Less common than expected: late displacement after minimally displaced pediatric lateral condyle fractures of the elbow

Robert J. Burkhart[a], David A. Kolin[b], Peter D. Fabricant[b], Raymond W. Liu[a] and R. Justin Mistovich[a,c]

The incidence of late displacement among pediatric lateral condyle fractures has been described as 1.3–26%. However, prior studies are limited by small cohort sizes. The aim of this study was to determine the rate of late displacement and delayed union among lateral condyle fractures following immobilization in a large cohort and to establish additional radiographic criteria to help surgeons choose between immobilization and operative fixation for minimally displaced fractures. We performed a dual-center retrospective study of patients with lateral condyle fractures between 1999 and 2020. Patient demographics, injury mechanism, time to orthopedic presentation, duration of cast immobilization, and complications following casting were recorded. There were 290 patients with lateral condyle fractures included. The initial management in 61% of patients (178/290) was nonoperative, of which four had delayed displacement at follow-up and two developed delayed union requiring surgery (failure in 6/178, 3.4%). The mean displacement on the anteroposterior view was 1.3 ± 1.1 mm and the lateral view was 0.50 ± 1.0 mm in the nonoperative cohort. In the operative cohort, the mean displacement on AP was 6.6 ± 5.4 mm and the lateral view was 5.3 ± 4.1 mm. Our analysis found the rate of late displacement in patients treated with immobilization was lower than previously reported (2.5%; 4/178). The mean displacement on the lateral film in the cast immobilization cohort was 0.5 mm, suggesting that necessitating near anatomic alignment on the lateral film to consider nonoperative management may lead to a lower incidence of late displacement than previously reported. Level of evidence: Level III, retrospective comparative study. *J Pediatr Orthop B* XXX: XXXX–XXXX

Journal of Pediatric Orthopaedics B XXX, **XXX**:XXXX–XXXX

Keywords: casting blind, fracture, late displacement, lateral condyle

[a]Department of Orthopaedic Surgery, Rainbow Babies and Children's Hospital, Case Western Reserve University School of Medicine, Cleveland, Ohio, [b]Department of Orthopaedic Surgery, Hospital for Special Surgery, New York, New York and [c]Department of Orthopaedic Surgery, MetroHealth Medical Center, Case Western Reserve University School of Medicine, Cleveland, Ohio, USA.

Correspondence to R. Justin Mistovich, MD, MBA, Division of Pediatric Orthopaedic Surgery, Rainbow Babies and Children's Hospital, 11100 Euclid Ave, Cleveland, OH 44106, USA
Tel: +1 216 844 5673; fax: +1 216 844 1122; e-mail: justin@mistovich.net

Received 6 September 2022 **Accepted** 1 February 2023.

Introduction

Lateral condyle fractures (LCFs) of the humerus are common among the pediatric population and account for 10–20% of all pediatric upper extremity fractures [1–3]. They most commonly occur in children 4–10 years of age and often result from direct trauma or a fall onto an outstretched hand [4,5]. The optimal treatment for lateral humeral condyle fractures varies based on stability and extent of fracture displacement. There is a consensus that fractures with significant displacement require surgical intervention [6–8]. However, the treatment for minimally displaced fractures remains less well defined.

Several classification systems have been proposed for LCF in an attempt to guide treatment [4,9–11]. The Milch classification was an early anatomical classification that describes the location of the fracture line in relation to the capitellar ossification center [4]. However, this system has been shown to have limited clinical utility [11]. Later classifications such as Jakob *et al.* [10], Rutherford [12], and Finnbogason *et al.* [13] have been suggested but were not adapted toward recommending surgical versus nonsurgical treatment. The Song [9] and Weiss [11] classifications address these issues by utilizing the amount of fracture displacement and stability to determine treatment recommendations. There is general agreement that nondisplaced and minimally displaced (≤2 mm) lateral condyle fractures (Weiss type 1; Song 1–2) can be successfully treated with cast immobilization. However, reportedly up to 26% of minimally displaced lateral condyle fractures further displace despite immobilization [14–20].

Despite the high incidence of late displacement in the reported literature, treating surgeons at our institution did not find this reflected the rates they were experiencing in practice. Therefore, the aim of this study was study was to (1) determine the rate of late displacement among LCF following immobilization at our institution and (2) if different than previously reported, examine our radiographic criteria for operative versus nonoperative management to allow others to potentially replicate our results and improve treatment outcomes.

 DOI: 10.1097/BPB.0000000000001085

Materials and methods

After institutional review board approval, we retrospectively reviewed all children presenting with a lateral humeral condyle fracture at two academic trauma centers between 1999 and 2020. We included all patients who were skeletally immature with a diagnosed LCF. Patients were excluded if they had a history of prior elbow trauma, were lost to follow-up before radiographic or clinical evidence of union, had incomplete records, or had complex elbow polytrauma involving more than an isolated LCF at the time of injury.

Patient demographics were recorded from the electronic medical record including age, sex, time from injury to orthopedic presentation, duration of immobilization, and total follow-up duration. Duration of immobilization was defined as time from the initial orthopedic visit to cast removal. Injury characteristics were extracted from the electronic medical record using operative reports, radiographs, and follow-up office visit notes. Injury variables assessed included the mechanism of injury and fracture displacement on the best anteroposterior (AP) and lateral radiographs obtained on initial films when available.

As our treating surgeons have not universally adopted previously proposed classifications to guide prior treatment, we sought to quantify treatment decisions utilizing available radiographs and simple measurements of displacement. The maximum distance between the humerus and the fracture fragment on each radiographic view was recorded (Fig. 1). We also noted if the maximal displacement was on the intraarticular or extraarticular aspect of the fracture.

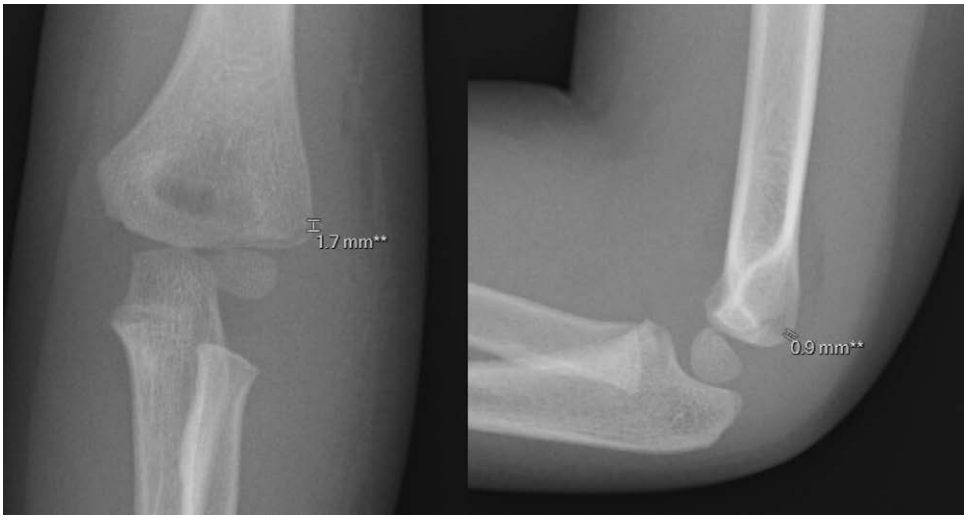
Following the initial orthopedic visit, patients were categorized into nonoperative and operative cohorts and were followed until radiographic union, with any potential complications recorded, including late displacement requiring conversion to operative treatment and delayed union. Delayed union was defined at the discretion of the treating surgeon who determined that the initial intended treatment was failing and required a change in treatment method. Similar to previous methodology, a nonunion was defined as a lack of callus with fragment migration by 8 weeks after initiation of treatment [21].

Statistical analysis

Baseline characteristics of the patients were calculated using means and standard deviations for continuous variables and frequencies and percentages for categorical variables. Comparisons between nonoperatively managed and operative patients were performed using independent t-tests for continuous variables and chi-square tests for categorical variables.

Inter- and intra-rater reliability intraclass correlation (ICC) tests were performed for AP and lateral distance measurements to ensure reliability among the two reviewers. Based on an absolute-agreement, two-way mixed effects model, the ICC was calculated as 0.955 [95% confidence interval (CI): 0.875–0.983] and 0.903 (95% CI: 0.817–0.948), respectively. This indicated excellent reliability between reviewers [22]. SPSS Statistics Version 28.0.0.0 (IBM, Armonk, New York, USA) and R software, version 4.0 (Vienna, Austria) were utilized for all statistical analyses. A P-value of <0.05 was determined to be significant.

Fig. 1



Anteroposterior and lateral radiographs of the elbow demonstrating fracture displacement measurements.

Results

Demographics

Four hundred thirty-nine children were identified with a LCF between 1999 and 2020. A total of 149 children were excluded due to no follow up visit (74 patients), incomplete records (53 patients), complex elbow fracture (not isolated LCF) (18 patients), and prior elbow trauma (4 patients). The final cohort included 290 patients, with 178 (61.4%) in the nonoperative cohort and 112 (38.6%) in the operative cohort (Table 1). The mean (±SD) time from fracture to orthopedic presentation was 4.5 ± 4.0 days. At the time of injury, patients had a mean age of 5.9 ± 3.3 years. The majority of patients were male (204/290; 70.3%). The most common mechanisms of injury were fall from height (72/290, 24.8%), fall off the monkey bars (21/290, 7.2%), and fall off of a bicycle (16/290, 5.5%). Overall, the majority of patients sustained a LCF due to a fall (181/290, 62.4%). The mean duration of cast immobilization in the nonoperative cohort was 3.8 ± 1.2 weeks. The mean follow-up time for overall cohort was 6.1 ± 3.6 weeks.

Nonoperative versus operative management

Patients in the nonoperative and operative groups had similar age distributions ($P = 0.53$), but operative patients were more likely to be male than nonoperative patients (70.3% vs. 63.0%, $P = 0.001$). Time to clinical presentation was significantly shorter for operatively treated patients than nonoperatively managed patients (3.5 vs. 5.0 days, $P = 0.01$). Both AP and lateral displacement were greater in the operatively managed patients ($P < 0.001$ for both comparisons) (Fig. 2). The mean displacement on AP view was 1.3 ± 1.1 mm and lateral view was 0.50 ± 1.0 mm in the nonoperative cohort. In the operative cohort, the mean displacement on AP was 6.6 ± 5.4 mm and lateral view was 5.3 ± 4.1 mm. All patients in the surgical cohort healed with no reported postoperative complications.

Complications of nonoperative management

There were four (4/178, 2.2%) instances of late displacement amongst nonoperatively treated patients. The first patient, who fell while trampolining, had displacement of 1.6 mm on AP radiographs and 2.1 mm of displacement on lateral radiographs (Fig. 3). The second patient, who fell off a slide, had displacement of 2.1 mm on AP radiographs and 0.65 mm of displacement on lateral radiographs. The remaining two patients did not have radiographs available. In all four cases, the late displacement was documented at the first follow up visit with an average of 1.8 weeks from initial presentation.

There were two events of delayed union (2/178, 1.1%) amongst patients treated with casting. The initial injury films of the first patient revealed no displacement on lateral radiographs and 2.6 mm of displacement on AP radiographs. The patient was identified at 10 weeks follow-up visit with limited range of motion and incomplete radiographic healing and was ultimately converted to an open surgical approach. A second patient was identified as a delayed union at 8.6 weeks. He had no displacement on the lateral and 1.8 mm displacement on AP radiographs. This patient was scheduled to return to clinic 2 weeks later for surgical evaluation but was lost to follow up.

Discussion

The optimal treatment and outcomes for pediatric lateral condyle fractures have been extensively discussed in the literature. When conservative treatment is indicated, current literature recommendations necessitate close follow-up due to the potential for complications such as late displacement and nonunion. Our study sought to evaluate the incidence of late displacement and delayed union among lateral condyle fractures following immobilization in a large patient cohort. We found the rate of late displacement and delayed union in patients treated with immobilization was 2.2 and 1.1%, respectively. Additionally, we found a mean displacement on AP view was 1.3 mm and lateral view of 0.50 mm was associated with the low incidence of late displacement among the nonoperative cohort. These simple measurements of maximal AP and lateral displacement had a high inter-rater reliability, and can be integrated into treatment decision making for surgeons facing fractures that border between operative and nonoperative management.

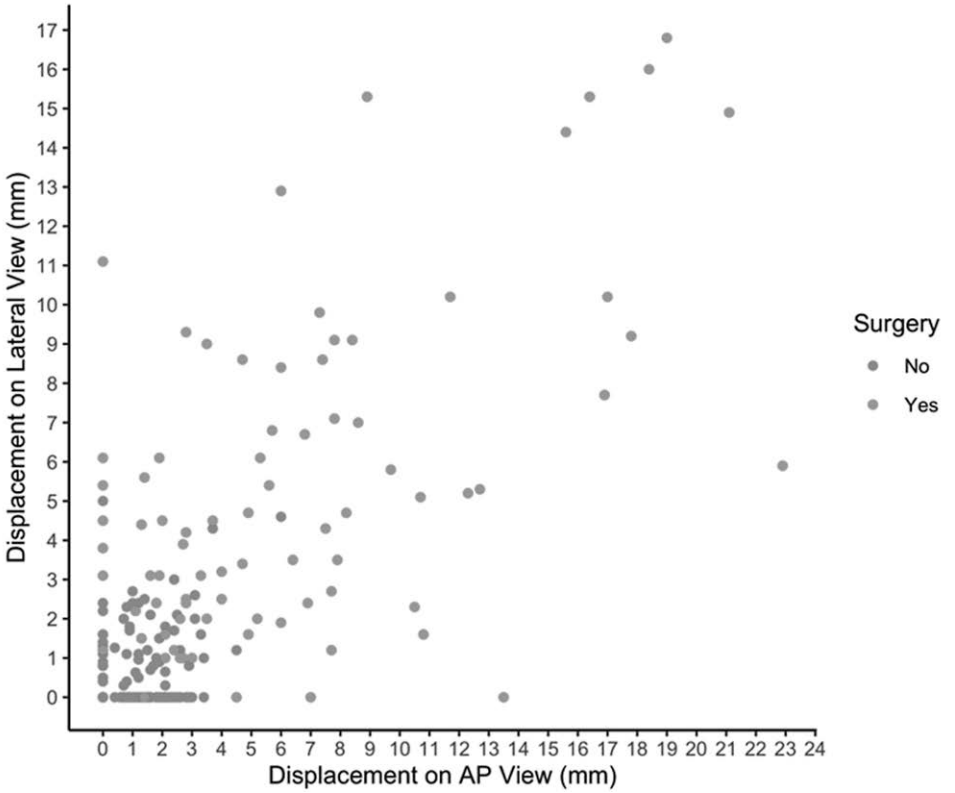
There has been variable reporting on the rate of late displacement in the literature. A systematic review by Knapik *et al.* found the incidence of late displacement among minimally displaced fractures treated with immobilization was 14.9% [18]. Other studies have reported rates of displacement ranging from 1.3% to 26% [14–17,19,20]. Among 114 LCF treated with casting, Greenhill and colleagues identified a displacement rate of 5 and 18% among Song 1 and 2 fractures, respectively. The authors found fracture extension into

Table 1 Patient demographics and injury characteristics

	All patients ($n = 290$)	Nonoperatively managed ($n = 178$)	Operatively managed ($n = 112$)	*P*-value
Age, years (SD)	5.9 (3.3)	5.8 (3.2)	6.0 (3.0)	0.53
Sex, male (%)	204 (70.3)	113 (63.0)	91 (81.0)	0.001
Time from injury to clinical presentation, days (SD)	4.5 (4.0)	5.0 (4.0)	3.5 (4.3)	0.01
Radiographic measures[a]				
AP view displacement, mm (SD)	3.1 (4.2)	1.3 (1.1)	6.6 (5.4)	<0.001
Lateral view displacement, mm (SD)	2.2 (3.4)	0.5 (1.0)	5.3 (4.1)	<0.001

[a]Radiographic measurements unavailable for 51 patients.

Fig. 2



Nonoperative and operative management based on fracture displacement on radiographs.

the epiphyseal cartilage and presence of a lateral gap (resembling Song stage 2) was associated with higher rates of displacement. Studies by Finnbogason *et al*. and Thonell *et al*. had similar findings with a displacement rate of 20.7 and 24.1% among minimally displaced Song 2 fractures [13,23]. However, both studies noted a much lower displacement rate of 2.6 and 0% for Song type 1 fractures. The results of our study, which is among the largest on this subject, fall in the lower range of the reported literature with only 2.2% (4/178) patients undergoing late displacement following immobilization. Our analysis found displacement on the lateral film in the cast immobilization cohort was 0.5 mm, suggesting near anatomic alignment on the lateral film (similar to Song 1) may lead to a lower incidence of late displacement than previously reported. Basts *et al*. reported a near equal rate of late displacement of 2.1% (2/95 patients) among LCF with <2 mm maximal displacement reported on AP, lateral, or internal oblique [15].

The average time until late displacement (1.8 weeks) among our immobilization cohort was similar to previous findings in the literature. Piker *et al*. and Greenhill *et al*. identified late displacement among patients at 1 week follow up [5,14]. Our late displacement patients were identified around 2 weeks, suggesting a single additional follow-up at 2 weeks may be sufficient to capture the majority of cases of late displacement. However, in settings with limited or finite resources, consideration may be given to follow up for all patients at 1 month after casting given the low incidence of late displacement and high number of follow up visits and radiographs necessary to detect a single late displacement, accepting that about 2 patients per 100 may require late open reduction and internal fixation.

Complications other than late displacement are relatively rare after acute treatment of minimally displaced LCF [18,21]. In a systematic review of the literature, Knapik *et al*. identified only two studies reporting on complications and found a nonunion rate of 7/45 patients (14.5%). In contrast, our study identified two cases of delayed union (2/178, 1.1%) following immobilization and zero cases of nonunion (0/290) reported among operative and nonoperative cohorts. These low complication rates are supported by similarly powered studies in the current literature. Greenhill *et al*. found zero cases of delayed union or nonunion among 94 patients with casting and 45 patients treated with in situ pinning or closed reduction and percutaneous pinning (CRPP). Likewise, a large retrospective study performed by Pace *et al*. identified 1.4% (7/500) patients went on to develop nonunion [21].

Fig. 3

(a) Anteroposterior and lateral radiographs of the elbow at initial office visit. (b) Anteroposterior and lateral radiographs demonstrating late displacement at 1.5 week follow-up visit following nonoperative treatment.

Several classification systems have been used to describe LCFs and guide treatment. Song [9] and Weiss [11] are two popular classifications that utilize the amount of fracture displacement and stability to determine treatment recommendations. Song *et al*. created a five-stage system that classifies fractures by stability, pattern, and fracture displacement utilizing a cutoff of 2 mm. Under this treatment algorithm, any fracture with >2 mm of displacement on internal oblique or AP radiographs (stage 4–5) should be treated operatively (i.e. CRPP or ORIF). Similarly, Weiss *et al*. created a three-type classification system that sorts fractures by displacement and stability. There is general agreement that nondisplaced and minimally displaced (≤2 mm) LCFs (Weiss type 1; Song 1–2) can be successfully treated with cast immobilization.

While we do not argue the potential utility of these existing classification schema, they have not been regularly applied in our clinical practices (though we do understand that some surgeons may use them). To better quantify our approach, we simply measured the maximal displacement on AP and lateral radiographs. The mean displacement on AP view was 1.3 ± 1.1 mm and lateral view was 0.50 ± 1.0 mm in the nonoperative cohort. In the operative cohort, the mean displacement on AP was 6.6 ± 5.4 mm and lateral view was 5.3 ± 4.1 mm. In light of the previous studies examining late displacement, we suggest that near anatomic alignment on the lateral (<0.5 mm displacement) for nonoperative management may be associated with our lower incidence of late displacement. Utilizing these displacement measurements alongside the established Weiss and Song classification may allow for additional treatment guidance for minimally displaced LCF.

Our study does have several limitations. First, biases related to the retrospective study design should be considered. Uncontrolled confounding exists due to the non-randomized nature of our study design. Second, the variation in practice among the orthopedic team over

the 20-year study period should be considered. Guidelines for nonoperative and operative management may have subtly evolved over the years, both collectively and by individual surgeons. Lastly, our analysis was limited by the radiographs available. A significant number of patients had no available AP or lateral radiographs. Follow-up radiographs were often taken while patients were still in their cast, which may compromise the accuracy of measuring fracture displacement [24]. Internal oblique films were also rarely available for any injury films, which Song *et al*. demonstrated can be an important data point in deciding between nonoperative and operative management. The absence of internal oblique radiographs may underestimate the displacement [9]. Despite these limitations, our study represents one of the largest in the literature investigating treatment outcomes following LCFs.

Conclusion

The rate of complications for nonoperative treatment of minimally displaced fractures is variable in the literature. Our analysis found the rate of subsequent displacement in patients treated with immobilization was lower than previously reported (4/178, 2.2%). Additionally, we identified two delayed unions among the nonoperative cohort (2/178, 1.1%) and found zero cases of nonunion among operative and nonoperative cohorts. In addition to current classification systems, we found that a mean displacement on AP view of 1.3 mm and lateral view of 0.50 mm in the nonoperative cohort was associated with a low incidence of late displacement and is a simple parameter to measure with high inter-rater reliability.

Acknowledgements

Ethical committee approval: This study was approved by the University Hospital Institutional Review Board Committee (UH IRB# STUDY20200287).

Conflicts of interest

P.D.F. – Clinical Orthopaedics and Related Research: editorial or governing board; Pediatric Orthopaedic Society of North America: board or committee member; Research in OsteoChondritis of the Knee (ROCK): board or committee member; WishBone Orthopedics: paid consultant. R.W.L. – AAOS: board or committee member; Journal of Pediatric Orthopedics: editorial or governing board; Publishing royalties, financial or material support; Limb Lengthening and Reconstruction Society (LLRS): board or committee member; Orthopediatrics – Royalties paid to my university: IP royalties; Pediatric Orthopaedic Society of North America: board or committee member. R.J.M. – Pediatric Research in Sports Medicine: board or committee member. For the remaining authors, there are no conflicts of interest.

References

1 Tejwani N, Phillips D, Goldstein RY. Management of lateral humeral condylar fracture in children. *J Am Acad Orthop Surg* 2011; **19**:350–358.
2 Leonidou A, Chettiar K, Graham S, Akhbari P, Antonis K, Tsiridis E, *et al*. Open reduction internal fixation of lateral humeral condyle fractures in children. A series of 105 fractures from a single institution. *Strategies Trauma Limb Reconstr* 2014; **9**:73–78.
3 Landin LA, Danielsson LG. Elbow fractures in children. An epidemiological analysis of 589 cases. *Acta Orthop Scand* 1986; **57**:309–312.
4 Milch H. Fractures and fracture dislocations of the humeral condyles. *J Trauma* 1964; **4**:592–607.
5 Pirker ME, Weinberg AM, Höllwarth ME, Haberlik A. Subsequent displacement of initially nondisplaced and minimally displaced fractures of the lateral humeral condyle in children. *J Trauma* 2005; **58**:1202–1207.
6 Badelon O, Bensahel H, Mazda K, Vie P. Lateral humeral condylar fractures in children: a report of 47 cases. *J Pediatr Orthop* 1988; **8**:31–34.
7 Flynn JC. Nonunion of slightly displaced fractures of the lateral humeral condyle in children: an update. *J Pediatr Orthop* 1989; **9**:691–696.
8 Hardacre JA, Nahigian SH, Froimson AI, Brown JE. Fractures of the lateral condyle of the humerus in children. *J Bone Jt Surg* 1971; **53**:1083–1095.
9 Song KS, Chul HK, Byung WM, Ki CB, Chul HC, Ju HL. Closed reduction and internal fixation of displaced unstable lateral condylar fractures of the humerus in children. *J Bone Joint Surg Am* 2008; **90**:2673–2681.
10 Jakob R, Fowles JV, Rang M, Kassab MT. Observations concerning fractures of the lateral humeral condyle in children. *J Bone Jt Surg* 1975; **57**:430–436.
11 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**:602–605.
12 Rutherford A. Fractures of the lateral humeral condyle in children. *J Bone Jt Surg* 1985; **67**:851–856.
13 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**:422–425.
14 Greenhill DA, Funk S, Elliott M, Jo CH, Ramo BA. Minimally displaced humeral lateral condyle fractures: immobilize or operate when stability is unclear? *J Pediatr Orthop* 2019; **39**:e349–e354.
15 Bast SC, Hoffer MM, Aval S. Nonoperative treatment for minimally and nondisplaced lateral humeral condyle fractures in children. *J Pediatr Orthop* 1998; **18**:448–450.
16 Janzen S, von Kalle T, Wirth T, Fernandez Fernandez F. Frequency of secondary dislocations of initially non displaced and minimally displaced fractures of the lateral humeral condyle in children - surveillance of a treatment algorithm. *Z Orthop Unfall* 2020; **158**:51–57.
17 Zale C, Winthrop ZA, Hennrikus W. Rate of displacement for Jakob Type 1 lateral condyle fractures treated with a cast. *J Child Orthop* 2018; **12**:117–122.
18 Knapik DM, Gilmore A, Liu RW. Conservative management of minimally displaced (≤2 mm) fractures of the lateral humeral condyle in pediatric patients: a systematic review. *J Pediatr Orthop* 2017; **37**:e83–e87.
19 Edmonds EW, Bland DC, Bastrom TP, Smith MM, Upasani V, Yaszay B, *et al*. Minimally displaced pediatric humerus lateral condyle fractures: risk factors for displacement and outcomes of delayed surgery. *J Pediatr Orthop B* 2021; **30**:167–173.
20 James V, Chng ACC, Ting FLM, Huak Chan Y, Ganapathy S. Lateral condyle fracture of the humerus among children attending a pediatric emergency department: a 10-year single-center experience. *Pediatr Emerg Care* 2021; **37**:E1339–E1344.
21 Pace JL, Arkader A, Sousa T, Broom AM, Shabtai L. Incidence, risk factors, and definition for nonunion in pediatric lateral condyle fractures. *J Pediatr Orthop* 2018; **38**:e257–e261.
22 Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med* 2016; **15**:155–163.
23 Thönell S, Mortensson W, Thomasson B. Prediction of the stability of minimally displaced fractures of the lateral humeral condyle. *Acta Radiol* 2016; **29**:367–370.
24 Ho CA, Mehlman CT. The community orthopaedic surgeon taking trauma call: lateral humeral condyle fracture pearls and pitfalls. *J Orthop Trauma* 2019; **33**:S12–S16.