—Original—

Kirschner Wire Fixation with and without Tension Band Wiring for Treatment of Fracture of the Lateral Humeral Condyle in Children

Yuji Tomori, Mitsuhiko Nanno and Shinro Takai

Departments of Orthopedic Surgery, Nippon Medical School Hospital, Tokyo, Japan

Background: Kirschner wires (K-wires) are commonly used to treat displaced lateral humeral condyle fracture in children. However, K-wire fixation alone is insufficient for early elbow range of motion (ROM) exercises. Fixation combined with tension band wiring (TBW) converts distraction forces into compression forces, which provides more rigid fixation than K-wire fixation alone. Here, we retrospectively evaluated clinical outcomes of patients with displaced lateral humeral condyle fracture treated with TBW or K-wires only.

Methods: We identified children with lateral condyle fractures who had undergone surgery during the period from April 2000 through March 2014. Nineteen patients were classified into 2 groups according to treatment: 10 were allocated to the TBW group (TBW and K-wires) and 9 to the K-wires group. The mean interval from injury to surgery was 5.1 days in both groups. Fractures were classified by using the Jacob's and Milch's classifications. In addition, we collected and analyzed data on postoperative complications, radiological and clinical evaluations, ROM, and Flynn's criteria.

Results: Mean duration of follow-up was 14.4 months in the TBW group and 5.9 months in the K-wires group. Mean bone union time was 38.6 days and 49.8 days, respectively. Mean duration of cast/splint use was significantly longer for K-wires patients (49.8 days) than for TBW patients (35.8 days). Range of flexion at the final follow-up was significantly lower in the K-wires group.

Conclusions: TBW fixation appears to be the optimal treatment for displaced lateral humeral condyle fracture in children, as it facilitates early active range of motion exercises.

(J Nippon Med Sch 2020; 87: 17–23)

Key words: lateral condyle humeral fracture, humerus, comparative study, elbow, children

Introduction

Fracture of the lateral humeral condyle is the second most common elbow injury in children. It accounts for 12% of pediatric fractures around the elbow joint and is usually caused by a fall onto an extended arm that generates excessive varus force[1]. Although undisplaced fractures of the lateral humeral condyle are treated nonsurgically[2], patients with displaced fracture should be treated surgically to prevent complications such as nonunion, malunion, or cubitus varus/valgus deformity[3]. Lateral humeral condyle fractures are intra-articular fractures, and a displacement greater than 2 mm should thus be treated with open reduction and internal fixation (OR/IF)[2,3]. Although several methods for fixation have been described, including fixation using bioabsorbable materials[4], screws[5–7], and Kirshner wires (K-wires)[2,8–11] with or without a larger divergence angle, fixation with K-wires is common[2,8,12].

At our center, we previously performed OR/IF with buried K-wires for displaced lateral condyle fracture. However, fixation with K-wires alone was insufficient for early range of motion (ROM) exercises of the elbow joint. Therefore, we have performed OR/IF using tension band wiring (TBW) with K-wires for fixation since 2005. This method converts distraction forces into compression forces, which promotes bone union. Thus, TBW is be-

Correspondence to Yuji Tomori, MD, PhD, Department of Orthopedic Surgery, Nippon Medical School, 1–1–5 Sendagi, Bunkyo-ku, Tokyo 113–8603, Japan
E-mail: s4064@nms.ac.jp
https://doi.org/10.1272/jnms.JNMS.2020_87-105
Journal Website (https://www.nms.ac.jp/sh/jnms/)

Table 1 Preoperative demographic characteristics of children with displaced lateral humeral condyle fracture

	TBW (*n* = 10)	K-wires (*n* = 9)	*P* value
Age (years)	6.4 ± 2.3	5.3 ± 2.6	.39
Male:Female	8 : 2	6 : 3	.44
Left:Right	6 : 4	6 : 3	.57
Interval from injury to surgery (days)	5.1 ± 3.4	5.1 ± 3.1	.99
Jacob classification (type II:III)	9 : 1	5 : 4	.12
Milch classification (type I:II)	1 : 9	1 : 8	.74

TBW: tension band wiring

Data (age and interval from injury to surgery) are presented as mean ± SD.

*$P < 0.05$

lieved to provide complete stability to fractures. To date, no study has specifically compared TBW and buried K-wire fixation after open reduction for treatment of lateral condyle fracture. Here, we retrospectively reviewed the records of children treated with TBW or K-wires alone to evaluate clinical outcomes after displaced lateral humeral condyle fracture.

Materials and Methods

In this retrospective case series, we analyzed patient records at our center for the period from April 2000 through March 2014. Patient demographic characteristics, medical history, imaging findings, and follow-up data were extracted. This study was conducted in accordance with the ethical guidelines of the 1975 Declaration of Helsinki, after approval from our institutional review board (No. 30-08-988).

Patients

Children with lateral condyle fracture of the humerus who had undergone primary surgery were investigated retrospectively. Demographic data, medical history, imaging, and follow-up data were extracted from the medical records. Inclusion criteria were age younger than 14 years and presence of lateral humeral condyle fracture treated by OR/IF with TBW or K-wires at our center. Patients with undisplaced fractures, fractures treated with another surgical approach, open fractures, other ipsilateral upper-limb fractures, pathological fractures, or fractures treated later than 14 days after injury were excluded.

The medical records and radiographs of 19 patients were reviewed. Patients were classified into 2 groups according to treatment method: Patients in the TBW group were treated by OR/IF with TBW and K-wires; those in the K-wires group were treated by OR/IF with K-wires only. The characteristics of the patients are shown in **Table 1**. The TBW group comprised 10 elbows of 10 patients (8 boys, 2 girls), and the K-wires group comprised 9 elbows of 9 patients (6 boys, 3 girls). Mean age at the time of surgery was 6.4 ± 2.8 (range, 3-11) years in the TBW group, and 5.3 ± 2.6 (3-10) years in the K-wires group. The mean interval from injury to surgery was 5.1 ± 3.4 (1-12) days in the TBW group, and 5.1 ± 3.1 (0-10) days in the K-wires group.

Fractures were classified according to the method of Jakob et al.[2], with modifications. Type I fracture was defined as a displacement less than 2 mm, type II as a displacement greater than 2 mm, and type III as displacement with rotation of the fragment. Using Jacob's classification, we identified 9 type II fractures and 1 type III fracture in the TBW group and 5 type II and 4 type III fractures in the K-wires group. Fractures were also classified as type I and type II, in accordance with Milch's classification of the fracture line on the distal humerus: Type I fracture was present through the capitellar-trochlear groove whereas type II passed through the trochlear groove[13]. Using Milch's classification, we identified 1 type I and 9 type II fractures in the TBW group and 1 type I and 8 type II fractures in the K-wires group. No preoperative neurological disturbances were observed in either group.

Surgical Procedures

Surgery was performed under general anesthesia, and open reduction using a posterolateral approach was performed, with or without a pneumatic tourniquet, with patients in a supine or prone position[14,15]. Briefly, a lazy S incision (approximately 3-4 cm) was made on the posterolateral side of the distal humerus and extended to the olecranon, while deviating radially. After dissecting through the subcutaneous tissue, the fascial layer on the triceps was separated at its lateral border. The intermuscular plane between the triceps and brachioradialis was then separated to access the distal humerus. Image-intensified radiographic guidance was used in all cases. After open reduction of the displaced fractures, all patients underwent initial fixation with 2 K-wires. In the TBW group, 2 K-wires were inserted with or without a larger divergence angle through the surgical wound and were augmented with TBW by using 0.8-mm suture wires. The K-wires were then bent back over the wires and buried beneath the skin (**Fig. 1A**). In the K-wires group, K-wires were inserted through the surgical wound and bent and buried beneath the skin (**Fig. 1B**). The surgical technique of open reduction for the fractures did not differ between the 2 groups. Postoperatively, all patients were given an above-elbow, long-arm, fiberglass cast or splint, with the elbow flexed at 90 degrees. All patients were seen at 1 week for radiographic examination and wound inspection. The full cast was changed twice monthly. Active ROM exercises were encouraged after removal of the cast.

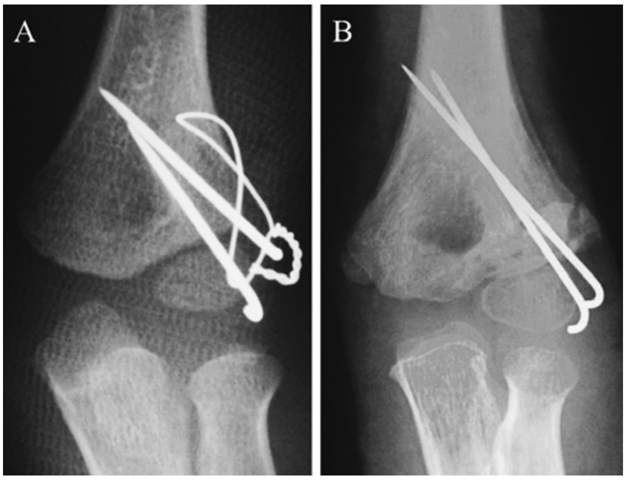

Fig. 1 Radiographs showing the two operative procedures. (A) Fixation with tension band wiring (TBW group); (B) Fixation with two K-wires (K-wires group).

Postoperative Evaluation

We recorded duration of follow-up, duration of cast or splint use, date of wire removal, and postoperative complications (iatrogenic nerve injury, ratio of nonunion, infection, contracture of the elbow joint, and valgus or varus deformity). Contracture of the elbow joint was defined as loss of extension or flexion of greater than 15 degrees, in accordance with the definition of poor functional outcome in Flynn's criteria[16], ie, extension less than −15 degrees or flexion less than 125 degrees. We also evaluated radiographs and clinical outcomes, including ROM and arc of the elbow joint. Postoperative radiographs were used to evaluate humeral deformity and fracture displacement. Radiological evaluations included Baumann's angle (BA), diaphyseal condyle angle (DCA), and carrying angle (CA)[17,18]. Postoperative loss of fracture reduction was evaluated by BA and DCA angular change (the difference between each angle on radiographs obtained immediately after surgery and at 6-8 weeks postoperatively). The clinical criteria described by Flynn[16] were used to evaluate postoperative cosmetic and functional outcomes at the final follow-up, specifically elbow ROM and CA (**Table 2**).

Statistical Analysis

All statistical analyses were done with SPSS 18 (SPSS Inc, Chicago, IL, USA). Quantitative variables are expressed as means ± SD or medians with ranges, and qualitative variables as percentages. Group comparisons for categorical data were made with the Pearson chi-square or Fisher exact tests, depending on the theoretical sample size, and continuous data were assessed with the Welch *t*-test or Mann-Whitney U-test. *P* values less than .05 were considered statistically significant.

Results

Overview

There was no significant difference between groups in the preoperative demographic variables age, sex, affected side, interval from injury to surgery, follow-up, or frac-

Table 2 Flynn's criteria (cosmetic and functional factors)

Results	Rating	Cosmetic factor, CA loss (degrees)	Functional factor, ROM loss (degrees)
Satisfactory	Excellent	0 to 5	0 to 5
	Good	5 to 10	5 to 10
	Fair	10 to 15	10 to 15
Unsatisfactory	Poor	>15	>15

CA: carrying angle, ROM: range of motion
The presence of any cubitus varus deformity is defined as Poor.

Table 3 Postoperative demographic data and complications

Demographic characteristics	TBW (n = 10)	K-wires (n = 9)	P value
Follow-up period (months)	14.4 ± 12.7	5.9 ± 3.3	.07
Duration of immobilization (days)	35.8 ± 11.4	49.8 ± 14.5	.03*
Time to bone union (days)	38.6 ± 8.0	49.8 ± 14.5	.05
Interval from OR/IF to removal of internal fixation (weeks)	11.6 ± 4.4	10.0 ± 4.6	.45
Complications			
Superficial infection	1	1	.74
Contracture of elbow joint	1	4	.12

Data are mean ± SD
*P < 0.05

Table 4 Results of radiographic evaluation and loss of reduction

	TBW (n = 10)	K-wires (n = 9)	P value
Postoperative BA	75.0 ± 8.3	72.9 ± 4.4	.50
6-8 w postoperative BA	73.8 ± 6.5	74.4 ± 6.2	.82
Loss of reduction on BA	−1.20 ± 4.6	1.56 ± 2.6	.13
Postoperative DCA	41.7 ± 6.1	35.8 ± 6.3	.05
6-8 w postoperative DCA	40.8 ± 7.3	38.7 ± 3.7	.43
Loss of reduction on DCA	−0.9 ± 7.6	2.9 ± 4.8	.21

BA: Baumann's angle, DCA: diaphyseal condyle angle
Data are mean ± SD
*P < 0.05

Table 5 Range of motion and arc of elbow joint

	TBW (n = 10)	K-wires (n = 9)	P value
Extension range of injured elbow	0.8 ± 9.2	0.5 ± 7.7	.95
Extension range of contralateral elbow	9.7 ± 7.4	6.7 ± 7.5	.39
Loss of extension	8.9 ± 9.3	6.1 ± 11.4	.57
Flexion range of injured elbow	137.4 ± 3.7	123.9 ± 18.5	.06
Flexion range of contralateral elbow	140.0 ± 3.7	140.0 ± 3.5	1.00
Loss of flexion	2.6 ± 3.1	17.2 ± 21.1	.04*
ROM (Arc) of injured elbow	138.2 ± 9.6	124.4 ± 17.6	.06
ROM (Arc) of contralateral elbow	149.7 ± 7.9	146.7 ± 9.7	.47
Loss of ROM (Arc)	11.5 ± 10.6	15.0 ± 17.9	.62

ROM: range of motion
Data are mean ± SD
*P < 0.05

ture classification (**Table 1**).

The outcomes for the groups are shown in **Table 3-6**. All patients required a second surgery to remove the wires. The follow-up time differed by 8.5 months; however, this difference was not significant (P = .07) (**Table 3**). Duration of cast/splint use was longer for patients in the K-wires group than for those in the TBW group, and the difference was significant (P < .05). Patients in the K-wires group used an upper-arm cast or splint for an average of 7 weeks after surgery. These patients were encouraged to perform active ROM exercises before bone union was achieved, but many complained of elbow pain and were unable to perform active ROM exercise for several weeks after removal of the cast or splint. Moreover, many patients required immediate removal of the K-wires after radiological confirmation of callus formation,

Table 6 Cosmetic and functional outcomes, according to Flynn's criteria

	TBW (n = 10)	K-wires (n = 9)	P value
Cosmetic factor			
CA of injured elbow	8.2 ± 6.8	8.3 ± 5.9	.99
CA of contralateral elbow	13.8 ± 6.3	11.6 ± 4.1	.37
Loss of CA	5.2 ± 5.1	4.0 ± 6.0	.65
Cosmetic factor; rating of Excellent and Good (%)	80 (8/10)	77.8 (7/9)	.67
Functional factor			
ROM (Arc) of injured elbow	138.2 ± 9.6	124.4 ± 17.6	.06
ROM (Arc) of contralateral elbow	149.7 ± 7.9	146.7 ± 9.7	.47
Loss of ROM (Arc)	11.5 ± 10.6	15.0 ± 17.9	.62
Functional factor; rating of Excellent and Good (%)	70 (7/10)	55.6 (5/9)	.43
General evaluation			
Rating of Excellent and Good (%)	50 (5/10)	33.3 (3/9)	.40

CA: carrying angle, ROM: range of motion
Data are mean ± SD

because irritation from the K-wires caused elbow pain. Time to radiographic union was slightly longer in the K-wires group, but the difference was not significant.

Bone union was achieved faster in the TBW group than in the K-wires group, but the difference was not significant (P = .05). The wires were left in situ for approximately the same duration in both groups.

Complications

No patient showed evidence of nonunion, fracture displacement, deep infection, neurovascular complications, or cubitus varus or valgus. Superficial wound infections were treated effectively with oral antibiotics (n=1 in each group). Contracture of the elbow joint was observed in 1 patient in the TBW group and in 4 patients in the K-wires group, but the difference was not significant. One patient in the K-wires group had severely restricted flexion and required joint capsular release, which was performed at the time of K-wire removal.

Radiographic Evaluation

The radiographic results are summarized in **Table 4**. BA and DCA were measured immediately postoperatively and at 6-8 weeks after surgery. We found no significant differences between the 2 groups. DCA measured immediately postoperatively was higher in the TBW group than in the K-wires group, but the difference was not significant. There was no significant loss of reduction in BA or DCA, as compared with the contralateral side, in either group.

Flexion, Extension, and ROM

Mean values for flexion, extension, and ROM are shown in **Table 5**. Patients in the K-wires groups had a significant loss of flexion, as compared with patients in the TBW group. No other significant difference was observed. According to Flynn's criteria, half the patients in the TBW group were classified as excellent or good, whereas, most were fair or poor in the K-wires group. There was no significant difference between groups when patients were classified with Flynn's criteria (**Table 6**).

Discussion

No study has specifically compared TBW and buried K-wire fixation after OR/IF for lateral condyle fracture. The present study compared clinical outcomes of these 2 procedures. One patient in each group developed a superficial wound infection; however, both were effectively treated with a short course of oral antibiotics. The rate of infection related to K-wire fixation with subcutaneous wires was 11% (1/9 cases), which was close to previously reported rates (3% to 8%)[19,20]. We observed contracture of the elbow joint in 1 patient in the TBW group and in 4 patients in the K-wire group, but there was no significant difference between groups. However, there was a significant difference in duration of external fixation and loss of flexion between groups. This disparity is attributable to the difference in the adequacy of internal fixation.

Although buried wires were bent close to the bone, to prevent fracture displacement, the fracture fragment was not sufficiently stable to allow patients to engage in early active ROM exercise. Numerous studies have reported that extended use of a plaster splint or cast was required after internal fixation with K-wires[3,19]. Foster et al.[3] reported that 6-8 weeks of elbow joint immobilization was required after open reduction with K-wire fixation. Launay et al.[19] reported that patients required a long-arm cast or splint for 4-10 weeks after internal fixation with K-wires. In our study, patients in the K-wires group used an upper-arm cast or splint for an average of 7 weeks after surgery. Although patients were encouraged to perform active ROM exercises before bone union, many reported elbow pain that prevented such exercises. Indeed, many patients in the K-wires group were unable to perform active ROM exercises for several weeks after cast/splint removal. Moreover, many patients required immediate removal of the K-wires after radiological confirmation of callus formation, because irritation caused by the K-wires resulted in elbow pain. In contrast, almost all patients in the TBW group were able to undergo active ROM exercise, without irritation attributable to fixation, at about 5 weeks postoperatively, which suggests that TBW provided greater stability than did K-wire fixation alone.

Time to radiographic union was slightly longer in the K-wires group, but the difference was not statistically significant. Although early active ROM exercises are essential to prevent restricted ROM, radiographic union was not evident at 4 weeks after OR/IF. Because lateral condyle humeral fracture is an intra-articular fracture, delayed radiographic union is a concern. Thus, if fixation is not reliable for early active ROM exercises, surgeons may choose to leave the fixation with a cast or splint. Although we noted no loss of reduction or malunion in patients in the K-wires group, many patients in that group were unable to perform early active ROM exercises, because of irritation caused by K-wires. We believe that TBW helps provide stable fixation, thereby encouraging early active ROM exercises.

Limitations

This study has some limitations. The most important limitation of this retrospective study is that the duration of follow-up might have been too short to identify a significant loss of flexion in the K-wires group. Although average follow-up was 10 months, the minimum follow-up period was only 3 months. This shorter follow-up was particularly evident in the K-wires group. In addition, the number of patients in both groups was small. Larger sample sizes would increase statistical power and provide a clearer understanding of the benefit of TBW in this surgical procedure.

Overgrowth of the lateral condyle has been noted in previous studies[21-23]. In this series, no patient showed radiographically or clinically apparent lateral overgrowth. While the short follow-up limits the ability to detect long-term problems (eg, growth arrest, fish-tail deformity, cubitus valgus or varus)[8,9,21-24], the absence of lateral overgrowth suggests good outcomes and a low incidence of clinically significant problems. Nevertheless, a longer follow-up is required in order to exclude any late deformities of the injured elbow.

Conclusions

This study evaluated the safety and effectiveness of fixation with TBW and buried K-wires after OR/IF for lateral condyle fracture. Fixation with only 2 K-wires may be inadequate for patients requiring early active ROM exercises, which help prevent elbow joint contracture. TBW with K-wires thus appears to be the optimal method for fixation of lateral humeral condyle fracture.

Acknowledgements: We thank Rebecca Jackson, PhD, from the Edanz Group (www.edanzediting.com/ac) for editing a draft of this manuscript.

Conflict of Interest: None of the authors received financial support for this study. The authors have no conflicts to declare.

References

1. Landin LA, Danielsson LG. Elbow fractures in children. An epidemiological analysis of 589 cases. Acta Orthop Scand. 1986;57:309–12.
2. 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.
3. Foster DE, Sullivan JA, Gross RH. Lateral humeral condylar fractures in children. J Pediatr Orthop. 1985;5:16–22.
4. Andrey V, Tercier S, Vauclair F, Bregou-Bourgeois A, Lutz N, Zambelli PY. Lateral condyle fracture of the humerus in children treated with bioabsorbable materials. Scientific World Journal. 2013;2013:869418.
5. Sharma JC, Arora A, Mathur NC, Gupta SP, Biyani A, Mathur R. Lateral condylar fractures of the humerus in children: fixation with partially threaded 4.0-mm AO cancellous screws. J Trauma. 1995;39:1129–33.
6. Loke WP, Shukur MH, Yeap JK. Screw osteosynthesis of displaced lateral humeral condyle fractures in children: a mid-term review. Med J Malaysia. 2006;61(Suppl A):40–4.
7. Shirley E, Anderson M, Neal K, Mazur J. Screw fixation of lateral condyle fractures: Results of treatment. J Pediatr Orthop. 2015;35:821–4.
8. Thomas DP, Howard AW, Cole WG, Hedden DM. Three weeks of Kirschner wire fixation for displaced lateral condylar fractures of the humerus in children. J Pediatr Orthop. 2001;21:565–9.
9. Song KS, Kang CH, Min BW, Bae KC, Cho CH, Lee JH. Closed reduction and internal fixation of displaced unstable lateral condylar fractures of the humerus in children. J Bone Joint Surg Am. 2008;90:2673–81.
10. 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.
11. Conner AN, Smith MG. Displaced fractures of the lateral humeral condyle in children. J Bone Joint Surg Br. 1970; 52:460–4.
12. Wilson JN. Fractures of the external condyle of the humerus in children. Br J Surg. 1955;43:88–94.
13. Milch H. Fractures and fracture dislocations of the humeral condyles. J Trauma. 1964;4:592–607.
14. Liu CH, Kao HK, Lee WC, Yang WE, Chang CH. Posterolateral approach for humeral lateral condyle fractures in children. J Pediatr Orthop B. 2016;25:153–8.
15. Mohan N, Hunter JB, Colton CL. The posterolateral approach to the distal humerus for open reduction and internal fixation of fractures of the lateral condyle in children. J Bone Joint Surg Br. 2000;82:643–5.
16. Flynn JC, Matthews JG, Benoit RL. Blind pinning of displaced supracondylar fractures of the humerus in children. Sixteen years' experience with long-term follow-up. J Bone Joint Surg Am. 1974;56:263–72.
17. Goldfarb CA, Patterson JM, Sutter M, Krauss M, Steffen JA, Galatz L. Elbow radiographic anatomy: measurement techniques and normative data. J Shoulder Elbow Surg. 2012;21:1236–46.
18. Beals RK. The normal carrying angle of the elbow. A radiographic study of 422 patients. Clin Orthop Relat Res. 1976;119:194–6.
19. 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.
20. Weiss JM, Graves S, Yang S, Mendelsohn E, Kay RM, Skaggs DL. A new classification system predictive of complications in surgically treated pediatric humeral lateral condyle fractures. J Pediatr Orthop. 2009;29:602–5.
21. Hasler CC, von Laer L. Prevention of growth disturbances after fractures of the lateral humeral condyle in children. J Pediatr Orthop B. 2001;10:123–30.
22. Davids JR, Maguire MF, Mubarak SJ, Wenger DR. Lateral condylar fracture of the humerus following posttraumatic cubitus varus. J Pediatr Orthop. 1994;14:466–70.
23. Pribaz JR, Bernthal NM, Wong TC, Silva M. Lateral spurring (overgrowth) after pediatric lateral condyle fractures. J Pediatr Orthop. 2012;32:456–60.
24. Skak SV, Olsen SD, Smaabrekke A. Deformity after fracture of the lateral humeral condyle in children. J Pediatr Orthop B. 2001;10:142–52.

(Received, March 26, 2019)
(Accepted, September 3, 2019)
(J-STAGE Advance Publication, October 15, 2019)