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Original article

Diagnostic arthroscopy in the treatment of minimally displaced lateral humeral condyle fractures in children

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ABSTRACT

Introduction: In minimally displaced pediatric lateral humeral condyle fractures, plain radiography cannot be used for accurate differential diagnosis of the cartilage lesion, and other imaging methods have demerits in their accuracy and their accessibility. The purpose of this study was to investigate the usefulness of arthroscopy to diagnose cartilage displacement in minimally displaced fractures.

Materials and methods: Nine children with minimally displaced lateral humeral condyle fractures, an average of 6.6 years old, underwent combined arthroscopy and fixation surgery. Percutaneous fixation was performed with nondisplaced articular surface according to the arthroscopic findings, while in case of displaced fracture under arthroscopy, open fixation was preferred. The difference between the arthroscopic and radiographic findings was investigated.

Results: Articular surface could be arthroscopically visualized in all patients. Under arthroscopy, cartilage hinges were maintained in seven cases and disrupted in two. Nondisplaced cartilage disruption was noted in one of these two cases, and percutaneous fixation was performed. A displaced articular surface was noted in the other one, where the patient underwent open surgery. At the last follow-up, an average of 14.7 months postoperatively, union and wide range of motion had been achieved without any complications.

Conclusion: Diagnosis of fracture displacement by merely using plain radiography was considered to be insufficient for minimally displaced cases. Diagnostic arthroscopy aided in the appropriate selection of either a percutaneous or open fixation method.

Level of evidence: Level IV, therapeutic case series.

1. Introduction

Lateral humeral condylar fractures (LHCFs) in children comprise not only physeal fractures such as Salter-Harris type IV [1] but also unique intra-articular fractures. The fracture line either does or does not pass through the cartilaginous articular surface, indicating whether the cartilage hinge at the distal humeral epiphysis is disrupted. The presence or absence of the cartilage hinge determines the stability of an LHCF [2], and treatment options vary accordingly. However, the cartilage lesion cannot be evaluated by conventional radiography owing to a lack of visibility. A metaphyseal lesion has been substituted for an epiphyseal chondral lesion to infer cartilage displacement on plain radiography. A metaphyseal fracture displacement $\geq$ 2 mm on radiography has been widely adopted as the indicator for surgical treatment, instead of conservative treatment [3–5]. Disagreement between the radiographic decision and the real articular surface may lead to unpredictable complications such as redisplacement after initial cast immobilization, delayed union, nonunion, or non-anatomical fixation with restriction of range of motion (ROM), or elbow deformity by physeal disturbance [6–8]. In our department, surgical treatment using a combination of diagnostic arthroscopic visualization of the cartilage lesion and fixation using wires or screws has been performed for minimally displaced LHCFs. This article presents the preliminary clinical results of nine patients with minimally displaced LHCFs treated with diagnostic arthroscopy and fixation. The hypothesis of this article is whether or not the arthroscopy diagnosing can differentiate the fracture types of pediatric minimally displaced LHCFs and aid in selection of the adequate operative methods.

2. Materials and methods

This study was approved by the review board of our hospital, and the patients' parents gave informed consent prior to participation.

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Table 1
Demographics of the nine patients with minimally displaced pediatric lateral humeral condyle fractures.

Case	Age	Gender	Injured side	Finnbogason classification	Days to operation	Associated injury
1	3	Male	Right	B	3	–
2	11	Male	Left	B	7	–
3	2	Male	Left	B	7	–
4	8	Female	Left	C	2	–
5	9	Male	Left	B	5	Medial column fx
6	5	Male	Left	B	9	–
7	11	Male	Right	B	5	–
8	6	Female	Left	C	6	–
9	4	Male	Right	B	6	–

					Final ROM	
A/S finding	Jakob classification	A/S time (minutes)	Fixation method	F/u (months)	Flexion (degrees)	Extension (degrees)
CC	1	18	PF	24	148	15
CC	1	19	PF	11	145	10
CC	1	22	PF	12	145	20
CC	1	17	PF	12	150	15
CC	1	20	PF	20	140	10
CC	1	15	PF	12	145	10
NCD	2	4	PF	5	125	15
CC	1	17	PF	24	145	20
DC	2	20	ORIF	12	138	10

fx: fracture; A/S: arthroscopy; CC: cartilage continuity; NCD: nondisplaced cartilage discontinuity; DC: displaced cartilage; PF: percutaneous fixation; ORIF: open reduction and internal fixation; f/u: follow-up; ROM: range of motion.

A total of nine pediatric patients with minimally displaced LHCFs were prospectively recruited between January 2010 and July 2013. LHCFs with minimal displacement (< 2 mm) diagnosed by 3R plain radiography (anteroposterior, lateral, and external oblique) were indicated for the combined arthroscopy and fixation surgery. Nondisplaced or evidently fragment-rotated LHCFs were excluded. We classified the fractures according to the minimally displaced fracture specific classification by Finnbogason et al. [6]: type A, the fracture does not reach the epiphyseal cartilage (this was considered to be nondisplaced in the present study and was excluded); type B, the fracture is observed all the way to the epiphyseal cartilage with a lateral gap; and type C, the gap is as wide, or almost as wide, medially as it is laterally.

The operation was performed in a lateral position, with the affected extremity suspended, so that all of the following methods could be performed: arthroscopy, percutaneous fixation, and open reduction and internal fixation (ORIF). Arthroscopy for the posterior articular surface was performed using the soft spot portal (as defined the center of the triangular area formed by the olecranon, the radial head, and lateral epicondyle). If necessary, the posterolateral portal (as defined by the lateral margin of the triceps at the level of the olecranon tip) was added. A 2.7 mm, 30° arthroscope was inserted through the soft spot portal, and the intraarticular hematoma or swollen synovium was resected through the posterolateral portal, which enabled direct observation of the posterior articular surface. According to the arthroscopic findings, either percutaneous fixation or ORIF was selected. When the cartilage hinge was not disrupted or a smooth articular surface was maintained with only a linear cartilage crack, percutaneous fixation was performed using Kirschner wires or a cannulated screw. ORIF was performed using the posterolateral approach when the articular surface was broken with disruption of the hinge. All the procedures of arthroscopy were performed by seniors (K.T. and J.N.) specialized in hand surgery. A long arm cast was applied for six weeks postoperatively, followed by wire removal and active ROM exercise.

We examined the feasibility of the arthroscopic diagnosis, i.e., the presence of a cartilage hinge and articular displacement, the differences between preoperative radiographs and intraoperative arthroscopic findings, and procedure-related complications. Clinical results at the final follow-up were also reviewed, including ROM, elbow deformity, radiographic results, and late complications.

3. Results

The average age of the patients was 6.6 years (range: 2–11 years). Using the Finnbogason classification, seven patients had type B fractures, and two patients had type C fractures. One patient (case 5) had associated injuries — a nondisplaced fracture of the medial column of the distal humerus (Table 1).

The articular surface could be arthroscopically visualized in all patients, via a single portal without any other procedure in two patients and via double portals in seven patients. The fracture line of the trochlear could also be assessed by directing the scope toward medial via the soft spot portal. The average time for arthroscopic diagnosis was 16.9 min (range: 4–22 min) (Table 1).

Under arthroscopy, seven patients had nondisplaced cartilage hinges, and two patients, who were diagnosed with a Finnbogason type B fracture, had disrupted cartilage hinges. Of these two patients, one (case 7) had a nondisplaced linear fracture and the other (case 9) had a displaced articular surface (Fig. 1). Accordingly, percutaneous fixation was performed in eight cases, and ORIF was performed only in case 9. There were no intraoperative complications.

The patients were followed for an average 14.7 months (range: 5–24 months). At the final follow-up, the average ROM was 142 degrees of flexion (range: 125–150 degrees) and 14 degrees of hyperextension (range: 10–20 degrees). Radiographically, bone union was obtained in all cases. Although follow-up periods of some cases were short, there were no late complications, such as wound problems, infection, avascular necrosis, elbow deformity, or growth disturbances (Table 1).

4. Discussion

In 1975, Jakob examined the mechanisms of LHCFs using pediatric cadavers and classified the fractures depending on the cartilage hinge and displacement (Fig. 2) [2]. Under this classification, LHCFs are divided into three stages: stage 1 is an incomplete type with a fracture line descending from the lateral side that does

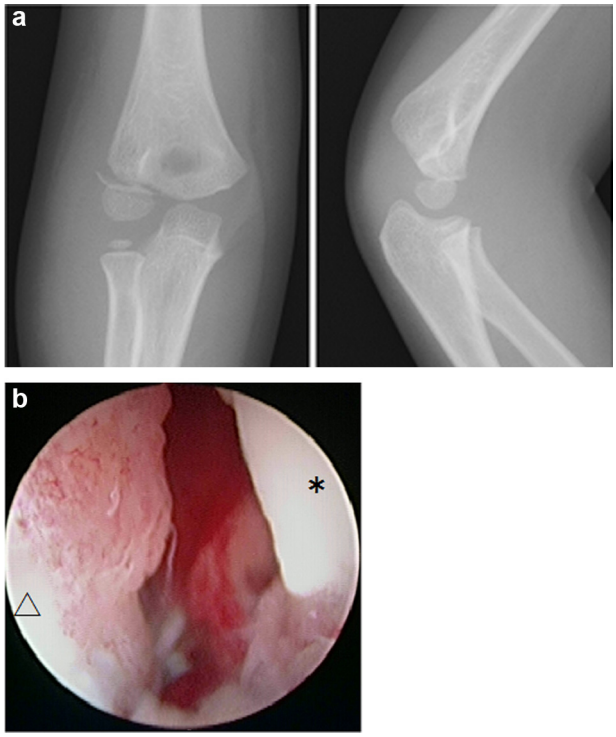

Fig. 1. Findings of case 9. a. Anteroposterior and lateral views of initial radiography showing a Finnbogason type B fracture. b. Arthroscopy of the right elbow revealing displacement of the articular surface (asterisk: the fragment of the lateral condyle; arrowhead: medial border of the lateral condyle).

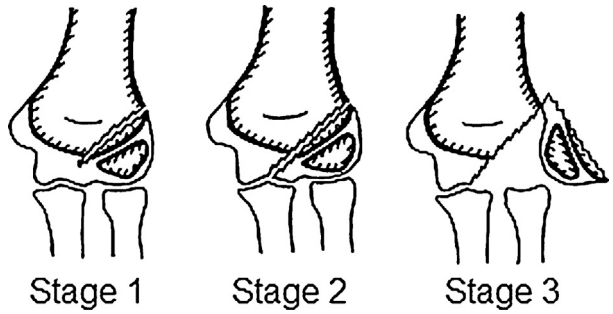

Fig. 2. The Jakob classification for lateral humeral condylar fractures [2].

not extend to the articular surface, stage 2 is a complete fracture with the fracture line passing through the joint cartilage, and stage 3 is a complete fracture with rotation of the lateral condylar fragment. Stages 2 and 3 appear to indicate a similar cartilage disruption. We postulate that classifying a fracture preoperatively using Jakob's classifications is not possible owing to the inability to visually confirm the presence of the cartilage hinge and displacement of the chondral articular surface using plain radiography.

It is generally accepted that displaced LHCFs must be anatomically reduced and nondisplaced LHCFs are treated successfully with a cast [3,4]. Meanwhile, the optimal treatment for minimally displaced LHCFs is still a matter of controversy [3,9]. Currently, there is no single modality that can precisely detect the intra-articular conditions to determine the appropriate surgical method.

Several imaging techniques using plain radiography that help us presume the displacement have been reported by Finnbogason et al. [6] and Song et al. [10]. However, in a cadaveric study, the radiographic measurements of fracture displacement were smaller than the true displacement measurements [7], which could be considered a limitation of radiographic evaluation. The use of other imaging equipment such as ultrasonography [11,12], arthrography [13], computed tomography [14], and magnetic resonance imaging (MRI) [15,16] have also been reported. However, accurate diagnosis of a cartilage hinge or articular displacement is challenging using these techniques. Arthrography has a risk of false-negative findings owing to the hematoma on the displaced cartilage surface [13]. MRI can detect the cartilage lesion, and unnecessary surgery may be avoided. However, it requires sedation for some children and is expensive. Moreover, it cannot always be immediately performed at most medical institutions such as our hospitals, and this is inappropriate in the situation of the fractures calling for the quick judgment.

Elbow arthroscopy provides direct visualization of the articular surface with minimal invasion. Therefore, it is a beneficial tool for detailed observation of the cartilage lesion, and can be applied in pediatric population [17]. However, it is usually technically demanding, and there have been reports of complications, such as nerve injury, compartment syndrome and infection [18–21]. The radial, median, and ulnar nerves are vulnerable during elbow arthroscopy, and injuries to these are primarily associated with portals for the anterior articular surface. In pediatric LHCF, the elbow generally has diffuse swelling, rendering the orientation of the elbow difficult to discern. To avoid the risks of nerve injury, compartment syndrome, and infection, we utilized two posterior portals that are easier to access within a shorter time. Posterior arthroscopic observation alone was sufficient to diagnose the fracture pattern and amount of displacement in the present study.

There was considerable disagreement between the displacement estimated preoperatively using 3R plain radiographs and the arthroscopic findings in our clinical cases. Both case 7 (a nondisplaced intra-articular linear fracture with cartilage disruption) and case 9 (a displaced fracture) had a Finnbogason type B minimally displaced fracture on preoperative imaging. In the former case, if the conservative treatment had been adopted, the linear cartilage fracture might have progressed to late rotational displacement. If in situ percutaneous fixation had been performed in the latter case, nonunion, malunion, or growth disturbance might have occurred. The use of Finnbogason's fracture classifications resulted in seven type B cases, of which, five had nondisplaced cartilage hinges and two had cartilage disruption, and two type C cases, in which nondisplaced cartilage hinges were observed (Table 1). Considering that a higher stage indicates more severe displacement, this classification does not seem to accurately represent the stability of LHCFs.

Previous reports have described arthroscopic reduction for LHCF [22,23]; however, it appeared to be too technically demanding and time-consuming. Hence, we did not conduct arthroscopic-assisted reduction maneuvers of the fracture displacement; instead, we used arthroscopy as a diagnostic mode only to reduce the diagnostic time and allow for sufficient time for the rest of the procedure.

5. Conclusion

We report that combined diagnostic arthroscopy and fixation was safely performed in pediatric minimally displaced LHCFs, resulting in satisfactory outcomes owing to the subsequent selection of an adequate operative method. Despite a small sample size, the review of these cases suggests that the proposed method might be an encouraging treatment option. We believe that the outcomes of studies conducted with a larger group of patients would further demonstrate its efficacy.

Disclosure of interest

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

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