

Original Article

Using suture and locking anatomical bridging plate to fix comminuted mid-shaft clavicle fractures with intramedullary nail assistance in reduction

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Received April 24, 2015; Accepted June 21, 2015; Epub July 15, 2015; Published July 30, 2015

Abstract: Background: During conventional plate fixation of comminuted midshaft fracture of the clavicle, wedge-shaped fragments often need to be fixed with lag screws. A new procedure, which included intramedullary K-wire assistance in reduction, binding fragments by suture, and eventually bridging plate fixation, was compared with conventional techniques. Hypothesis: This new procedure is more effective than the conventional techniques, and the fixation of free fragments using lag screws is not necessary. Material and methods: This was a retrospective study of 60 patients from August 2008 to March 2013 with comminuted midshaft clavicular fractures with wedge-shaped fragments. Seventeen patients were treated with conventional plate fixation, and the wedge-shaped fragments were fixed using lag screws (LSPF). Another 43 patients were treated with the new procedure, including intramedullary K-wire assistance in reduction, binding of wedge-shaped fragments by suture, and bridging plate fixation (KSB). Patients were followed for an average of 13 months and radiographs were used to observe fracture healing. Shoulder function was assessed using the Constant Score System (CSS). Results: There was no significant difference in bone healing time and shoulder function between the two study groups. The operating time for KSB was significantly shorter than conventional LSPF ($P=0.014$). Fractures healed in 14.9 ± 5.59 weeks for the conventional LSPF group and in 13.6 ± 3.59 weeks for the KSB group. One patient treated with conventional LSPF had implant failure and underwent a second operation. Conclusions: KSB is a simple and effective procedure for comminuted midshaft clavicular fractures. The wedge-shaped fragments in comminuted midshaft clavicular fractures do not always need to be fixed by lag screws and the new procedure described is an effective treatment alternative. Level of evidence: Level IV.

Keywords: Clavicle, K-wire, screw plate fixation, midshaft

Introduction

Approximately 80% of clavicle fractures are located midshaft [1], and most are displaced comminuted fractures with wedge-shaped fragments. For these patients, nonunion rates with conservative treatment can be as high as 15% [2] making them candidates for surgery. Conventional lag screw plate fixation (LSPF) is still the gold standard [3] surgical method, but use of intramedullary fixation is increasing [4]. For midshaft clavicular fractures with wedge-shaped fragments, one of the principal techniques in conventional LSPF uses lag screws to fix the wedge-shaped fragments as much as possible. Historically, this technique has achieved satisfactory results in most cases.

However, some nonunions still occur in patients treated with conventional LSPF. To reduce surgical complications, we modified the conventional method by first using intramedullary K-wires to aid in reduction of the main fracture, then bound the wedge-shaped fragments together by suture, and eventually fixed the main fracture fragments by a bridging plate (KSB). The hypothesis of this study is that the new KSB procedure is simpler and more effective than the conventional LSPF method.

Materials and methods

General information

From August 2008 to March 2013, 72 patients with comminuted midshaft clavicular fractures

Fixation of comminuted midshaft clavicle fracture

Table 1. Patient information

	Lag screw plate fixation (n=17)	KSB (n=43)	P-value
Mean age at surgery (range) (year)	41.7 (19-79)	44.6 (13-86)	0.615
Ratio of male to female, n/n	13/4	25/18	0.184
Ratio of right/left side of injury, n/n	6/11	14/29	0.839
Time from injury to operation (mean \pm SD) (day)	3.35 \pm 1.50	3.73 \pm 2.50	0.564
Ratio of B1 fracture to B2/B3 fracture	4/13	11/32	0.869
Ratio of patients injured by car accident to high falling	2/15	11/32	0.183

SD: standard deviation. KSB: K-wire assistance in reduction, binding of wedge-shaped fragments by suture, and bridging plate fixation.



Figure 1. A 24-year-old male patient treated with KSB. A. AP view of the left shoulder, showed left clavicle fracture with OTA of type B2.1, B. Beach chair position, C. Temporary fixation using K-wire, D. The wedge-shaped fragment was reduced and bound by three pieces of suture, E. Fluoroscopy showed satisfactory reduction, F. Placement of bridging plate. Locking screws were placed as far as possible away from the fracture zone, G. Fluoroscopy confirming satisfactory implant position, H. AP film of the left shoulder at 12 weeks postoperation, confirming complete fracture healing.

(15B2 fractures in Orthopedic Trauma Association (OTA) classification [5]) accepted operation, and 60 of them were followed up com-

pletely. The average age of the 60 patients was 43.5 y (13–86 y), and all accepted surgery within an average 3.6 days from injury. Among the

Fixation of comminuted midshaft clavicle fracture

Table 2. Clinic outcomes

	Lag screw plate fixation (n=17)	KSB (n=43)	P-value
Operation time (mean ± SD, min)	80.6±17.13	70.5±12.48	0.014*
Bone healing time (mean ± SD, week)	14.9±5.59	13.6±3.59	0.280
Constant evaluation score (mean ± SD)	93.6±3.74	91.6±6.16	0.216
Second surgery to remove implant, n (%)	6 (35.29)	19 (44.19)	0.529
Nonunion, n (%)	1 (5.89)	0 (0)	0.109

*: significantly different. SD: standard deviation.

study cohort, 9 had B2.1-type fractures (i.e., spiral fracture with 1 wedge-shaped fragment), 6 had B2.2-type fractures (i.e., short oblique fractures with 1 wedge-shaped fragment), and 45 had B2.3-type fractures (i.e., fractures with 2 or more wedge-shaped fragments and main fracture fragment can directly contact after reduction). Forty-seven patients were injured in falls, ten patients were involved in traffic accidents, and three patients were injured in high-level falls. Seventeen patients were treated with conventional lag screw plate fixation (LSPF) and the other forty-three patients were treated with the new KSB procedure. Details of the two study groups are summarized in **Table 1**.

Surgical methods

Patients were in beach chair position under cervical plus brachial plexus anesthesia, or general anesthesia. In the KSB group, the posterior lateral edge of the shoulder, upper arm, and forearm were disinfected to guarantee adequate passive motion of the shoulder during operation. A transverse incision on the clavicle surface was used in both groups.

Conventional LSPF: If the wedge-shaped fragment was large enough, it was reduced to one of the main fracture ends by clamp first, and then fixed by a lag screw. This essentially changed the comminuted fracture to a simple fracture, and another lag screw was used to fix the remaining simple fracture line. After this, a reconstruction plate which neutralizes and protects was placed to fix the main fracture ends. If the wedge-shaped fracture fragments were relatively small, a reconstruction plate or anatomical plate was used fix the main fracture end first, which was first reduced by clamp. After this, the wedge-shaped fragments were fixed by lag screws. The internal fixation position was confirmed by fluoroscopy.

Intramedullary K-wire fixation, binding wedge-shaped fragment by suture, and bridging plate fixation (KSB): First, a double-tip intramedullary K-wire with a diameter of 2 mm or 2.5 mm was inserted retrograde into the medullary cavity of the proximal main frag-

ment until its distal end was at the same level with the tip of the proximal main fragment. Then, the upper arm was elevated upwardly and backwardly by the assistant to achieve reduction of the distal and proximal main fragment. Once the cortexes contacted, the K-wire was pushed laterally along distal cavity, and pierced out of the skin from the upper edge of the posterior horn of the acromion to maintain reduction. Then, any free, wedge-shaped fragments were reduced and bound together by #5 non-absorbable sutures. Attention was paid to the periosteum and soft tissue to protect them during the procedure. Next, a long anatomical plate (Weigao Co., China or GE Healthcare., USA) was placed on the upper surface of the clavicle. One locking screw was placed into the most distal and proximal holes respectively, and then the K-wire was removed. Two other locking screws were placed from lateral to middle at the distal and proximal ends of the plate, respectively. The distal and proximal ends should then have had three locking screws each. If the intramedullary K-wire affected the placement of the first screw in the most proximal holes, a short, single cortical locking screw was placed first and then eventually replaced with a bi-cortical locking screw. The internal fixation position was confirmed by fluoroscopy (**Figure 1**).

Postoperative management

The shoulder was immobilized with a sling after surgery. On the second postoperative day, patients started passive shoulder activities, mainly external rotation and abduction, 10~15 times in the morning, afternoon, and evening. Four weeks after operation, the sling immobilization was discontinued and patients were allowed to perform daily living activities except heavy lifting and weight-bearing activities. Patients were followed up at 4, 8, 12, and 24 weeks post-operation. Radiographs were ac-

Fixation of comminuted midshaft clavicle fracture

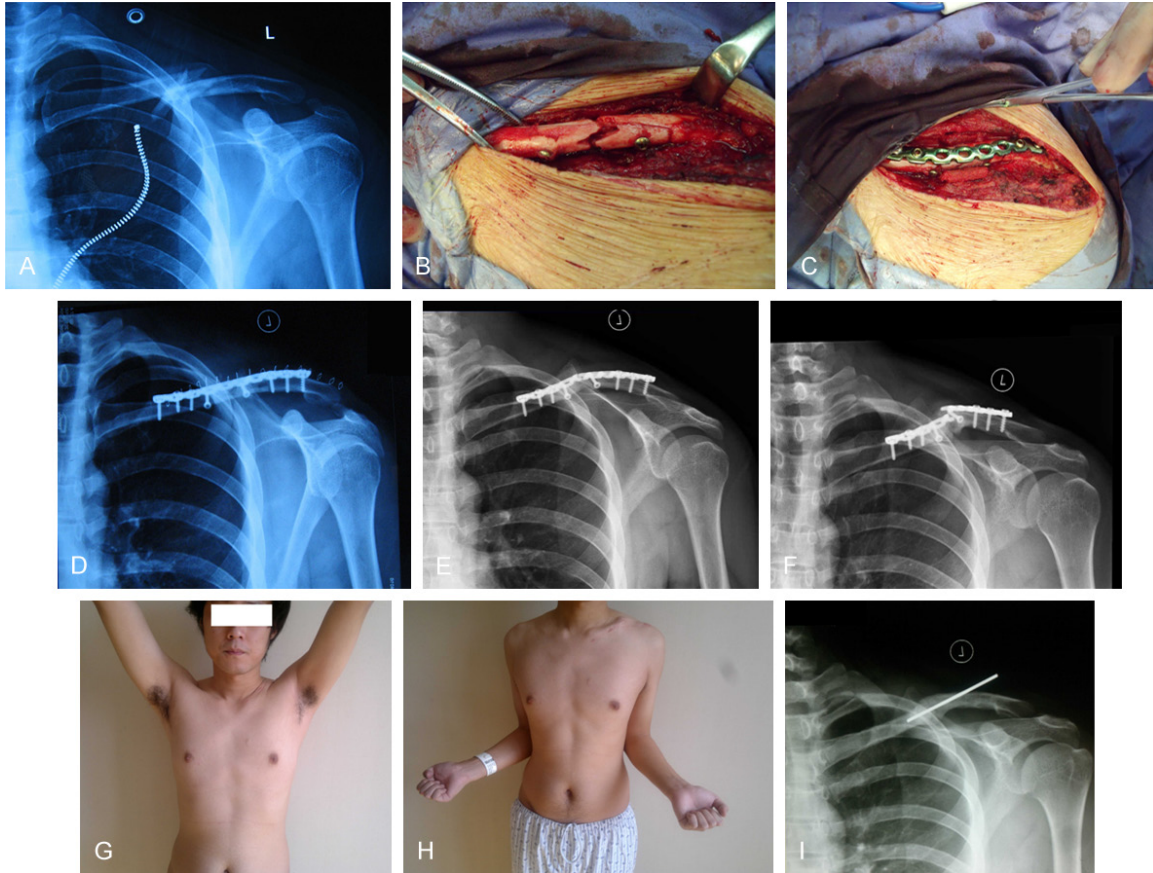


Figure 2. A 28-year-old male patient treated with conventional open reduction and lag screw plate fixation who suffered from failure. A. AP view of the left shoulder showed left clavicle fracture with OTA of type B2.3 with two fragments, B. During first operation, the free wedge-shaped fragments were fixed using two lag screws, C. Fixation of main fragment with reconstruction plates, and autogenous bone graft was performed, D. Postoperative AP film showing satisfactory reduction and fixation, E. 24 weeks after first surgery, AP film showed implant failure, F. 24 months after first surgery, AP film showed hypertrophic nonunion, G, H. Normal shoulder function, I. AP view at 4 months after second surgery that removed the original implant and fixed the nonunion by one intramedullary K-wire showed satisfactory bone healing.

quired during each follow-up examination and patients were allowed to perform heavy work after complete fracture healing. Shoulder function was assessed at follow-up using the Constant Score Assessment [6].

Statistics

Microsoft Excel 2003 and SPSS 17.0 for Windows were used to analyze the differences in information between patients treated with conventional LSPF and KSB. Chi-square and t-tests were performed with $P < 0.05$ indicating statistical significance.

Results

There was no significant difference in healing time and postoperative Constant score be-

tween the two groups (**Table 2**). The operation time was 70.5 ± 12.48 min for patients treated with KSB, significantly less than 80.6 ± 17.13 min for patients treated with LSPF ($P < 0.05$). The ratio of performing a second surgery to remove the internal implant was not significantly different between the two groups ($P = 0.529$).

In the LSPF group, one patient had nonunion complications. This patient was a young man who had suffered a B2.3 midshaft clavicular fracture due to a sports injury and was the only case that required an autogenous ilium graft (**Figure 2**).

At 12 weeks post-operation, radiographs showed the fracture was almost healed, and the patient was allowed to perform normal activities. However, 24 weeks post-operation,

the patient suddenly felt unwell. Radiographs showed implant failure though the patient refused a second operation at that time. Two years after the first operation, the patient requested removal of the implant for aesthetic reasons. Examination suggested hypertrophic nonunion with satisfactory function, but the patient still refused a second plate fixation of the fracture and bone graft. After further communication, he accepted the second surgery to remove the original, ruptured implant, and fix the hypertrophic nonunion solely with a K-wire, which is easy to remove. Four months after the second surgery, union occurred, and the patient achieved complete function.

In the KSB group, no nonunions were observed. Although 17 patients accepted a second surgery to remove the implant, only two patients insisted on a second surgery for aesthetic reasons.

Discussion

Historically, conservative treatment for displaced, midshaft clavicular fractures was the dominant method and is still recommended by some physicians today [7, 8]. However, most doctors believe that surgery can improve outcomes, and has been verified through a multicenter prospective RCT study [2] and a meta-analysis [9]. In reference to LSPF or intramedullary fixation techniques, there is some uncertainty regarding which is better [10-12]. Some retrospective studies and meta-analyses have confirmed that both methods exhibit positive and negative characteristics [9, 13]. Intramedullary fixation has the advantage of being minimally invasive, which could protect soft tissue and obtain better aesthetics. However, because of poor stability during rotation and keeping clavicle length, intramedullary fixation can cause implant drifting, breakage, and nonunion. The reported incidence of complications varies greatly, and nonunion rates can be as high as 15/58 with intramedullary fixation [4, 14]. These complications have lead most doctors to believe the risk of nonunion in intramedullary fixation is relatively high, and prefer to use LSPF for comminuted midshaft clavicular fractures.

Literature has shown conventional LSPF to be the standard of care for comminuted midshaft clavicular fractures [3]. However, nonunion and infection can still occur with this method [2,

15]. In addition, skin bulging increases the rate of second surgery; reportedly as high as 10/86 to remove the implant [8]. To improve implant irritation with the traditional LSPF method, two major modifications have been made. First, anatomical plates have replaced conventional reconstruction plates [2, 16], and are becoming more accepted. Second, these plates are now positioned on the anterior surface rather than the superior surface of the clavicle. Although biomechanical experiments have confirmed the fixation strength with the new position [17], few doctors are willing to try this technique [18]. However, no matter the design of the plate and where it is positioned, avoiding damage to the blood supply of the wedge-shaped fragments mainly relies on the technique of the surgeon.

Comminuted midshaft clavicular fractures typically have at least one wedge-shaped fragment, though most have two or more. In our study, 45/60 patients had two or more free fragments (type B2.3). For patients with wedge-shaped fragments, one of the principle techniques of conventional LSPF uses lag screws to fix the free wedge-shaped fragments. This procedure not only increases operation time, but also affects the blood supply to the fragments, because muscles on the midshaft of clavicle are not firmly attached through tendons, but instead are loosely attached to the periosteum. Placing lag screws in these types of injuries may lead to soft tissue stripping and damage of the blood supply of the fragments, which may be the main reason of failure. In addition, if surgeons place screws very close to the fracture site, there could be concentrated stresses, resulting in implant failure. Furthermore, long, straight reconstruction plates used in conventional LSPF are often not a perfect match, and repeated precontouring also increases the likelihood of implant failure.

To avoid complications and improve outcomes, we modified the conventional LSPF techniques. First, we performed an indirect reduction of the main fracture ends by elevating the upper arm, and then used intramedullary K-wires to temporarily fix main fracture ends to maintain the reduction. The best diameter of K-wire was found to be 2.0 mm or 2.5 mm. Because of the thin and irregular cavity, K-wires with diameters greater than 2.5 mm do not match well to midshaft, and make the main fracture ends separate. If the K-wire diameter is less than 2.0 mm,

Fixation of comminuted midshaft clavicle fracture

it is too flexible and cannot maintain reduction of the main fracture ends. Intramedullary K-wire fixation has been shown to facilitate temporary reduction and simplify surgery, though verification of the percutaneous placement needed additional fluoroscopy [19]. Second, we bound the free wedge-shaped fragments together to protect soft tissue attachment and blood supply, instead of using lag screws. Because of the placement of the K-wire, reduction of free fragments can be extremely simple, and can be completed by gentle flipping. Strong, non-absorbable sutures were used to bind the free fragments together to ensure maximal contact with main fracture ends and maintain reduction. Third, anatomical locking plates of appropriate length were used to bridge the main fracture. A locking bridging plate with at least nine holes was used to increase the working length, and reduce the risk of stress concentration. This plate has been shown to have improved efficiency in the healing of these fractures [20].

The sequence of positioning and number of locking screws used must be carefully thought through using the new KSB method. One locking screw should first be placed in the most distal hole, and then another added in the proximal hole of the plate. Because of the S-shaped structure of clavicle, an intramedullary K-wire generally does not affect the placement of the first two screws. After removal of the K-wire, the remaining screws at both the proximal and distal ends should be positioned as far as possible from the fracture site. In the instance of three double cortical screws in each side of the plate, there is no need to place more screws, even if empty holes remain. No additional screws are needed in this instance because of the inherent stability in the KSB technique, and additional screws could lead to stress concentration.

Minimally invasive percutaneous plate osteosynthesis (MIPPO) methods are also gaining interest in the treatment of comminuted midshaft clavicular fractures [19, 21]. Some problems exist with these methods, including incomplete reduction of free wedge-shaped fragments, leading to longer healing times. The average healing time has been reported as 15.6 weeks [19] for MIPPO techniques, compared with 13.6 weeks in our study.

The proposed KSB procedure does have some drawbacks, as any surgical method does. First, placement of a long plate needs a long incision,

which may make trauma more apparent. To improve the aesthetic outcome and reduce scarring, we used intradermic sutures. Second, because of the irregular shape of the clavicle, long anatomical plates are impossible to be perfectly matched, and can cause skin bulging. Because locking screws and bridging plates function as internal fixators, a perfect match was never sought out and the plates were not precontoured. In the KSB group, our rate of second surgery (2/40) to remove implants for aesthetic reasons and/or implant irritation was lower than that in the literature (10/86) [8]. It is worth mentioning that patient psychology and surgeon's preference are the main reasons for second surgery to remove implants in China, so our rate of second surgery is higher in both study groups than that reported in the literature [8]. It should also be noted that there is uncertainty regarding the effectiveness of the KSB technique for type B3 fractures.

The authors do recognize the retrospective nature of this study and the limitations of a relative small sample size. Future work is needed to conduct a prospective, randomly controlled study with a longer follow-up to fully analyze and understand clinical outcomes.

Conclusions

For comminuted midshaft clavicular fractures with wedge-shaped fragments, lag screw fixation may affect the blood supply of the fragments. Using intramedullary K-wires to aid reduction can make surgery simple, and binding of free fragments with sutures can protect soft tissue. Bridging plate osteosynthesis was satisfactory with these fixation techniques. Therefore, it is not necessary to perform strong fixation with lag screws between wedge-shaped fragments in comminuted midshaft clavicular fractures.

Acknowledgements

This study was funded by Chinese National Ministry of Science and Technology 973 Project (No.2014CB542201) and 863 project (No. SS2015AA020501), the ministry of education innovation team (IRT1201), the National Natural Science Fund (31271284, 31171150), the Educational Ministry New Century Excellent Talents Support Project (No. BMU20110270) and Peking University People's Hospital R&D Fund (RDB2014-01).

Fixation of comminuted midshaft clavicle fracture

Disclosure of conflict of interest

None.

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