları değerlendirdik.

BULGULAR: Ortalama cerrahi süre 55.9±9.4 dakika (aralık: 50–70 dakika) ve floroskopi süresi 146.5±29.0 saniye (aralık: 110–190 saniye) idi. Tüm hastalarda, gecikmeli kaynama veya kaynamama olmadan 8.8±1.0 haftada (aralık: 8–10 hafta) kemik kaynaması sağlandı. Takipte ortalama Constant skoru 99.1±1.2 (aralık: 96–100) idi. Enfeksiyonlar, vidanın dışarı çıkması, donanım çıkıntısı ve nörovasküler yaralanma gibi ameliyat sonrası komplikasyonlar gözlenmedi, ancak bir hastada hafif plak rahatsızlığı şikayeti görüldü.

TARTIŞMA: Giriş kılavuzu kullanılarak uygulanan MIPO'nun klavikula orta şaft kırıklarının operatif tedavisinde kabul edilebilir ve etkili bir seçenek olduğu düşünülmektedir.

Anahtar sözcükler: Fiksasyon; giriş kılavuzu; kırık; klavikula; MIPO.

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