Operative treatment of clavicle midshaft fractures using a locking compression plate: Comparison between mini-invasive plate osteosynthesis (MIPPO) technique and conventional open reduction

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KEYWORDS
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Summary
Hypothesis: The goal of the present study was to compare minimally invasive percutaneous plate osteosynthesis (MIPPO) technique and conventional open reduction with LCP for the treatment of clavicle midshaft fractures in adults in a randomized, controlled, clinical trial with a minimum of 1-year follow-up.

Materials and methods: Between June 2006 and May 2008, 64 cases of open reduction and internal plate fixation were performed for clavicle midshaft fractures. The operative indications were complete displacement, severe comminution and marked shortening of the clavicle (>2 cm). MIPPO and conventional open reduction surgery procedures with LCP were used in 32 and 32 cases, respectively.

Results: The mean time to union was 13 weeks in the open reduction group compared to 12 weeks in MIPPO group (P > 0.05). The MIPPO group had no significantly superior Constant shoulder scores or DASH scores at all time-points (P > 0.05). However, the complications in the open reduction group were dysesthesia in the area of the incision and directly below in 10 cases, hypertrophic scarring in five cases, painful shoulder in two cases and a limitation of shoulder motion in one case (P > 0.05). The complications in the MIPPO group were dysesthesia in two cases, no hypertrophic scarring, no painful shoulder, no limitation of shoulder motion were noted (P < 0.05). Patients in this operative group were more satisfied with cosmetic appearance and overall outcome than those in the conventional open reduction group.

Conclusions: Operative treatment with a LCP for clavicle shaft fractures can be used to obtain stable fixation. Particularly, MIPPO of displaced midshaft clavicular fractures resulted in a lower rate of dysesthesia, hypertrophic scarring, and a better cosmetic than conventional open...
Operative treatment of clavicle midshaft fractures

Introduction

Clavicle fractures are common injuries in adults, accounting for 5% of all fractures and 44% of all shoulder fractures [1–3]. Most of the clavicular fractures occur in the mid-shaft and about half are displaced. Furthermore, there is an increasing incidence of complex fracture patterns after high-energy trauma [4,5]. Clavicle midshaft fractures have classically been treated non-operatively. However, factors including severity of displacement, degree of comminution, and greater than 2 cm of shortening have been reported in the literature to predispose patients to unsatisfactory outcomes with non-operative treatment [6,7]. Because of these factors, there has been a trend toward operative treatment of clavicle midshaft fractures. There are various methods for treating clavicle midshaft fractures, such as intramedullary K-wires or elastic stable intramedullary nailing and plate fixation [6,8–12]. In particular, plate fixation can provide stable anatomical fixation and locking compression plate (LCP), which can be bent to the S-shaped curvature of the clavicle, are the most preferred [13].

Material and methods

Inclusion/exclusion

Inclusion criteria were: complete displacement; severe comminution; marked shortening of the clavicle (> 2 cm). Exclusion criteria were: pathological and open fracture; fracture in the proximal or distal third of the clavicle; inability to comply with follow-up; contraindication for surgery in general anesthesia; lack of consent.

Randomization

Between June 2006 and May 2008, 64 cases of open reduction and internal plate fixation were performed for clavicle mid-shaft fractures. The operative indications were complete displacement, severe comminution and marked shortening of the clavicle (> 2 cm). MIPPO and conventional open reduction surgery procedures with locking compression plate were used in 32 and 32 cases, respectively. The randomization schedule was done initially according to Vinzenz Smekal’s methods [14]. Fractures were classified according to Robinson’s classification [11].

In the MIPPO group, the mean follow-up period was 15 months (range, 12 to 24 months). There were 20 males and 12 females with a mean age of 40 years (range, 20 to 70 years). The cause of the injury was a traffic accident in 23 cases, fall down in four cases, a sport injury in five cases. There were 18 B1 type and 14 B2 type fractures according to Robinson classification [11]. The mean interval from injury to surgery was 7 days (range, 1 to 15 days).

In the conventional open reduction group, the mean follow up period was 15 months (range, 12 to 24 months). There were 20 males and 12 females with a mean age of 45 years (range, 18 to 69 years). The cause of the injury was a traffic accident in 25 cases, fall down in six cases, a sports injury in one case. There were 15 B1 type and 17 B2 type fractures. The mean interval from injury to surgery was 7 days (range, 1 to 15 days).

Operative technique

Under general anesthesia, the patient was positioned in a beach-chair semi-sitting position. The involved shoulder was prepared and draped.

In the MIPPO group, a small skin incision (approximately 3 cm) was centered over the fracture site. Larger branches of the identifiable supraclavicular nerves were identified and protected throughout the procedure; smaller branches were sacrificed at the surgeon’s discretion. The fracture site was identified, and the fracture was reduced. Comminuted fragments were secured with lag screws if possible. Next, a distal incision (approximately 1 cm) and a proximal incision (approximately 1 cm) were made approximately 2 cm lateral of the fracture site respectively. Each plate was contoured to the shape of the clavicle and placed in the anterosuperior position. The distal incision was the insertion site (Fig. 1). Fixation was performed following a reduction with minimal periosteal stripping. To obtain maximum fixation strength, three screws were used in the primary distal (in the distal incision) and proximal fragments (in the proximal incision), respectively (Fig. 2). Bone-grafting was not performed.

In the conventional open reduction group, an oblique incision (approximately 8–10 cm) was made over the fracture site. Larger branches of the identifiable supraclavicular nerves were identified and protected throughout the procedure; smaller branches were sacrificed at the surgeon’s discretion. Each plate was contoured to the shape of the clavicle. Fixation was performed following a reduction with minimal periosteal stripping. Three screws were used in the proximal and distal areas, respectively. Bone-grafting was not performed.

Postoperatively, the patients were given a simple sling for approximately 2 weeks, and pendulum exercise and active range of motion exercise were then started.

Main outcome measurements

For a radiological assessment, the bone union period was compared using radiographic evidence, such as callus...
formation and trabecular bridging across the fracture site. Radiographs were taken after 1 week, 3 weeks, 6 weeks, and again after 3 months and 6 months. For the clinical assessment, Assessment included standardized clinical evaluation and completion of the Constant shoulder score [15] and the Disability of the arm, shoulder and hand (DASH) score [16]. Statistical analysis was performed using SPSS ver. 14.0 (SPSS Inc., Chicago, IL, USA). An independent t-test and Chi² test were used. A P-value less than 0.05 was considered significant [17]. Postoperative complications were noted in both groups.

Results

Sixty-four patients volunteered to participate and signed written informed consent. All of them completed the study. Thirty-two patients were randomized to both the MIPPO and the conventional open reduction treatment groups, respectively. Demographic data are shown in (Table 1). The patients’ age, gender, cause of injury, fracture pattern, interval from injury to operation were not statistically different in the two groups (P > 0.05). The mean operative time was 60 min (range, 45 to 90 min) in the MIPPO group and 60 min (range, 45 to 90 min) in the conventional open reduction group, showing no notable intergroup differences (P > 0.05).

Bony union was achieved in all cases after surgery at an average of 12 weeks (range, 8 to 20 weeks) in the MIPPO group and 13 weeks (range, 8 to 24 weeks) in the conventional open reduction group, respectively, indicating no significant intergroup difference (P > 0.05). Patients returned to activity from injury on average at 14 weeks (range, 8 to 20 weeks) in the MIPPO group and 16 weeks (range, 8 to 24 weeks) in the conventional open reduction group, indicating no significant intergroup difference (P > 0.05). There were no non-unions or malunions. In the clinical assessment, the MIPPO group had no significantly superior Constant shoulder scores (Fig. 3a) or DASH scores (Fig. 3b) at all time-points (P > 0.05).

However, postoperative complications were noted in both groups. The complications in the open reduction group were dysesthesia in the area of the incision and directly below in 10 cases, hypertrophic scarring in five cases, painful shoulder in two cases and a limitation of shoulder motion in zero case. The complications in the MIPPO group were dysesthesia in two cases, no hypertrophic scarring, no painful shoulder, no limitation of shoulder motion were noted. Patients were specifically questioned about their satisfaction or dissatisfaction regarding the appearance of the shoulder (and incision, if applicable) at 1-year following the injury. Patients in the MIPPO group were more likely to be satisfied with the appearance of the shoulder (P < 0.005) (Table 2). Reasons for dissatisfaction in the MIPPO group included dysesthesia and the three incisions, while reasons for dissatisfaction in the conventional open reduction group included dysesthesia and hypertrophic scarring (Fig. 4).
more rapid union, excellent clinical outcomes, and lower complication rates in 132 patients with displaced clavicle fractures than non-operative treatments [22]. Hence, there has been increasing interest in surgical treatments with open reduction and internal fixation.

The operative methods for the treatment of clavicle midshaft fractures involve intramedullary K-wire fixation or Steinmann pin fixation or elastic stable intramedullary nailing and plate fixation. The procedures using the former two materials result in low resistance to torque, carry risks of pin loosening and infection, and require a long-term fixation period [23]. In addition, Elastic stable intramedullary nailing leads to good cosmetic and functional results. Patients profit from marked postoperative pain reduction and a rapid recovery of range of motion in the shoulder joint [24–26]. However, multifragmentary fractures or oblique fractures can lead to a telescoping of the fracture site. This leads to a postoperative length reduction. To prevent this complication, Elastic stable intramedullary nailing is only recommended for simple or displaced wedge fractures [27].

Open reduction and internal fixation with plates (plate osteosynthesis) is still the standard method for the surgical treatment of clavicular shaft fractures [28]. The goal of surgical treatment is the anatomic reduction with reconstruction of clavicular length and alignment of the shoulder girdle. To prevent early stress fracture of the implant, a fairly strong implant in comparison to the bone strength should be chosen. LCP have been preferred for plate osteosynthesis of the clavicle. The advantages of LCP include strong fixation due to locking between the screw and plate, and blood supply preservation due to minimal contact between plate and cortical bone [29,30]. When LCP are used to treat clavicle midshaft fractures, the risks of injury to the subclavian artery or brachial plexus could potentially be reduced because fixation can be achieved without the tip of the screw reaching the opposite bone cortex and periosteal stripping can be minimized to promote rapid union [31]. It is believed that the surgery time can be reduced using LCP because accurate plate contouring is not necessary and periosteal stripping could be minimized using self-tapping screws. Surgical treatment of displaced midclavicular fractures with locking compression plate, which can be shaped to match the shape of the clavicle, can be effective in the treatment of clavicle midshaft fractures. However, it remains some problem such as increased soft

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**Table 1** Demographic data of the patients.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIPPO group (n = 32)</th>
<th>Conventional group (n = 32)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Follow-up, range (mo)</td>
<td>15 (12–24)</td>
<td>15 (12–24)</td>
<td>1</td>
</tr>
<tr>
<td>Age, range (yr)</td>
<td>40 (20–70)</td>
<td>45 (18–69)</td>
<td>0.796</td>
</tr>
<tr>
<td>Case (%)</td>
<td></td>
<td></td>
<td>0.845</td>
</tr>
<tr>
<td>Traffic accident</td>
<td>23</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Fall down</td>
<td>4</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Sports injury</td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Type of fractures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type B1</td>
<td>18</td>
<td>15</td>
<td>0.446</td>
</tr>
<tr>
<td>Type B2</td>
<td>14</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Interval from injury to operation, range (day)</td>
<td>7 (1–15)</td>
<td>7 (1–15)</td>
<td>1</td>
</tr>
</tbody>
</table>

MIPPO: minimally invasive percutaneous plate osteosynthesis.

![Figure 3](image-url) In the clinical assessment, the minimally invasive percutaneous plate osteosynthesis (MIPPO) group had no significantly superior Constant shoulder scores (a) or DASH scores (b) at all time-points.

**Discussion**

The clavicle acts as a strut, which transfers power from the trunk to the arm. The clavicle is S-shaped with a medial convexity and a lateral concavity. The middle third is the thinnest part of the clavicle and is located directly under the skin with no soft tissue or muscle attachment. Thus, it is vulnerable to direct and indirect trauma. This explains the high frequency of fractures in the middle third.

Fractures of the clavicular shaft were considered to be a domain of non-operative treatment for a long time. This dogma was based on the studies conducted by NEER CS and Rowe CR in the 1960s [18,19]. However, recent studies have shown that the rate of malunion and non-union after non-operative treatment might be much higher than previously shown. Subjective contentment with the results of non-operative treatment is not uniformly high [20,21]. In 2007, the Canadian Orthopaedic Trauma Society reported that internal fixation with plates resulted in
Table 2 Results of patients treated with fixation using MIPPO technique and conventional open reduction.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>MIPPO group (n = 32)</th>
<th>Conventional group (n = 32)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OP time, range (min)</strong></td>
<td>60 (45–90)</td>
<td>60 (45–90)</td>
<td>1</td>
</tr>
<tr>
<td><strong>Bone union period range (wk)</strong></td>
<td>12 (8–20)</td>
<td>13 (8–24)</td>
<td>0.618</td>
</tr>
<tr>
<td><strong>Returned to activity range (wk)</strong></td>
<td>14 (8–20)</td>
<td>16 (8–24)</td>
<td>0.322</td>
</tr>
<tr>
<td><strong>Complication (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyesthesa</td>
<td>2</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Hypertrophic scarring</td>
<td>0</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Painful shoulder</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Motion limitation</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><strong>Satisfaction with appearance</strong></td>
<td>30</td>
<td>25</td>
<td>0.004∗</td>
</tr>
</tbody>
</table>

MIPPO: minimally invasive percutaneous plate osteosynthesis.  
* P < 0.05.

Figure 4 Post-operation. A. Minimally invasive percutaneous plate osteosynthesis (MIPPO): little scarring. B. Conventional open: hypertrophic scarring.

tissue stripping, infections, extensive scars, supraclavicular nerve injury.

Minimally invasive percutaneous plate osteosynthesis (MIPPO) has been widely applied to treat long bone shaft fractures in recent years because of its technical advantages and satisfactory clinical outcomes [32–34]. However, the MIPPO technique has been rarely used until now in the treatment of clavicle fractures. MIPPO technique uses indirect reduction methods and allows stabilisation of clavicle midshaft fractures while preserving the vascularity of the soft tissue envelope and supraclavicular nerve. Classically in MIPPO techniques fracture site is not exposed nor comminution reduced and fixed. So if comminuted fragments are fixed, it’s no more really a MIPPO technique. To our knowledge, this is the first study with LCP and the MIPPO technique in the treatment of clavicle midshaft fractures. In our study group, the MIPPO technique with the application of LCP offered an ideal combination in terms of bone fixation and soft-tissue sparing.

In summary, operative treatment with a LCP for clavicle shaft fractures can be used to obtain stable fixation. Particularly, MIPPO of displaced midshaft clavicular fractures resulted in a lower rate of dyesthesia, hypertrophic scarring, and a better cosmetic than conventional open reduction, although the functional outcomes (Constant and DASH) were no different between the two groups. Overall satisfaction was higher in the MIPPO group than conventional open reduction group.

**Disclosure of interest**

The authors declare that they have no conflicts of interest concerning this article.

**References**


