Closed Reduction and Internal Fixation of Displaced Unstable Lateral Condylar Fractures of the Humerus in Children

Kwang Soon Song, Chul Hyung Kang, Byung Woo Min, Ki Cheor Bae, Chul Hyun Cho and Ju Hyub Lee
J Bone Joint Surg Am. 2008;90:2673-2681. doi:10.2106/JBJS.G.01227

Closed Reduction and Internal Fixation of Displaced Unstable Lateral Condylar Fractures of the Humerus in Children

By Kwang Soon Song, MD, Chul Hyung Kang, MD, Byung Woo Min, MD, Ki Cheor Bae, MD, Chul Hyun Cho, MD, and Ju Hyub Lee, MD

Investigation performed at the Department of Orthopedic Surgery, Keimyung University, Daegu, South Korea

Background: Open reduction and internal fixation of a displaced unstable fracture of the lateral condyle of the humerus in a child usually produces a good result. Only a few reports have focused on closed reduction and internal fixation of these fractures. We prospectively studied closed reduction and internal fixation to determine its usefulness as the initial treatment for displaced unstable fractures of the lateral condyle of the humerus.

Methods: We classified lateral condylar humeral fractures into five groups according to the degree of displacement and the fracture pattern as determined on four radiographic views and created an algorithm for the treatment of these fractures on the basis of this classification system. We prospectively treated sixty-three unstable fractures (in forty-two boys and twenty-one girls) and assessed the quality of closed reduction.

Results: Thirteen of seventeen stage-3 fractures were reduced to ≤1 mm of residual displacement. Thirty of forty stage-4 fractures and three of six stage-5 fractures were reduced to ≤2 mm of displacement. In ten of forty stage-4 fractures and three of six stage-5 fractures, closed reduction to within 2 mm failed and open reduction and internal fixation was performed. There were no major complications such as osteonecrosis of the trochlea or capitellum, nonunion, malunion, or early physeal arrest.

Conclusions: Closed reduction and internal fixation is an effective treatment for unstable displaced lateral condylar fractures of the humerus in many children. If fracture displacement after closed reduction exceeds 2 mm, open reduction and internal fixation is recommended.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Open reduction and internal fixation of displaced unstable lateral condylar humeral fractures in children usually produces good results, as does closed treatment with a posterior plaster splint or long-arm cast for nondisplaced and minimally displaced stable lateral condylar humeral fractures. Several reports have recommended open reduction and internal fixation as the best procedure for unstable fractures to prevent further displacement, nonunion, and malunion[1-10]. However, only a few reports have focused on closed reduction and internal fixation of lateral condylar humeral fractures[11,12]. We believe that satisfactory reduction and secure fixation of a lateral condylar fracture of the humerus in a child can often be achieved by means of closed reduction and internal fixation without the need for open reduction. We prospectively studied the use of closed reduction and internal fixation as the initial treatment for a group of displaced unstable lateral condylar humeral fractures.

Materials and Methods

After obtaining informed consent from the patients' parents or guardians and the approval of our institutional review board, we prospectively studied sixty-three consecutive unstable lateral condylar fractures of the humerus between March 2001 and December 2005. We excluded forty-three stable

Disclosure: In support of their research for or preparation of this work, one or more of the authors received, in any one year, outside funding or grants of less than $10,000 from Dongsan Medical Center, Keimyung University. Neither they nor a member of their immediate families received payments or other benefits or a commitment or agreement to provide such benefits from a commercial entity. No commercial entity paid or directed, or agreed to pay or direct, any benefits to any research fund, foundation, division, center, clinical practice, or other charitable or nonprofit organization with which the authors, or a member of their immediate families, are affiliated or associated.

TABLE I Classifications According to Degree of Displacement and Fracture Pattern

Stage	Degree of Displacement	Fracture Pattern	Radiograph Views Used as Basis	Stability
1	≤2 mm	Limited fracture line within the metaphysis	All 4 views	Stable
2	≤2 mm	Lateral gap	All 4 views	Indefinable
3	≤2 mm	Gap as wide laterally as medially	Any of 4 views	Unstable
4	>2 mm	Without rotation of fragment	Any of 4 views	Unstable
5	>2 mm	With rotation of fragment	Any of 4 views	Unstable

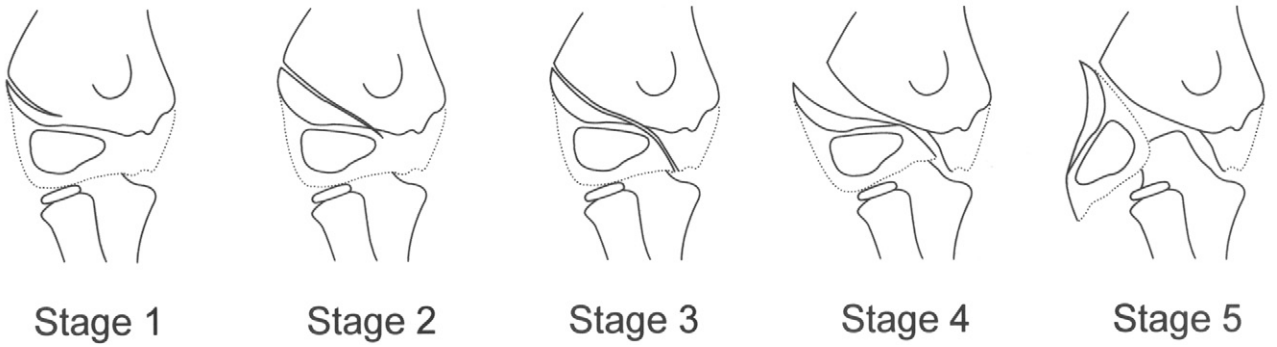

Fig. 1

Illustrations depicting the stages of displacement of fractures of the lateral condyle of the humerus in children. In stage 1, the fracture is stable, displacement is ≤2 mm, and the fracture line is limited to within the metaphysis. In stage 2, the fracture is indefinable, displacement is ≤2 mm, the fracture line extends to the epiphyseal articular cartilage, and there is a lateral gap. In stage 3, the fracture is unstable, displacement is ≤2 mm, and there is a gap that is as wide laterally as it is medially. In stage 4, the fracture is unstable and displacement is >2 mm. In stage 5, the fracture is unstable and displacement is >2 mm with rotation.

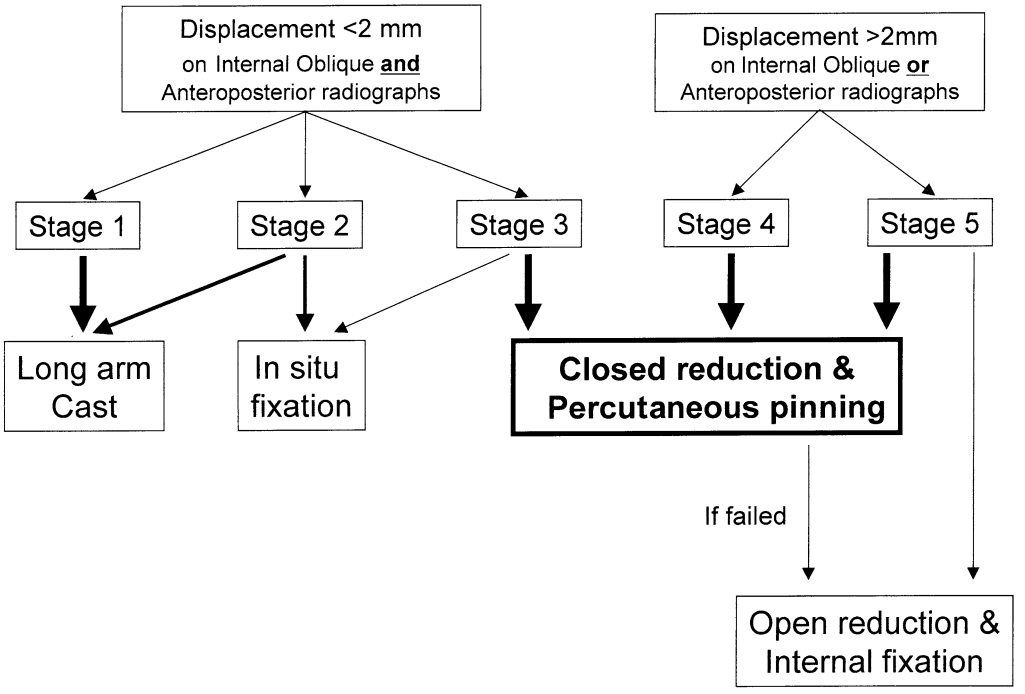

Fig. 2

The treatment algorithm according to the stage of fracture displacement.

Fig. 3-A

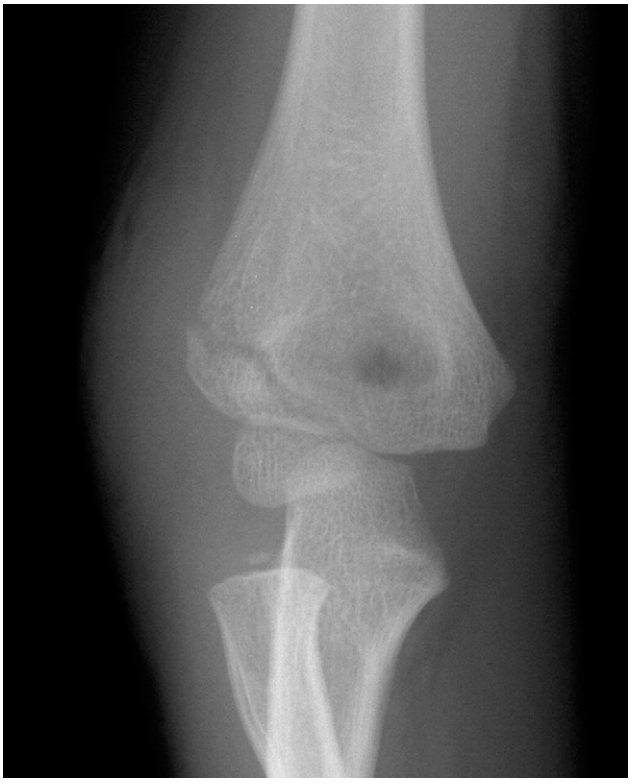

Fig. 3-B

Fig. 3-C

Fig. 3-A Anteroposterior radiograph of the right elbow, showing a stage-3 fracture of the lateral cortex with a minimal lateral gap and ≤2 mm of displacement. **Fig. 3-B** Internal oblique radiograph showing a fracture through the lateral humeral condyle, extending into the joint, with the fracture gap being as wide laterally as it is medially. **Fig. 3-C** Short T1-weighted inversion recovery magnetic resonance image showing complete fracture of the cartilage.

(stage-1) and indefinable (stage-2) fractures that had uniformly good results after treatment with a long-arm cast during the study period. All patients in the present study were managed by a single pediatric orthopaedic surgeon (K.S.S.), and three experienced orthopaedic surgeons (C.H.K., B.W.M., and K.C.B.) measured the amount of fracture displacement and classified the fracture pattern three times for each patient over a more than two-week interval with use of a PACS (picture archiving and communications system) network (Marosis, DICOM version 3.0; INFINITT, Seoul, South Korea). Fracture fragment displacement was measured from the lateral metaphyseal cortex of the distal part of the humerus to the lateral cortex of the

Fig. 4-A

Fig. 4-B

Fig. 4-A Anteroposterior radiograph of the left elbow, showing an apparent stage-3 fracture with displacement of ≤2 mm and a gap as wide laterally as medially. **Fig. 4-B** Internal oblique radiograph of the same elbow, showing a stage-4 fracture with 7 mm of fracture fragment displacement.

Fig. 4-C

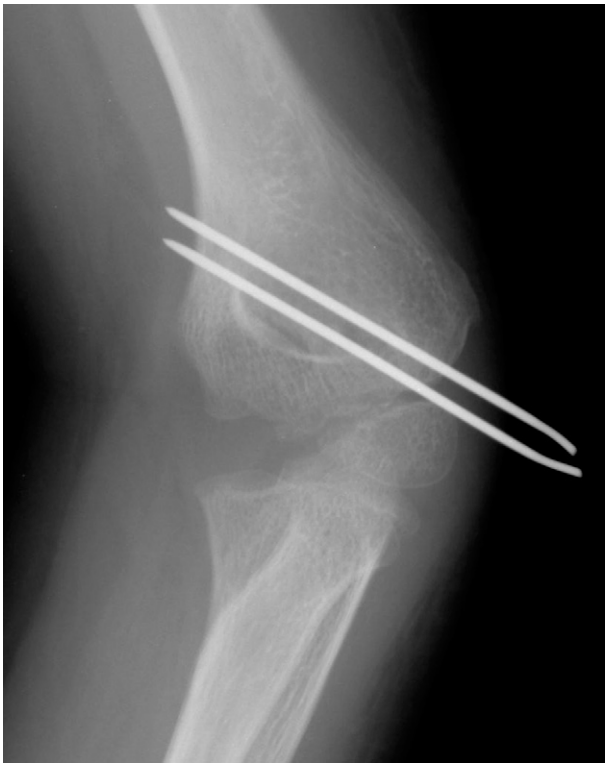

Fig. 4-D

Figs. 4-C and 4-D Postoperative anteroposterior (Fig. 4-C) and internal oblique (Fig. 4-D) radiographs showing a good reduction, achieved by closed means, and internal fixation with two parallel Kirschner wires.

Fig. 4-E

Fig. 4-F

Figs. 4-E and 4-F Anteroposterior (Fig. 4-E) and internal oblique (Fig. 4-F) radiographs, made six months after surgery, showing fracture union.

fracture fragment on the anteroposterior, internal oblique, and external oblique radiographic views. The posterior cortex was used to measure displacement on the lateral radiograph. The greatest displacement on any single radiograph was recorded as the amount of displacement of the fragment.

Observer agreement was measured to determine interobserver and intraobserver reliability. We calculated the kappa value (κ value) to assess interobserver and intraobserver reliability regarding the fracture pattern; a kappa value of 1 indicates complete agreement. The interobserver reliability regarding the measurement of fracture displacement on the preoperative and postoperative anteroposterior and internal oblique radiographs was very high (range, 0.911 to 0.928 for preoperative anteroposterior radiographs, 0.980 to 0.985 for preoperative internal oblique radiographs, 0.890 for postoperative anteroposterior radiographs, and 0.787 to 0.807 for postoperative internal oblique radiographs).

We divided the fractures into five groups according to the amount of displacement and the fracture pattern as determined on the basis of the four radiographic views, with a special emphasis on the internal oblique view (Table I, Fig. 1). Stage 1 indicated a fracture through the lateral humeral condyle with a minimal lateral gap and ≤2 mm of displacement. Stage 2 indicated a fracture through the lateral humeral condyle to the epiphyseal articular cartilage with a lateral gap and ≤2 mm of displacement. Stage 3 indicated a fracture through the lateral humeral condyle into the joint, a fracture gap that was as wide laterally as it was medially, ≤2 mm of displacement, and a high risk of further displacement. Stage 4 indicated a fracture with >2 mm of displacement without rotation of the distal fragment. Stage 5 indicated a fracture with >2 mm of displacement with rotation of the distal fragment.

An algorithm was created to treat these fractures on the basis of this classification system (Fig. 2). Fractures with the possibility of further displacement were defined as unstable and as either displaced (>2 mm of displacement; i.e., stage-4 and 5 fractures) or minimally displaced (≤2 mm of displacement with a fracture through the lateral humeral condyle extending into the joint and a fracture gap as wide laterally as medially on any of the four radiographic views; i.e., stage-3 fractures). As a first step, we attempted closed reduction and internal fixation for all sixty-three unstable displaced fractures, including those that were classified as stage 3 (Figs. 3-A, 3-B, and 3-C), stage 4 (Figs. 4-A through 4-F), or stage 5 (Figs. 5-A through 5-E).

To reduce unstable fractures, traction with a gentle varus force was applied to the elbow while the patient was under general anesthesia. For stage-3 and 4 fractures, gradual direct compression was applied to the fracture fragment anteromedially without the use of Kirschner wires. For stage-5 fractures, an attempt was made to reposition the rotated fragment by using Kirschner wires as joysticks or by pushing directly on the fragment. After repositioning, fracture fragment reduction was performed in the same manner as for stage-3 and 4 fractures. A slight valgus

Fig. 5-A

Fig. 5-B

Figs. 5-A and 5-B Anteroposterior radiograph (Fig. 5-A) and internal oblique radiograph (Fig. 5-B) showing a severely displaced fracture with rotation of the fracture fragment. This fracture is classified as a stage-5 (unstable) fracture.

force was applied to the elbow, with the forearm supinated and the elbow slightly extended, to maintain the reduction. After the fracture reduction was confirmed to be within 2 mm, especially on the internal oblique, anteroposterior, and lateral radiographs, percutaneous pinning with two parallel smooth Kirschner wires was performed. We used 1.2-mm-diameter Kirschner wires for patients younger than three years of age, 1.4-mm-diameter wires for those between three and five years of age, and 1.8-mm-diameter wires for those older than five years of age.

If we could not reduce the fragment to within 2 mm as shown on any of the four radiographic views, open reduction and internal fixation was performed. A long-arm cast was applied in all cases and was left in place for four weeks. We removed the pins four to five weeks after surgery. At the time of the latest follow-up, we evaluated the degree of fracture displacement, elbow range of motion, radiographic changes (including osteophyte formation and hypertrophy of the capitellum), and clinical symptoms. Results were graded according to the criteria suggested by Hardacre et al.[7].

Results

A total of sixty-three fractures were evaluated (see Appendix). The patients included forty-two boys and twenty-one girls with an average age of six years and four months (range, twenty-one months to eleven years and three months). Thirty-five fractures involved the right elbow, and twenty-eight involved the left elbow. The average time from the injury to surgery was 2.4 days (range, zero to fourteen days). The average duration of follow-up was twenty-five months (range, one year and three months to six years).

Seventeen of the sixty-three fractures were stage 3, forty were stage 4, and six were stage 5. The average amount of initial displacement was 3.5 mm (range, 0 to 33 mm) on the anteroposterior radiograph and 4.5 mm (range, 0.5 to 27 mm) on the internal oblique radiograph. For the entire group, the average amount of postoperative displacement was <1 mm on both the anteroposterior and the internal oblique radiographs. Thirteen (76%) of the seventeen stage-3 fractures were reduced to ≤1 mm of residual displacement. Thirty (75%) of the forty stage-4 fractures and three (50%) of the six stage-5 fractures were reduced to ≤2 mm of residual displacement. All of these fractures (representing forty-six of all sixty-three fractures) were stabilized with percutaneous Kirschner wires. The remaining four stage-3 fractures were treated with in situ pin fixation without further attempts at reduction. In the cases of the remaining ten stage-4 fractures and three stage-5 fractures, closed reduction to within ≤2 mm failed and open reduction and internal fixation was performed.

Minor complications included eleven instances of osteophyte formation without any subjective symptoms and four

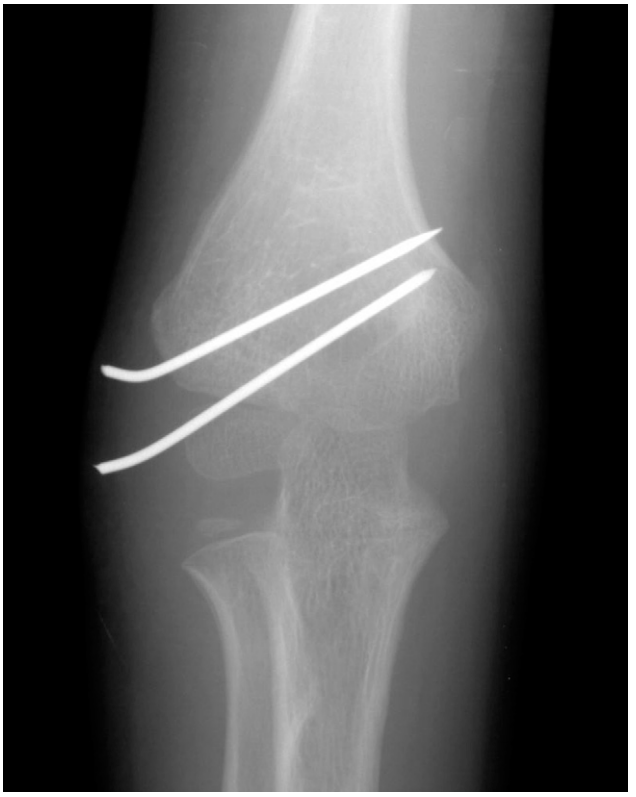

Fig. 5-C

Fig. 5-D

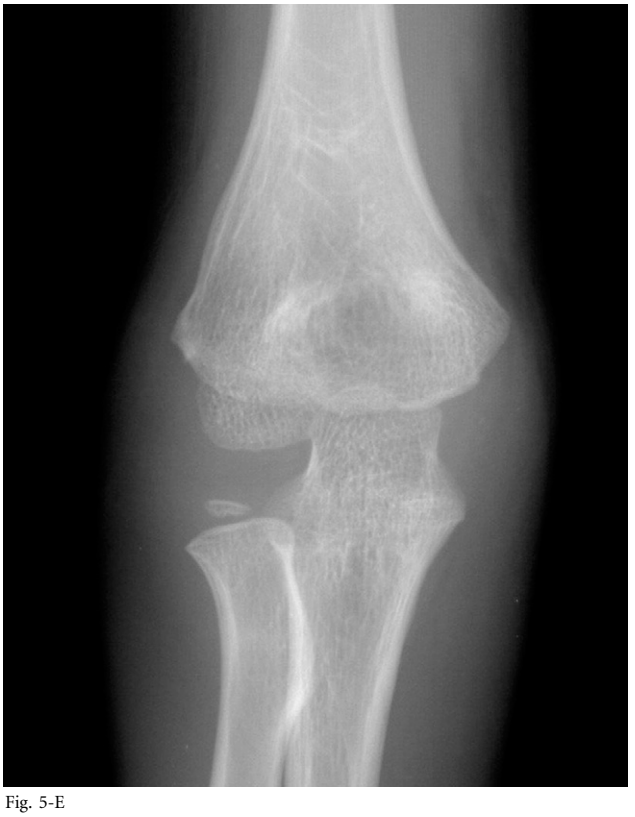

Fig. 5-E

Figs. 5-C and 5-D Postoperative anteroposterior radiograph (Fig. 5-C) and lateral radiograph (Fig. 5-D) showing an anatomic reduction, achieved by closed means, and internal fixation with two parallel Kirschner wires. **Fig. 5-E** Anteroposterior radiograph, made five months after surgery, showing fracture union.

instances of mild hypertrophy of the capitellum with no change in the carrying angle. There were no serious complications such as osteonecrosis of the trochlea or capitellum, nonunion, malunion, or early physeal arrest. According to the criteria of Hardacre et al.[7], the clinical result was excellent in forty-four (96%) of the forty-six patients undergoing closed reduction and pin fixation, good in two patients (4%), and poor in no patients.

Thus, forty-six (73%) of the sixty-three unstable fractures of the lateral humeral condyle were reduced and stabilized with good results and no serious complications with use of our treatment algorithm.

Discussion

A fracture of the lateral condyle of the humerus is the second most frequent fracture of the elbow in children. This diagnosis may be less obvious both clinically and radiographically. As with other elbow fractures in children, a poorly treated lateral condylar fracture is more likely to result in a substantial functional loss of elbow motion[1].

Treating a minimally displaced fracture may be difficult primarily because it is difficult to determine whether the distal fracture fragment is prone to further displacement. The common practice of using only anteroposterior and lateral elbow radiographs does not always provide adequate information to allow one to determine fracture stability, to prevent further displacement, and to identify an optimal treatment method for these fractures[1,4,5,10,12-14]. Many other studies, such as magnetic resonance imaging, arthrography, stress tests, and ultrasonography, have been suggested as additional methods to evaluate fracture stability[15-19]. However, the routine use of these modalities may not be warranted because of their cost and the need for sedation of the patient.

The importance of the internal oblique radiograph for the diagnosis of fracture stability and the amount of displacement at the site of lateral condylar fractures of the humerus in children has been well established[13]; in the present study, we have suggested a new system for the classification of these fractures with use of the internal oblique view. Our results strongly imply that the failure of assessment of stability with use of previous radiographic criteria was due to the exclusion of the findings from the internal oblique radiograph. We classified these fractures according to the degree of displacement and the fracture pattern demonstrated on all four radiographic views.

Generally, there has been uniform agreement regarding the need for open reduction and internal fixation of displaced fractures of the lateral condylar physis. Because it is difficult to maintain the reduction of a displaced lateral condylar fracture and because of the high prevalence of poor functional and cosmetic results associated with closed reduction and casting, open reduction and internal fixation has become the most widely advocated method for the treatment of unstable fractures with Jakob stage-2 or 3 displacement[1-10]. However, even patients who are managed with open reduction and internal fixation may have development of malunion because of a lack of intraoperative confirmation of the reduction status or osteonecrosis caused by excessive soft-tissue dissection.

Only a few reports have focused on percutaneous pin fixation of these fragments. Mintzer et al. reported good results after percutaneous pin fixation of twelve lateral condylar fractures with displacement in excess of 2 mm[11]. They believed that the method is appropriate for selected fractures with 2 to 4 mm of displacement and an arthrographically demonstrated congruent joint space. Foster et al. reported that percutaneous pin fixation of nondisplaced and minimally displaced fractures is an acceptable alternative in any situation in which close clinical and radiographic follow-up cannot be ensured[12]. It was often our personal experience that many fractures that were treated with open reduction and internal fixation could be reduced by closed means. Because it appeared that open reduction and internal fixation was not always necessary for these displaced fractures, we conducted the present study.

The present study showed a high success rate (73%) in association with closed reduction and pin fixation for the treatment of unstable displaced fractures. While others have reported that closed reduction and internal fixation is not recommended for the treatment of Jakob stage-3 displaced and rotated lateral condylar fractures[1] (which are classified as stage-5 fractures in our system), we achieved excellent results in three of six such fractures with use of closed reduction and pin fixation (Figs. 5-A through 5-E). We acknowledge that the number of cases is small and that additional prospective studies are needed to further evaluate this approach for the treatment of fractures with an unstable and rotated fragment. It is our impression that the reasons for our high success rate with closed reduction and internal fixation were (1) the accurate interpretation of the direction of fracture displacement (mainly posterolaterally, not purely laterally) and the amount of displacement of the fracture fragment on the basis of our classification system, (2) routine intraoperative confirmation of the reduction on both anteroposterior and internal oblique radiographs, and (3) maintenance of the reduction with two parallel percutaneous Kirschner wires.

The present study demonstrates that fracture classification on the basis of four elbow radiographs, with an emphasis on the internal oblique view, is useful for determining fracture fragment stability and the optimal treatment method and that closed reduction and pin fixation often results in effective treatment for unstable displaced lateral condylar fractures of the humerus in children.

Appendix

eA A table showing clinical details on all study subjects is available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD/DVD (call our subscription department, at 781-449-9780, to order the CD or DVD). ■

NOTE: This study was partially supported by the research-promoting grant from the Keimyung University Dongsan Medical Center. The authors thank Katharine O'Moore-Klopf for providing editorial assistance.

Kwang Soon Song, MD
Chul Hyung Kang, MD
Byung Woo Min, MD
Ki Cheor Bae, MD
Chul Hyun Cho, MD

Ju Hyub Lee, MD
Department of Orthopedic Surgery, School of Medicine,
Keimyung University, 194 Dong san dong,
Daegu 700-712, South Korea.
E-mail address for K.S. Song: skspos@dsmc.or.kr

References

1. Beaty JH, Kasser JR, editors. Rockwood and Wilkins' fractures in children. 6th ed. Philadelphia: Lippincott Williams and Wilkins; 2005.

2. Canale ST, editor. Campbell's operative orthopaedics. 10th ed. St. Louis: Mosby; 2003.

3. Jakob R, Fowles JV, Rang M, Kassab MT. Observations concerning fractures of the lateral humeral condyle in children. J Bone Joint Surg Br. 1975;57:430-6.

4. Badelon O, Bensahel H, Mazda K, Vie P. Lateral humeral condylar fractures in children: a report of 47 cases. J Pediatr Orthop. 1988;8:31-4.

5. Flynn JC. Nonunion of slightly displaced fractures of the lateral humeral condyle in children: an update. J Pediatr Orthop. 1989;9:691-6.

6. Conner AN, Smith MG. Displaced fractures of the lateral humeral condyle in children. J Bone Joint Surg Br. 1970;52:460-4.

7. Hardacre JA, Nahigian SH, Froimson AI, Brown JE. Fractures of the lateral condyle of the humerus in children. J Bone Joint Surg Am. 1971;53:1083-95.

8. Crabbe WA. The treatment of fracture-separation of the capitular epiphysis. J Bone Joint Surg Br. 1963;45:722-6.

9. Launay F, Leet AI, Jacopin S, Jouve JL, Bollini G, Sponseller PD. Lateral humeral condyle fractures in children: a comparison of two approaches to treatment. J Pediatr Orthop. 2004;24:385-91.

10. Flynn JC, Richards JF Jr. Non-union of minimally displaced fractures of the lateral condyle of the humerus in children. J Bone Joint Surg Am. 1971;53:1096-101.

11. Mintzer CM, Waters PM, Brown DJ, Kasser JR. Percutaneous pinning in the treatment of displaced lateral condyle fractures. J Pediatr Orthop. 1994;14:462-5.

12. Foster DE, Sullivan JA, Gross RH. Lateral humeral condylar fractures in children. J Pediatr Orthop. 1985;5:16-22.

13. Song KS, Kang CH, Min BW, Bae KC, Cho CH. Internal oblique radiographs for diagnosis of nondisplaced or minimally displaced lateral condylar fractures of the humerus in children. J Bone Joint Surg Am. 2007; 89:58-63.

14. Finnbogason T, Karlsson G, Lindberg L, Mortensson W. Nondisplaced and minimally displaced fractures of the lateral humeral condyle in children: a prospective radiographic investigation of fracture stability. J Pediatr Orthop. 1995;15:422-5.

15. Horn BD, Herman MJ, Crisci K, Pizzutillo PD, MacEwen GD. Fractures of the lateral humeral condyle: role of the cartilage hinge in fracture stability. J Pediatr Orthop. 2002;22:8-11.

16. Kamegaya M, Shinohara Y, Kurokawa M, Ogata S. Assessment of stability in children's minimally displaced lateral humeral condyle fracture by magnetic resonance imaging. J Pediatr Orthop. 1999;19:570-2.

17. Marzo JM, d'Amato C, Strong M, Gillespie R. Usefulness and accuracy of arthrography in management of lateral humeral condyle fractures in children. J Pediatr Orthop. 1990;10:317-21.

18. Milch H. Fractures and fracture dislocations of the humeral condyles. J Trauma. 1964;4:592-607.

19. Vocke-Hell AK, Schmid A. Sonographic differentiation of stable and unstable lateral condyle fracture of the humerus in children. J Pediatr Orthop B. 2001;10:138-41.