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Original article

Outcomes and function of conoid ligament on the basis of postoperative radiographic findings of arthroscopic stabilization for the distal clavicle fractures

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ABSTRACT

Purpose: Distal clavicle fractures are divided into three types according to Neer's classification. These fractures are usually treated with a sling to immobilize the upper extremity, however, the treatment of type 2 fractures remain controversial. We focused on the anatomical basis of these fractures in which disruptions in the conoid ligament led to the distraction between the two bony fragments. In this study, we report an arthroscopic procedure for conoid ligament reconstruction and its therapeutic outcomes, and discuss the function of the reconstructed conoid ligament.
Hypothesis: Arthroscopic conoid ligament reconstruction alone is sufficient to retain the posteriorly displaced proximal fragment of the clavicle in its reduced position.
Materials and methods: A retrospective cohort study were conducted on 18 patients with type 2 distal clavicle fractures. Arthroscopic techniques were performed with the patients in the beach chair position. Dacron artificial ligament® was used to reconstruct the conoid ligament, and the internal bone fixation materials included an EndoButton® on the coracoid process side and a screw with a spiked washer on the clavicle side. Preoperative assessment was performed via plain radiography or three-dimensional computed tomography to evaluate the displacement of the proximal fragment. Although the displacement was superoposterior in all the cases, the acromioclavicular joint was maintained. The mean duration of postoperative follow-up was 2 years and 5 months.
Result: There were no injury-related complications during the surgery and bony union was achieved within 3 months after surgery. Evaluation using 3DCT also showed that the preoperative superoposterior displacement of the proximal fragment of the clavicle was immediately reduced postoperatively, and this reduced position was maintained until the final follow-up examination.
Conclusions: We achieved good results by indirectly reducing fractures of the distal clavicle with conoid ligament damage using the minimally invasive surgical technique of arthroscopic conoid ligament reconstruction. Anatomical reconstruction of the conoid ligament might stabilize not only the superior displacement of the displaced proximal fragment of the clavicle but also its posterior displacement.
Study design: Case series with no comparison study.
Level of evidence: 4, retrospective cohort study.

1. Introduction

According to Neer's or Craig's classification, a type 2 or type 2b fracture with rupture of the conoid ligament is a type of distal clavicle fracture in which the proximal fragment of the clavicle is significantly displaced superoposteriorly to the acromioclavicular joint, with a high likelihood of instability [1–3]. Numerous internal fixation materials, for which successful surgical outcomes have been reported, have been suggested for the reduction and fixation of such fractures. However, given the possibility of complications caused by internal fixation materials and the frequency of postoperative pseudarthrosis, surgical treatment does not always provide results superior to those of conservative treatment [4]. Because conoid ligament rupture is greatly involved in the pathology of this type of fracture, we performed indirect fracture reduction by arthroscopically reconstructing the conoid ligament [5], rather than open reduction. Although conoid ligament function has been well studied in terms of the biomechanics of the acromioclavicular

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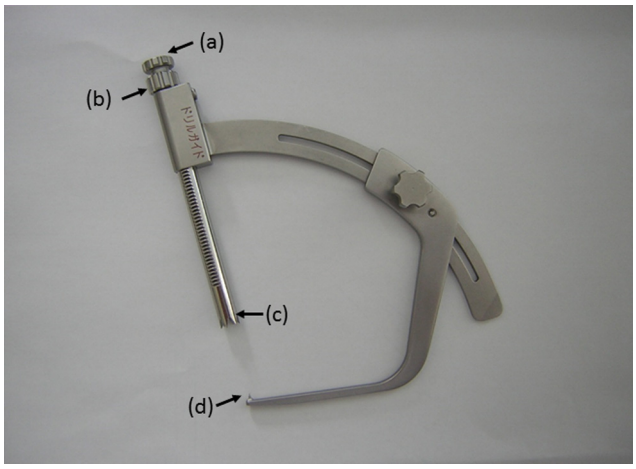

Fig. 1. Original target device (a: drill sleeve with 2 mm diameter, b: compression rod with 4 mm diameter, c: tube spike for the clavicle, d: blade hook for the coracoid process).

joint, there have been only a few reports on its role in stabilizing the posterior displacement of the clavicle [6]. In this paper, we report our surgical procedure for conoid ligament reconstruction and its therapeutic outcomes, with a discussion on the function of the reconstructed conoid ligament. Moreover, we used preoperative and postoperative diagnostic imaging to investigate whether arthroscopic conoid ligament reconstruction alone is sufficient to retain the posteriorly displaced proximal fragment of the clavicle in its reduced position.

2. Materials and methods

A retrospective cohort study was conducted on 18 patients with type 2 distal clavicle fractures. They (16 male and 2 female) underwent arthroscopic conoid ligament reconstruction for a type 2 or 2b fracture and had been followed up for at least 2 years postoperatively. Mean age at surgery was 43.5 years (range: 35–62 years), mean time from injury to surgery was 4.1 days (range: 2–7 days), and mean postoperative follow-up was 2 years 5 months (2 years to 5 years and 2 months). The right and left sides were affected in 9 and 9 patients, respectively. Of these 18 patients, in 7 patients who were treated before in 2011, a bone tunnel was made under fluoroscopy for conoid ligament reconstruction; whereas for the subsequent 11 patients, surgery was performed using a conoid ligament reconstruction target device developed in our department (Fig. 1). Preoperative assessment was performed via plain radiography or three-dimensional computed tomography (3DCT) to evaluate the displacement of the proximal fragment; in all cases the displacement was superoposterior but the acromioclavicular joint was maintained (Figs. 2 and 3). CT scan and three-dimensional reconstruction were performed on a four-slice CT scanner (Ziostation; Ziosoft. Inc., Tokyo, Japan) with a slice thickness of 1 mm.

Approval for the study was given by Ethics Committee (Tokyo Medical University; number of approbation: 2908) and informed consent was obtained from all patients.

3. Surgical methods

Arthroscopic procedure was performed with the patients in the beach chair position. A 30° oblique arthroscope was used with the posterior portal for endoscopic observation and the anterior portal as the working portal. Operations were performed only within the glenohumeral joint. Dacron artificial ligament® (Smith & Nephew Endoscopy, Andover, MA) was used to reconstruct the conoid ligament, and the internal bone fixation materials included an EndoButton® (Smith & Nephew Endoscopy, Andover, MA)on the coracoid process side (Fig. 4) and a screw with a spiked washer on the clavicle side. First, a shaver was used to remove the anterosuperior joint capsule and soft tissue to avoid damage to the superior and middle glenohumeral ligaments and the subscapularis tendon. The soft tissue was then curetted from the base of the coracoid process with a radiofrequency device until the bone cortex was exposed (Fig. 5a). The aim of this technique was to ensure the firm fixation of the EndoButton® to the coracoid process side and to prevent it from sinking. To achieve this, it was important not to leave any tissue between the fixation material and the bone. Next, a bone tunnel was made in the bone from the conoid tubercle of the clavicle towards the base of the coracoid process to enable the conoid ligament to be reconstructed along its anatomical course based on our cadaver study [7]. For the first 7 patients, a k-wire, 1.6 mm in diameter, was inserted using a combination of fluoroscopy and arthroscopy. For the other 11 patients, the k-wire was inserted using a target device developed in our department (Fig. 5b, c). A 4.5-mm-diameter hollow drill was inserted using this k-wire as a guide and the holes in the clavicle and coracoid process were enlarged. At this point, a guide pin with an aperture was inserted through the hole in the bone from the conoid tubercle of the clavicle toward the coracoid process (Fig. 5d). A suture thread was passed through this aperture before the pin was inserted and the thread was drawn out of the anterior portal. The suture was sewn to the Dacron artificial ligament® attached to the EndoButton® outside the joint; and

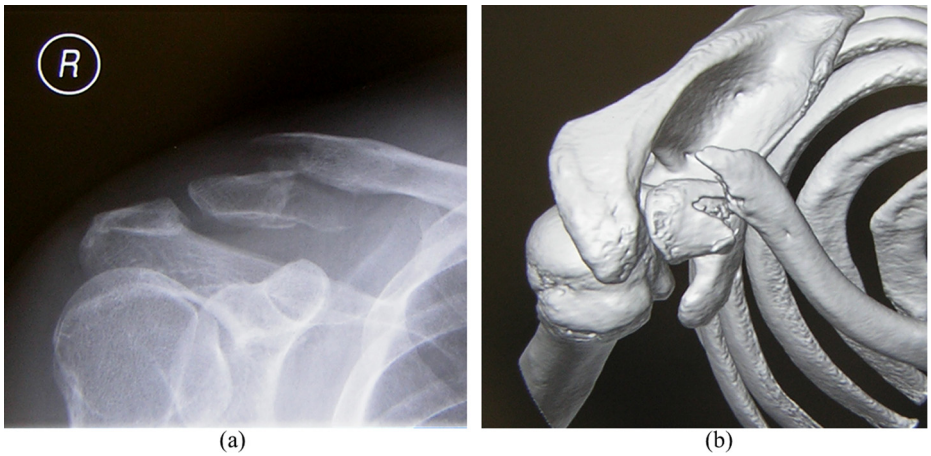

Fig. 2. 64-years-old man. Preoperative assessment was performed via plain radiography (a) or three-dimensional computed tomography (b) to evaluate the displacement of the proximal fragment. The displacement was superoposterior but the acromioclavicular joint was maintained.

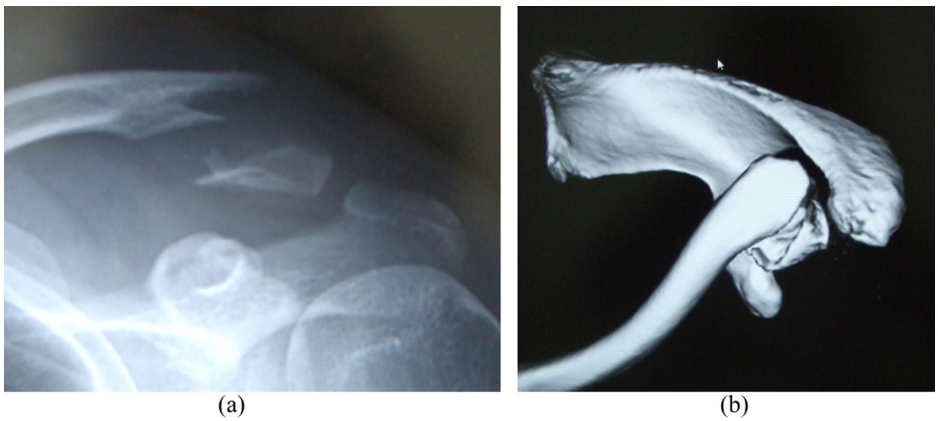

Fig. 3. 43-years-old man. Preoperative assessment was performed via plain radiography (a) or three-dimensional computed tomography (b) to evaluate the displacement of the proximal fragment. The displacement was superoposterior but the acromioclavicular joint was maintained.

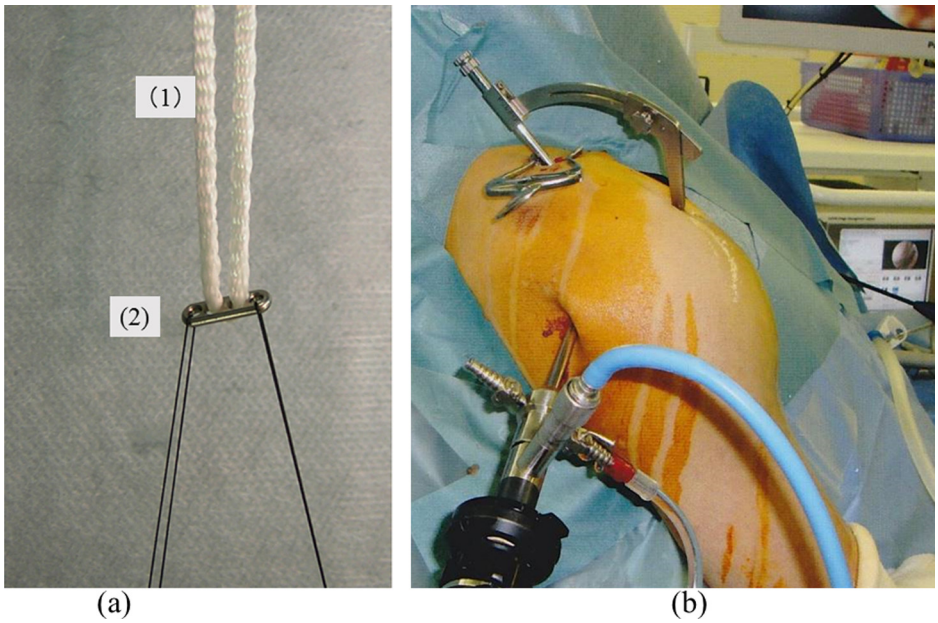

Fig. 4. (a) Preparations of a graft for the conoid ligament (1: artificial ligament®, 2: EndoButton®), (b) Setting of original target device. Insertion of k-wire from the conoid tubercle of the clavicle to the base of coracoid process.

the guide pin was passed sequentially through the tunnels in the coracoid process and clavicle before being withdrawn from the clavicle side (Fig. 5e). When the guide pin was drawn out of the clavicle, the Dacron artificial ligament® was pulled to the outside of the clavicle. Arthroscopy was used to confirm that pulling on the artificial ligament® fixed the EndoButton® to the undersurface of the base of the coracoid process (Fig. 5f). Finally, at the same time as it was confirmed arthroscopically that the EndoButton® was firmly fixed in a good position, the artificial ligament® was pulled until the distal fragment of the clavicle could be seen to be in the reduced position, under fluoroscopy. A screw with a spiked washer was then used to fix the artificial ligament® to the top of the clavicle. Postoperative treatment consisted of immobilization in the Desault position immediately postoperatively, which was replaced by a sling on postoperative week 2; all external immobilizations were removed in week 3. Range of motion and rotor cuff function exercises were then started, but the patient was only permitted to carry heavy weights with the affected arm after 3 months.

4. Results

The mean time required to prepare the bone tunnel for conoid ligament reconstruction was 1 hour 10 min (58 min to 1 hour and 32 min) for the first 7 patients treated via a combination of fluoroscopy and arthroscopy. However, the use of the target device reduced this time remarkably to a mean of 8 min (5 to 10 min) for the 11 other patients.

There were no injury-related complications during the surgery and bony union was achieved within 3 months after surgery in all cases (Fig. 6). No patient complained of shoulder joint pain or fatigue at the final follow-up. The therapeutic results were 24 to 30 (mean: 29.4) points according to UCLA scoring system. Concerning the range of motion at final examinations, forward flexion ranged from 160 to 180 degrees (mean; 174), abduction ranged from 160 to 180 degrees (mean; 170), external rotation with arm down ranged from 30 to 70 degrees (mean; 46), internal rotation ranged from L3 to Th6 (mean; Th10), and horizontal adduction ranged from 125 to 140 degrees (mean; 134).

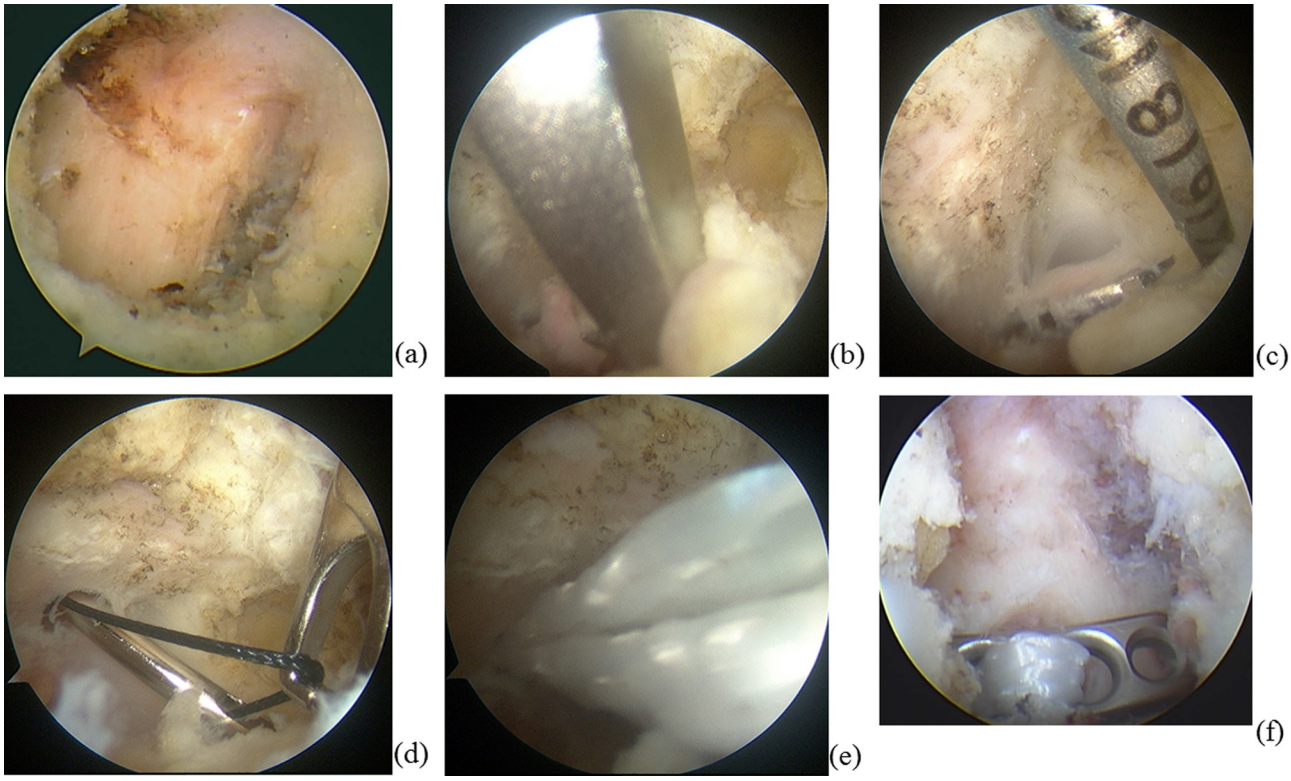

Fig. 5. During operations. (a) A shaver was used to remove the anterosuperior joint capsule and soft tissue. The soft tissue was then curetted from the base of the coracoid process with a radiofrequency device until the bone cortex was exposed. (b) A bone tunnel was made in the bone from the conoid tubercle of the clavicle towards the base of the coracoid process using a target device. (c) A k-wire, 1.6 mm in diameter, was inserted along its original anatomical course. (d) A guide pin with an aperture was inserted through the hole in the bone from the conoid tubercle of the clavicle toward the coracoid process. (e) The suture was sewn to the Dacron artificial ligament® attached to the EndoButton® outside the joint. The guide pin was passed sequentially through the tunnel in the coracoid process and the tunnel in the clavicle. (f) Arthroscopy was used to confirm that pulling on the artificial ligament® fixed the EndoButton® to the undersurface of the base of the coracoid process.

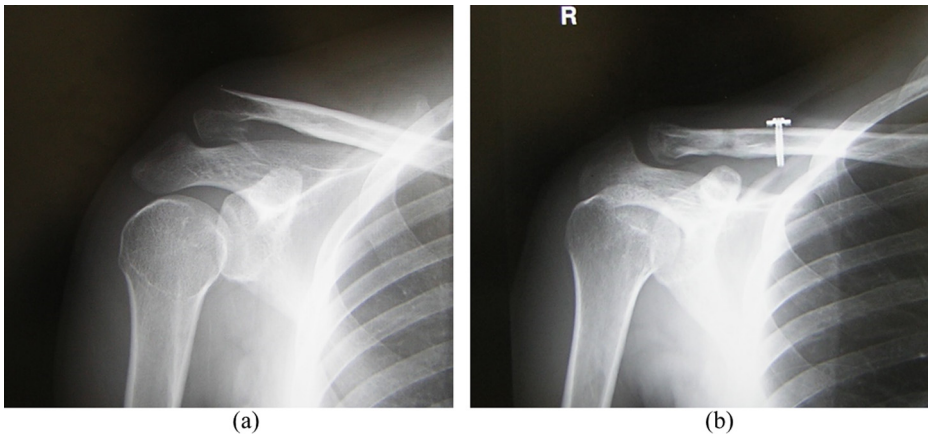

Fig. 6. Case presentation (38 year-old man). (a) Preoperative radiographic findings, (b) Postoperative radiographic findings (2 years after surgery).

Evaluation using plain radiography did not reveal any coracoclavicular ligament calcification, osteoarthritic changes of the acromioclavicular joint, displacement or sinking of the internal fixation materials, or enlargement or erosion of the bone tunnel in the clavicle or coracoid process by the reconstructed ligament. Evaluation using 3DCT also showed that the preoperative superoposterior displacement of the proximal fragment of the clavicle reduced immediately postoperatively, and this reduced position was maintained until the final follow-up examination (Fig. 7).

5. Discussion

Distal clavicle fractures are injuries that are commonly encountered in everyday clinical practice, but in Neer type 2 or Craig type 2b fractures, the restraining effect of the coracoclavicular ligament on the proximal fragment of the clavicle is lost, meaning that this bone easily becomes unstable. Several corrective surgical procedures have been devised. Numerous recent reports have described the use of a hook plate or locking plate to achieve firm fixation of the fracture site by open direct plating [8,9]. However,

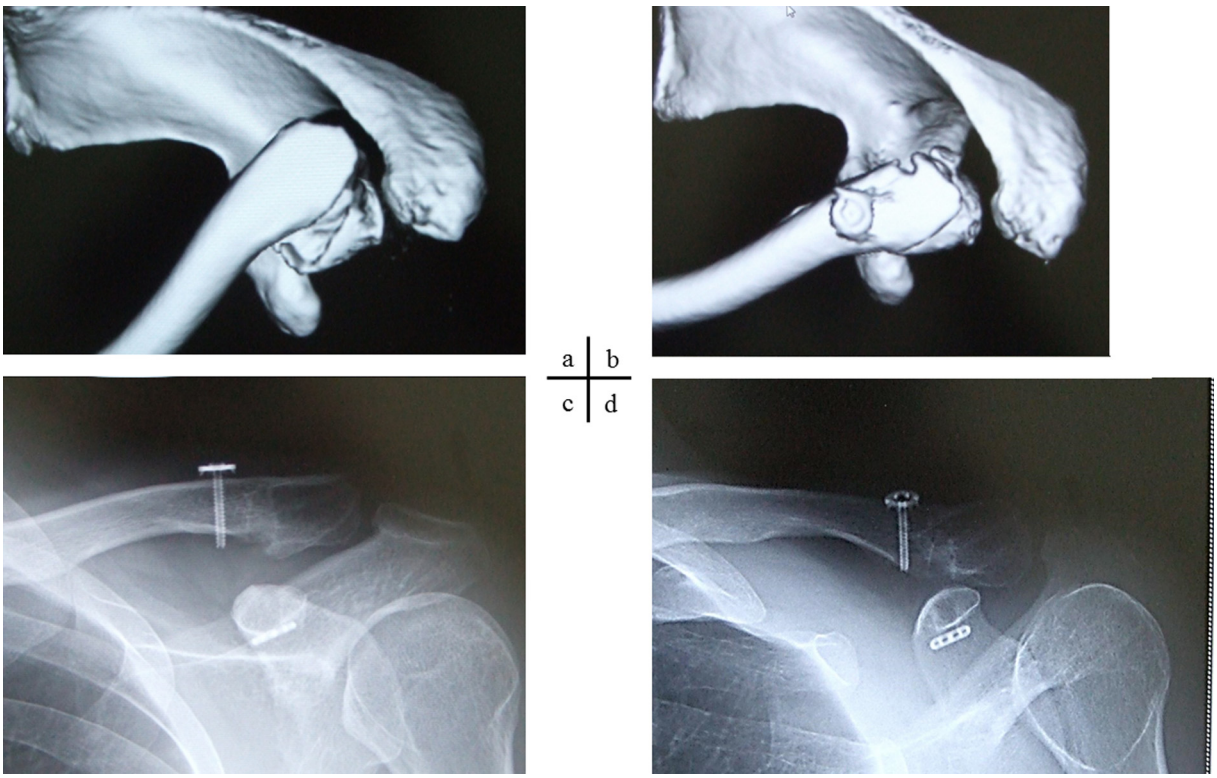

Fig. 7. Case presentation (42 year-old man). (a) Preoperative findings of 3DCT, (b) Postoperative findings of 3DCT (2months after surgery), (c) and (d) Postoperative findings of plain radiographs (2 years and 3 months after surgery).

the use of a hook plate entails the risk of complications, including bone destruction such as erosion of the acromion by the hook [10]; subacromial impingement syndrome, resulting from mechanical irritation [10]; and eventually, rotator cuff damage. Many studies recommend early removal of the internal fixation materials after bony union has been achieved [11].

In 1997, Goldberg et al. reported the use of coracoclavicular ligament reconstruction via open surgery using Dacron artificial ligament to treat a distal clavicle fracture without exposing the fracture site [12]. Since that paper was published, cases of the use of indirect fracture reduction for Neer type 2 or Craig type 2b fractures by repairing the coracoclavicular ligament rather than exposing the fracture have been reported. If it is possible to repair only the damaged ligament without exposing the fracture site, this means that the surgery can be performed arthroscopically; and some surgical procedures have been reported. These include suture anchoring [13,14], ligament reconstruction using the TightRope system [15,16], cerclage to bind the clavicle to the coracoid process [17,18], and ligament reconstruction using a Dog Bone Button [19,20] to compensate for the disadvantages of the TightRope system. Apart from ligament reconstruction by suture anchoring, anatomical repair of the conoid ligament which is part of the pathology of this fracture was not exactly performed. When the TightRope system or a Dog Bone Button is used, the device that fixes the reconstructed ligament in place is located on the undersurface of the body of the coracoid process and the superior surface of the clavicle, and this does not reproduce the anatomical course of the conoid ligament. The reconstructed ligament is vulnerable to stress during posterior rotation of the clavicle when the shoulder joint is raised. The same is true for the cerclage method, in which the coracoclavicular ligament is considered as a single ligament for the purpose of repair. The suture anchor method, however, enables anchor insertion so that it follows the anatomical course of the conoid ligament, but the anchor insertion point is difficult to observe arthroscopically. It may thus be difficult to create a reconstructed conoid ligament that follows its anatomical course using previously reported techniques for arthroscopic coracoclavicular ligament repair. The procedure that we described in this paper reconstructs the conoid ligament based on the anatomical structure of the coracoclavicular ligament reported in 2010 from a systematic cadaver study [7]. Because we initially treated the first 7 patients using a fluoroscopically guided free-hand technique, it took over 1 hour to create the bone tunnel needed for conoid ligament reconstruction, but the use of a target device shortened the operative time to less than 10 minutes.

However, there are doubts as to whether arthroscopic conoid ligament reconstruction can stabilize the translation of the posteriorly displaced proximal fragment of the clavicle. No study has investigated the role of the conoid ligament in fractures of the distal clavicle. Therefore, we investigated the function of the conoid ligament in the acromioclavicular joint on the basis of previous biomechanical studies. Fukuda et al. [21] reported that the conoid ligament functions to restrict anterior or superior translation, and posterior rotation of the clavicle; Debski et al. [22,23] reported that the conoid ligament functions to restrict anterior or superior translation of the clavicle; and Mazzocca et al. [6] reported that the conoid ligament functions to restrict superior or posterior translation of the clavicle. Although all of these authors agree that the conoid ligament functions to restrict the superior translation of the clavicle, whether it has any other function in stabilizing translation is unclear, perhaps because of differences in the research methodology. Because the anatomical course of the conoid ligament runs from the base of the coracoid process to the conoid tubercle, reconstructing it so that it follows its original course might reduce or stabilize the displacement of the posterior margin of the clavicle to a line extending from the posterior margin of the base of the coracoid process in the sagittal plane. Therefore, anatomical reconstruction of the conoid ligament might stabilize not only the superior

displacement of the displaced proximal fragment of the clavicle but also its posterior displacement. In fact, postoperative plain radiography and 3DCT revealed good reduction of the posterosuperiorly displaced proximal fragment of the clavicle in all cases.

Our study suggests that reconstruction of the conoid ligament along its original anatomical course may stabilize the posterosuperiorly displaced proximal fragment of the clavicle. However, further biomechanical studies are required to confirm whether the conoid ligament functions to restrict the posterior translation of the clavicle.

6. Conclusions

We achieved good results by indirectly reducing fractures of the distal clavicle with conoid ligament damage using the minimally invasive surgical technique of arthroscopic conoid ligament reconstruction. The use of a target device developed in our department reduced the operative time and enabled the conoid ligament to be reconstructed along its anatomical course with greater accuracy.

Disclosure of interest

The authors declare that they have no competing interest.

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Contribution

All authors approved the final version of the manuscript, and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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