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ORIGINAL ARTICLE • SHOULDER - FRACTURES

Management of acute unstable distal clavicle fracture with a modified coracoclavicular stabilization technique using a bidirectional coracoclavicular loop system

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Abstract
Background Fracture of the distal clavicle is not uncommon. Despite the vast literature available for the management of this fracture, there is no consensus regarding the gold standard treatment for this fracture.
Purpose To assess the clinical and radiographic outcomes and complications of acute unstable distal clavicle fracture when treated by a modified coracoclavicular stabilization technique using a bidirectional coracoclavicular loop system.
Methods Thirty-nine patients (32 males, 7 females) with acute unstable distal clavicle fractures treated by modified coracoclavicular stabilization using the surgical technique of bidirectional coracoclavicular (CC) loops seated behind the coracoacromial (CA) ligament were retrospectively reviewed. Mean follow-up time was 35.7 months (range 24–47 months). The outcomes measured included union rate, union time, CC distances when compared to the patients' uninjured shoulders, and the Constant and ASES shoulder scores, which were evaluated 6 months after surgery.
Results All fractures displayed clinical union within 13 weeks postoperatively. The mean union time was 9.2 weeks (range 7–13 weeks). At the time of union, the CC distances on the affected shoulders were on average 0.9 mm (range 0–1.6 mm) longer than the unaffected shoulders. At 6 months after surgery, the Constant and ASES scores were on average 93.4 (72–100) and 91.5 (75–100), respectively. No complications related to the fixation loops, musculocutaneous nerve injuries, or fractures of coracoid or clavicle were recorded. One case of surgical wound dehiscence was observed due to superficial infection. Enlargement of the clavicle drill hole without migration of the buttons was observed in 9 out of 16 cases at a follow-up time of at least 30 months after the original operation.
Conclusions Modified CC stabilization using bidirectional CC loops seated behind the CA ligament is a simple surgical technique that naturally restores stability to the distal clavicle fracture. It also produces predictable outcomes, a high union rate, good to excellent shoulder function, and a low complication rate. The buttons and suture loops were routinely removed in a second operation in order to prevent late stress fracture of the clavicle.

Keywords Unstable distal clavicle fracture · Coracoclavicular stabilization · Clavicle nonunion

Introduction

Fracture of distal clavicle is not uncommon, and it accounts for 15–20 % of all clavicle fractures [1, 2]. Type II, classified by Neer [3, 4], is often unstable and significantly displaces due to the disruption of the coracoclavicular (CC) ligament. A high incidence of nonunion is reported, with the distal clavicle nonunion comprising up to 30 % of all clavicle fracture nonunions [5, 6]. The treatment options of this fracture include both conservative and operative management. Conservative treatment consists of sling immobilization and can be used for stable and nondisplaced fractures. However, for most displaced fractures,

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surgical fixation is recommended [7–9]. Although a variety of surgical techniques have been proposed [3, 4, 6–12] including plate-screw fixation, hook plating, k-wires, tension band wiring, CC screw, CC sling using tendon or synthetic suture, and arthroscopic TightRope (Arthrex, Naples, FL, USA), there is no consensus regarding the gold standard treatment for this fracture [13]. Several studies have reported complications related to fixation techniques, including metal breakage and migration and adverse effects such as clavicle and coracoid fracture [11, 12, 14–17]. This fracture has three main problematic characteristics. The first is that the distal fragment is usually small, comminuted, and consists of soft cancellous bone. The second is that the fracture is located near the acromioclavicular (AC) joint. The last is that there is upward displacement of the proximal fragment due to the huge deforming force caused by rupture of the CC ligament. Stable fixation is always difficult. The objective of this study was to assess the clinical and radiographic outcomes and complications of acute unstable distal clavicle fractures (type IIb) when treated by modified CC stabilization using the surgical technique of bidirectional CC loops seated behind the coracoacromial (CA) ligament.

Materials and methods

Between January 2008 and May 2014, 54 patients with unstable distal clavicle fractures Neer's classification type IIb were retrospectively reviewed. Fifteen cases were excluded due to associated fractures ($n = 4$), significant head injuries ($n = 2$), late presentation (>21 days) ($n = 6$), and loss of follow-up ($n = 3$). A total of 39 acute cases (acute defined as ≤21 days) were enrolled in this study (Table 1). Thirty-two patients were male and seven were female, with a mean age of 37.5 years (range 17–52 years). The mean follow-up period was 35.7 months (range 24–47 months). The mechanism of injuries included road traffic accidents ($n = 19$), sports-related accidents ($n = 12$), and falls ($n = 8$). All patients were scheduled for modified CC stabilization using bidirectional CC loops seated behind the CA ligament by one surgeon (Kanchanatawan W). The operations were performed within a time period of 3–20 days from the date of injury (average 12.5 days). All patients were assessed using clinical status and radiographic evaluation at follow-up every 3–4 weeks until clinical union was observed. The outcomes were measured by union rate, union time, the functional shoulder score at 6 months after surgery (Constant score [18] and ASES score [19]), and the difference of the CC distance of the affected shoulder to the patient's uninjured shoulder measured in a plain radiograph at time of clinical union. The complications were recorded.

Table 1 Demographic data

	n	Percent (%)
Sex		
Male	32	82.1
Female	7	17.9
Age		
Mean (SD)	37.5	7.7
Side of injury		
Right	23	59
Left	16	41
Dominant side		
Dominant	27	69.2
Nondominant	12	30.8
Mechanism of injury		
Road traffic	19	48.7
Sports related	12	30.7
Falls	8	20.6

Surgical technique

Under general anesthesia, the patients were placed in the beach chair position (at 60°). A 6-cm vertical incision was made from the tip of the coracoid to the clavicle. The deltoid fibers were split to expose the tip and base of the coracoid as well as the CA ligament. Four strands of no. 5 FiberWire (Arthrex, Naples, FL, USA) were passed around the coracoid base from the medial to lateral side by a suture retriever (mini-open rotator cuff repair instrument, blue color, Conmed, Linvatec, USA) (Fig. 1a). In order to avoid injury to the musculocutaneous nerve, subperiosteal dissection at the medial side of coracoid base was recommended [20]. All sutures stayed behind the CA ligament and at least 1.4 cm posterior to the tip of the coracoid (range 1.4–1.7 cm). A 2.5-mm hole was drilled 1 cm medial to the fracture. Fluoroscopy was used to confirm bicortical purchase, which was particularly important for oblique fracture. A second hole was then placed 1.5–2 cm medially (Fig. 1b). Two loops (4 strands) of no. 5 FiberWire were passed through each clavicle hole strand by strand, assisted by a two-way shuttle (Fig. 1c). The FiberWire loops were then passed through the medial hole of the buttons (Endobutton, Smith & Nephew, MA, USA). The fracture was manually reduced, and one loop over the lateral button was tied. Once complete reduction was confirmed visually and fluoroscopically, the other three loops were also tied tightly (Fig. 1d).

Postoperative care

Six weeks of using an arm sling was recommended postoperatively. Controlled passive mobilization of the

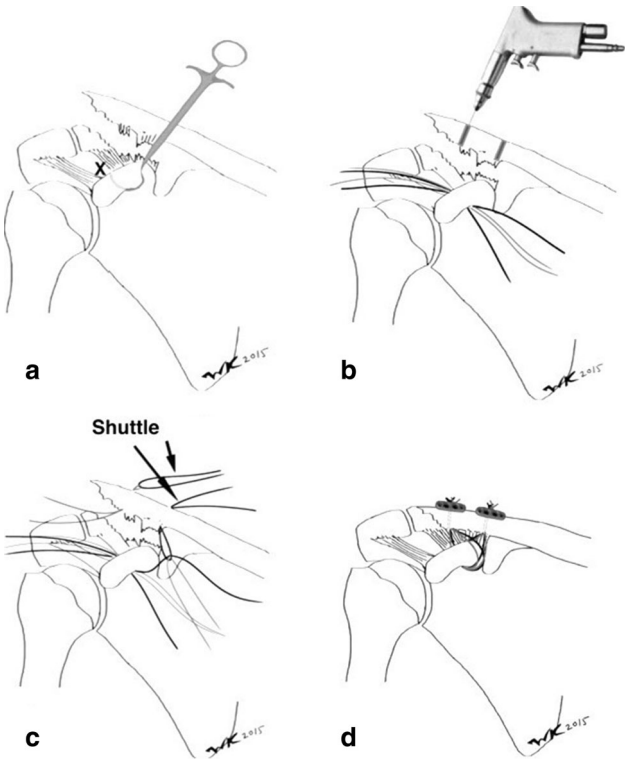

Fig. 1 **a** Suture retriever was passed around the coracoid base and exited posterior to the CA ligament (*X*). **b** The 2.5-mm clavicle hole was placed 1 cm medial to the fracture, and the second hole was placed 1.5–2 cm medially. **c** The two-way shuttle delivered four strands of no. 5 FiberWire strand by strand through the relatively small clavicle hole. **d** FiberWire loops were tied over buttons after achieving complete reduction

shoulder was allowed on the second day after surgery. Active assisted exercise was allowed after the third week.

Results

All fractures displayed clinical union within 13 weeks postoperatively. The mean union time was 9.2 weeks (range 7–13 weeks). Once the bony union was observed, the differences in CC distances were measured in a plain radiographs. The distances in the affected shoulders were found to be an average of 0.9 mm (range 0–1.6 mm) longer than the unaffected shoulders (Fig. 2a, b). At 6 months after surgery, the Constant and ASES scores were on average 93.4 (72–100) and 91.5 (75–100), respectively. No complications related to the fixation loops, musculocutaneous nerve injuries, or fractures of the coracoid or clavicle were recorded. One surgical wound dehiscence was observed due to superficial infection (N.Y. 52-year-old male). Local wound care and oral antibiotics were continued for an additional 10 days in this patient. The wound healed without additional surgical management. Enlargement of the clavicle drill hole without migration of the buttons was observed in 9 out of 16 cases at a follow-up time of at least 30 months after the original operation. The buttons and suture loops were removed under local anesthesia in a second operation (Fig. 3a, b).

Discussions

Unstable distal clavicle fracture retains high risk of nonunion; thus, surgical fixation is widely accepted as the treatment of choice. Although there are a variety of surgical options reported in the literature [3, 4, 6–12], none of the fixation techniques have been proposed as the "Gold Standard" of treatment for acute unstable distal clavicle fracture. There are several factors that contribute to the instability and complications of fixation. First of all, the distal fragment is usually small, comminuted, and consists of soft cancellous bone. Secondly, the fracture is located near the AC joint. Lastly, there is upward displacement of the proximal fragment due to the huge deforming force caused by the ruptured CC ligament. Various operative techniques treated distal clavicle fractures have been described. These include direct fracture repair (k-wire fixation, tension band wiring, plate and screws, hook plating), CC interval stabilization (CC screw, CC suspension using tendon or synthetic suture, arthroscopic TightRope), and combined direct fracture repair with CC interval stabilization. The rigid fixation used in the direct fracture repair and the CC screw fixation have high potential for complications related to fixation failure, metal breakage, and migration [10, 14, 16]. The hook plate was reported to have complications of secondary clavicle fracture, acromial erosion, impingement, and rotator cuff injury [9–11, 21]. According to a meta-analysis by Stegeman et al. [17], these major complications when using the hook plate had an 11-fold increased risk compared to intramedullary fixation and had a 24-fold increased risk when compared to suture anchoring. They recommended avoiding use of the hook plate due to the number and severity of the complications. Most of the metal fixation methods used in the direct fracture repair group usually required second operations for implant removal. Current surgical techniques have focused more on CC interval stabilization [22–25]. These types of surgical techniques were developed with the aim of providing anatomic augmentation of the CC ligaments using both open and arthroscopic approaches. However, arthroscopic TightRope requires a high level of arthroscopic skill and has also had serious reported complications related to fracture of the coracoid and clavicle [25]. Some combined techniques were reported successful outcomes such as tension band wiring combined with suture anchors or a flip button [22, 23] or use of a T-plate combined with a TightRope [24].

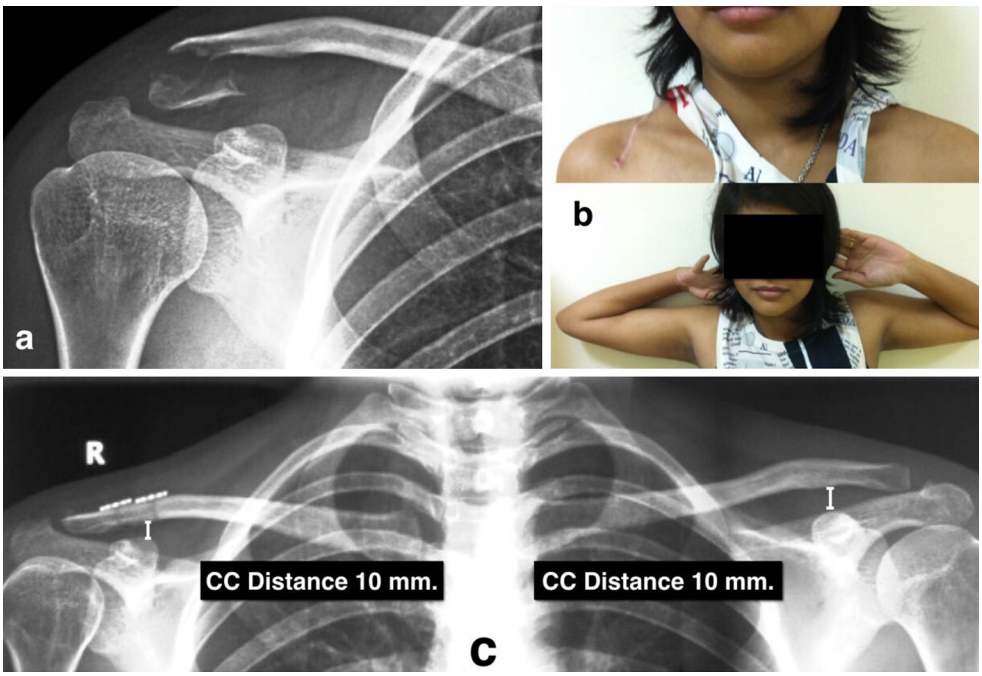

Fig. 2 **a** A 22-year-old female with an acute unstable distal clavicle fracture. **b** The patient's clinical status and radiograph at follow-up 20 weeks after surgery

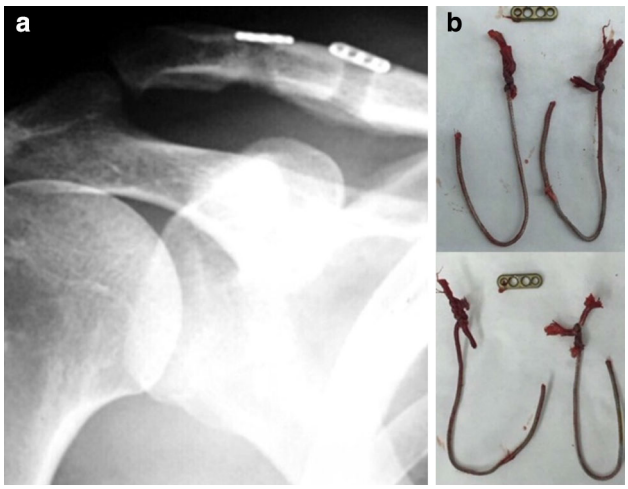

Fig. 3 **a** Enlargement of the clavicle drill holes without button migration at a follow-up time of 36 months. **b** The FiberWire loops and buttons were removed

In this study, acute (≤21 days) unstable distal clavicle fractures were treated by modified CC stabilization using bidirectional CC loops seated behind the CA ligament. The aim of this technique was to restore a strong and stable anatomic CC interval that permitted indirect anatomic reduction in the fracture and biological healing of the ruptured native CC ligament. The advantages of this technique are the CC loops seated close to the axis of clavicle in sagittal plane, so it minimizes anterior instability. The CA ligament prevents slippage of the CC loops during shoulder movement. To avoid stress fracture, smaller clavicle holes were used and the coracoid was looped instead of drilled. The bidirectional CC loops also provided control in both the coronal and sagittal planes, similar to the native conoid and trapezoid ligaments [26]. With a minimally invasive indirect reduction, fracture healing was expected to be earlier than with alternate direct fracture repair technique.

Limitations of this study include a small number of study subjects and that only midterm (follow-up period range 24–47 months) results were assessed. Any possible late complications such as stress fracture of coracoid, clavicle, or AC joint arthritis cannot be detected. There was no control group in this study because all clavicle fractures Neer type IIb in our services were treated by only one surgical technique (modified CC stabilization using bidirectional CC loops seated behind the CA ligament).

Conclusions

The ideal surgical technique that can be considered as the gold standard to treat an acute unstable distal clavicle fractures should provide stable fixation that allows the fracture to heal and have minimal complications. Modified CC stabilization using bidirectional CC loops seated behind the CA ligament is a simple surgical technique that

naturally restores stability to the distal clavicle fracture and produces predictable outcomes, a high union rate, good to excellent shoulder function, and a low complication rate. In order to prevent late stress fracture of the clavicle, it was recommended to routinely remove the buttons and suture loops under local anesthesia.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interests.

Informed consent Informed consent was obtained from all individual participants included in the study. Approval for this study was given by the Committee on human related to research involving human subjects at Lerdsin General Hospital.

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