Acta Orthop. Belg., 2022, **88**, 237-244

ORIGINAL STUDY

doi.org/ 10.52628/88.2.8595

Reliability of radiological measurements and treatment recommendations of displaced paediatric humeral medial epicondyle fractures

Christoph Arneitz, Christoph Castellani, Sebastian Tschauner, Johannes Schalamon, Georg Singer, Holger Till

From the Department of Paediatric and Adolescent Surgery, Medical University of Graz, Graz, Austria

There are conflicting recommendations regarding the amount of displacement necessitating stabilization of paediatric humeral medial epicondyle fractures. Our aim was to assess the reliability of the measurements of the displacement and the treatment recommendations of these fractures. The maximum displacement of 57 children with displaced humeral medial epicondyle fractures was analyzed on radiographs by six raters (4 paediatric surgeons, 2 paediatric radiologists) at two time points. In addition, the four surgeons recorded their treatment recommendation. Intraobserver and interobserver reliability were calculated with intraclass correlation coefficients (ICC) and Kappa values. The ICC for the intraobserver reliability ranged between 0.67 and 0.93. The raters disagreed with their own measurements between 8.8% and 28.1%. The ICC for the interobserver reliability of all six raters was 0.90 for measurement 1 and 0.93 for measurement 2. All six raters disagreed (difference > 2mm) in 93% of the cases in measurement 1 and in 91.2% in measurement 2. Treatment recommendations of the four paediatric surgeons between the two time points differed in 5.3% to 28.1% of the cases. Furthermore, the treatment recommendations were concordant in 24 cases (42%) at time point 1 and 32 cases (56.1%) at time point 2. In displaced paediatric medial epicondyle fractures, disagreement regarding measurement of displacement and recommendation for treatment is high. Validated and standardized measurement tools and a clear threshold for operative fixation of displaced medial epicondyle fractures are needed.

Conflict of Interest: The authors declare no conflict of interest.
Funding: No funding was received for this study.

Keywords: Intraobserver and interobserver reliability, paediatric humeral medial epicondyle fractures

INTRODUCTION

The medial humeral epicondyle is an apophysis serving as origin and insertion of several key components of the elbow joint. The epicondyle provides a bony anchor for the ulnar collateral ligaments and serves as origin of the flexor mass of the forearm *(1)*.

In children and adolescents, fractures of the humeral medial epicondyle account for about 10% of elbow fractures and the annual incidence has been described with 12/10,000 *(2)*. There is a clear male predominance with a male to female ratio of 3:1 and a peak between 9 to 14 years of age *(3)*.

- Christoph Arneitz[1], MD
- Christoph Castellani[1], Assoc. Prof.
- Sebastian Tschauner[2], MD[2]
- Johannes Schalamon[1], Univ.-Prof.
- Georg Singer[1], Assoc. Prof.
- Holger Till[1], Univ.-Prof.

[1]*Department of Paediatric and Adolescent Surgery, Medical University of Graz, Graz, Austria.*
[2]*Division of Paediatric Radiology, Department of Radiology, Medical University of Graz, Graz, Austria.*

Correspondence :Assoc. Prof. Christoph Castellani, Department of Paediatric and Adolescent Surgery, Medical University of Graz, Auenbruggerplatz 34, 8036 Graz, Austria. Phone: 0043/316/385/13762. Fax: 0043/316/385/13775.

Email: christoph.castellani@medunigraz.at

There is consensus in the literature that undisplaced or minimally displaced (< 2 mm) fractures of the medial humeral epicondyle can be treated non-operatively in a long-arm cast for three to four weeks *(4)*. Open fractures and intra-articular incarceration of the epicondyle are absolute indications for open reduction and fixation. Furthermore, high energy trauma mechanism, ulnar neuropathy, elbow instability, and significant displacement have been described as indications for operative treatment *(5)*. However, there are conflicting recommendations regarding the amount of displacement necessitating surgical intervention. There are reports advocating fixation of fractures with as little as 2 mm and 5 mm displacement, respectively *(6,7)*. In contrary, successful non-operative treatment has been demonstrated for lesions with displacement of up to 15 mm *(8,9)*.

Taken together, there is great variability in the indication for a surgical approach for these fractures with displacement ranging between 2 and 15 mm *(2)*. A reliable result of the measurement of displacement is a prerequisite to indicate operative treatment. However, Pappas and coworkers have recently shown that both the intraobserver and interobserver agreement in the measurement of the displacement of humeral medial epicondyle fractures is low even for experienced orthopedic surgeons *(10)*. These findings cast doubts if the fracture displacement alone is a reliable decision tool to indicate operative or non-operative management.

The aim of the present study was to assess both the intraobserver and interobserver agreement of the measurements of the displacement of paediatric humeral medial epicondyle fractures performed by paediatric surgeons and paediatric radiologists with various levels of training. Moreover, the degree of agreement concerning treatment recommendations (non-operative versus operative) of paediatric surgeons was evaluated.

MATERIALS AND METHODS

Following approval of the institutional review board, digital antero-posterior (ap) and lateral radiographs of 57 paediatric patients (mean age 11.3 years, range 4 to 17 years) with displaced humeral medial epicondyle fractures were retrospectively analyzed by six separate independent reviewers (measurement 1). These included four paediatric surgeons (two fellows and two senior attending paediatric surgeons with at least four years experience in paediatric trauma) and two fully trained paediatric radiologists. Using the measurement tool of synedra View Personal® (Version 17, synedra information technologies GmbH, Innsbruck, Austria) each reviewer was instructed to measure and record the maximum displacement of the medial epicondyle in millimeters. Additionally, the four paediatric surgeons were requested to record their treatment recommendation (non-operative versus operative).

In order to assess the intraobserver reliability, all 57 radiographs were re-evaluated a second time by all six reviewers after six weeks (measurement 2). Again, maximum displacement of the medial humeral epicondyle (six reviewers) and treatment recommendation (four paediatric surgeons) were assessed.

At all times, reviewers were blinded to the patients' names and medical records.

Absolute values of the displacement measurements are displayed as means, standard deviation and range. For statistical analysis SPSS® statistical package version 21 (SPSS Inc, Chicago, IL) was used, if not otherwise mentioned. To assess intraobserver reliability, intraclass correlation coefficients (ICC) estimates and their 95% confident intervals were calculated based on a single measure, absolute agreement, two way mixed-effects model. Interobserver reliability was assessed with ICC(2,*k*) estimates and their 95% confident intervals based on a mean of k raters, absolute agreement, two way random-effects model.

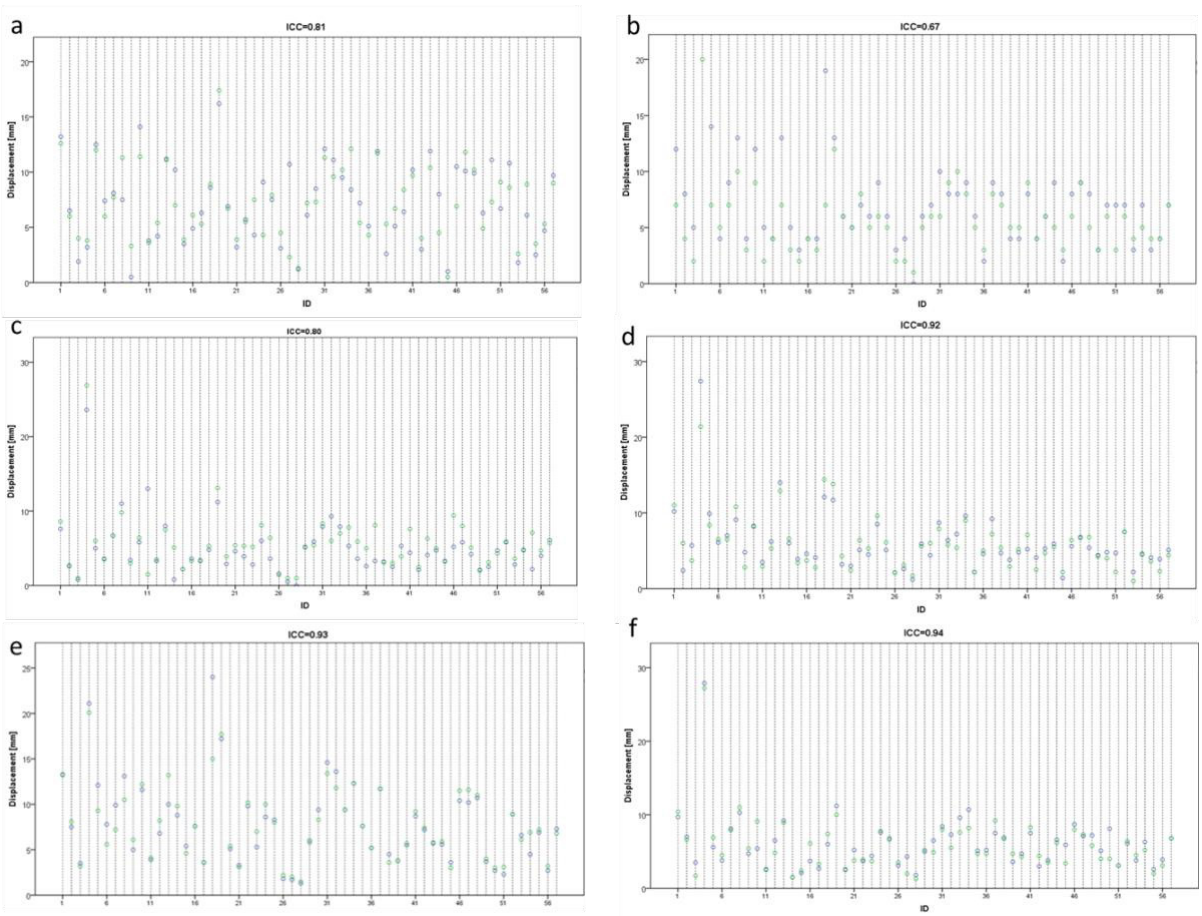
Additionally, clinical disagreement of the different measurements of displacement was defined as ratings differing more than 2 mm as described before *(10)*.

Intrarater variability of the treatment recommendations of the paediatric surgeons at the two time points was calculated with Cohen's Kappa. Sankey diagrams were drawn with RStudio Version 1.2.1335 (RStudio Inc., Boston, MA, USA) using the sankeyNetwork function of the networkD3 package version 0.4.

Table 1. — Measurement of displacement in mm, ICC for intraobserver agreement, and percentage of disagreement of 57 humeral medial epicondyle fractures assessed by six different raters at two time points

	PS1 (Senior Attending)	PS2 (Senior Attending)	PS3 (Fellow)	PS4 (Fellow)	PR1	PR2
Measurement 1 mean (SD) range	 7.3 (3.7) 0.5-16.2	 7.4 (5.6) 0-40	 4.9 (3.6) 0-23.6	 7.8 (4.6) 1.3-24.0	 6.0 (3.9) 1.2-26.2	 6.1 (3.8) 1.2-28.0
Measurement 2 mean (SD) range	 7.1 (3.3) 0.5-17.4	 5.7 (3.0) 1.0-20.0	 5.5 (3.8) 1.0-26.9	 7.8 (4.0) 1.5-20.1	 5.9 (3.6) 1.0-21.4	 5.8 (3.7) 1.3-27.2
ICC for intraobserver agreement (95% Cl)	0.81 (0.70-0.88)	0.67 (0.44-0.81)	0.80 (0.68-0.88)	0.93 (0.88-0.96)	0.92 (0.88-0.96)	0.94 (0.90-0.97)
Intraobserver disagreement (%)	28.1%	26.3%	26.3%	12.3%	8.8%	10.5%

PS...paediatric surgeon, PR...paediatric radiologist, SD...standard deviation, ICC…intraclass correlation coefficient, Cl...confidence interval.



Supplementary Figure 1. — ICC plots for the six different raters as well as ICC for intraobserver agreement for each rater (a…PS1, b…PS2; c…PS3, d…PS4, e…PR1, f…PR2).

To assess the interrater variability of the treatment recommendations of the four paediatric surgeons, Fleiss Kappa values were computed with RStudio using the kappam.fleiss function of the IRR package version 0.84.1.

RESULTS

The displacement of the humeral medial epicondyle fractures was measured two times by six reviewers. The mean results of the two measurements of the displacement of the humeral medial epicondyle fractures performed by the six examiners are shown in Table I. The intraclass correlation coefficient (ICC) for the intraobserver reliability was 0.81 and 0.67 for the attending paediatric surgeons, 0.80 and 0.93 for the fellows and 0.92 and 0.94 for the paediatric radiologists, respectively. ICC plots for the six different raters are depicted in Supplementary Figure 1. The reviewers disagreed with their own measurements between 8.8% and 28.1% (Table I). While the paediatric surgeons achieved values between 12.3% and 28.1%, the percentage of disagreement (difference > 2 mm between measurements) of the two paediatric radiologists was 8.8% and 10.5%.

The ICC for the interobserver reliability of all six raters was 0.90 (95% CI 0.84-0.93) for measurement 1 and 0.93 (95% CI 0.89-0.95) for measurement 2, respectively. Figure 1 depicts an ICC plot for the measurements of all raters at both time points. Nevertheless, applying a cut-off of 2 mm, all six raters disagreed in 93% of the cases in measurement 1 and in 91.2% in measurement 2. The interobserver ICCs at both time points and the percentage of disagreement of the four paediatric surgeons, the two seniors, the two fellows and the two paediatric radiologists are displayed in Table

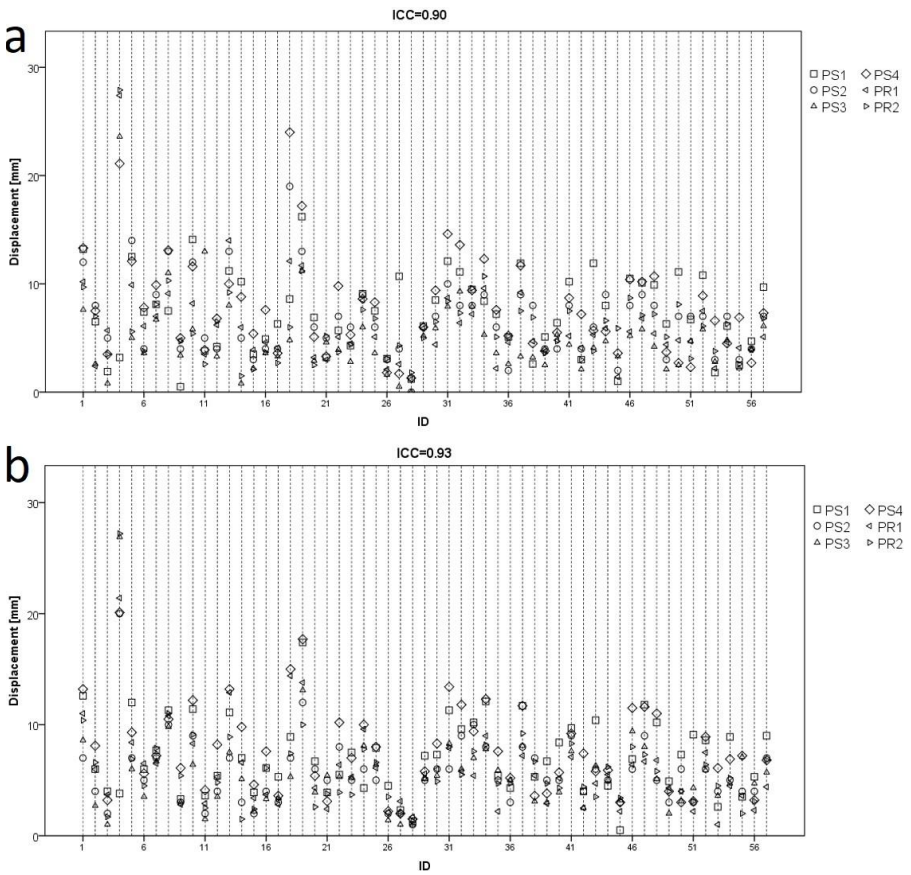


Figure 1. — ICC plot for the measurements of all six raters at both time points (a…measurement 1, b…measurement 2).

Table II. — ICC for interobserver agreement and percentage of disagreement (defined as a difference greater than 2 mm between measurements) of the different raters.

	PS1-PS4	PS1&PR2 (Senior Attendings)	PS3&PR4 (fellows)	PR1&PR2
Measurement 1 ICC for intraobserver agreement (95% CI)	0.80 (0.69-0.88)	0.44 (0.04-0.67)	0.65 (0.13-0.83)	0.92 (0.86-0.95)
Measurement 2 ICC for intraobserver agreement (95% CI)	0.86 (0.77-0.92)	0.65 (0.37-0.80)	0.81 (0.31-0.92)	0.91 (0.85-0.95)
Measurement 1 Interobserver disagreement (%)	89.5%	42.1%	64.9%	29.8%
Measurement 2 Interobserver disagreement (%)	91.2%	43.9%	54.4%	21.1%

PS...paediatric surgeon, PR...paediatric radiologist, CI…Confidence Interval

Table III. — Number and percentage of non-operative or operative treatment recommendations and their respective displacement (mean and range) of the four paediatric surgeons at the two separate time points; a total of 57 radiographs of displaced humeral medial epicondyle fractures were included

	Measurement 1		**Measurement 2**	
	non-operatively	operatively	non-operatively	operatively
PS1	n=16 (28%) 2.8 mm (0.5-4.9)	n=41 (72%) 9 mm (4.7-16.2)	n=26 (45.6%) 4.8 mm (0.5-9.6)	n=31 (54.4%) 9.1 mm (2.3-17.4)
PS2	n=22 (38.6%) 3.6 mm (0-5)	n=35 (61.4%) 9.7 mm (6-40)	n=20 (35.1%) 3 mm (1-4)	n=37 (64.9%) 7.1 mm (5-20)
PS3	n=35 (61.4%) 3 mm (0-4.8)	n=22 (38.6%) 7.4 mm (2.6-23.6)	n=23 (40.4%) 2.9 mm (1-4.7)	n=34 (59.6%) 7.3 mm (3-26.9)
PS4	n=11 (19.3%) 2.8 mm (1.3-3.8)	n=46 (80.7%) 9.1 mm (3.6-24)	n=13 (22.8%) 3 mm (1.5-4)	n=44 (77.2%) 9.2 mm (4.1-20.1)

II. Example radiographs of two measurement are shown in Figure 3.

Treatment recommendations of the four paediatric surgeons and the respective displacement of the fractures for both time points are shown in Table III. Treatment recommendations between time point 1 and 2 differed in 21.2% (n=12) for PS1, 10.5% (n=6) for PS2, 28.1% (n=16) for PS3 and 5.3% (n=3) for PS4. The corresponding Cohen´s Kappa values are 0.56, 0.77, 0.46 and 0.90 for the four raters. Figure 2 depicts a Sankey diagram showing the amount of disagreement between the time points for each rater.

All four raters gave concordant treatment recommendations in 24 out of 57 cases (42%) at time point 1 and 32 out of 57 cases (56.1%) at time point 2. The corresponding Fleiss Kappa values were 0.33 and 0.49 for measurement 1 and 2, respectively.

DISCUSSION

The results of the present study reveal that both the measurements of displacement as well as the resulting treatment recommendations of displaced medial epicondyle fractures in paediatric patients are highly variable between different raters.

Following supracondylar, radial neck and lateral condyle fractures, fractures of the medial humeral epicondyle are the fourth most common fractures of the paediatric elbow. They have been described to constitute about 10% of elbow fractures and are therefore relatively rarely encountered lesions *(11)*.

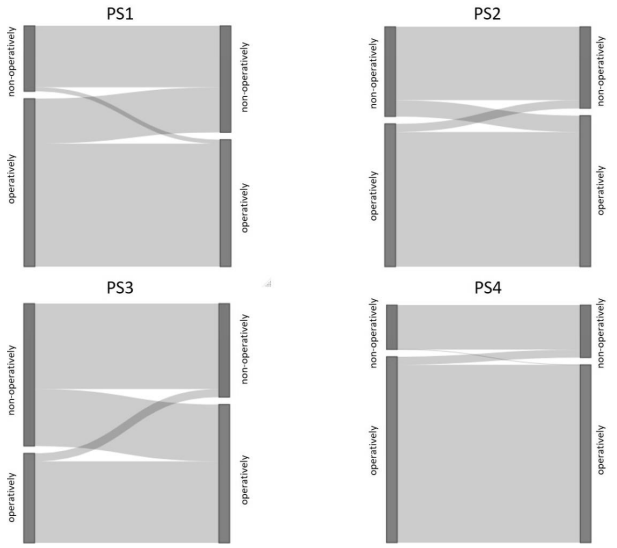


Figure 2. — Sankey diagram showing the amount of disagreement between the two time points for each of the six raters.

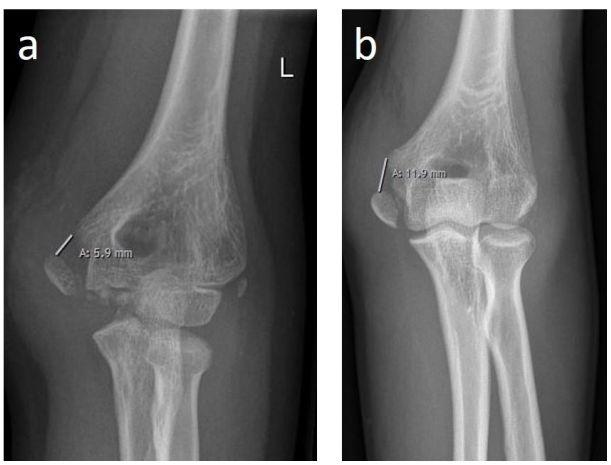


Figure 3. — Example antero-posterior radiographs; a: 10-year-old girl with a displaced humeral medical epi condyle fracture, measurements ranged from 5.2 to 6.1 mm (measurement 1) and 5 to 6.8 mm (measurement 2) and were rated as clinical agreement; b: 15-year-old boy with a displaced humeral medical epicondyle fracture, measurements ranged from 7.5 to 11.9 mm (measurement 1) and 7.2 to 11.7 mm (measurement 2) and were rated as clinical disagreement.

While the possibility of conservative treatment of non-displaced fractures is undisputed, the amount of displacement demanding surgical reduction and fixation is currently unknown *(5)*. Despite missing data about the clinical significance, most published reports have applied displacement limits ranging between 2 and 5 mm *(6,7,12)*. However, there are reports describing a favorable outcome in patients with even more displacement. For instance, Axibal et al. have compared 22 operatively treated to 22 matched non-operatively treated participants with a mean displacement of 9.7 mm in both groups and have found no differences in the length of immobilization as well as median time to gain full range of motion *(13)*.

In addition to the aforementioned debate concerning the threshold of the displacement of humeral epicondyle fractures, measurements of the displacement itself seem to be highly variable. Pappas and coworkers have noticed low interobserver and intraobserver agreements comparable to our findings *(10)*. In their study, the displacement of 39 paediatric medial epicondyle fractures was rated by five separate reviewers with various levels of orthopedic training. Ten of the 39 radiographs were measured a second time. The ICC for intraobserver reliability ranged from 0.24 to 0.98 and the ICC for interobserver reliability was 0.8 *(10)*. The values of the present study (intraobserver ICC ranging between 0.67 and 0.94; interobserver ICC 0.9 and 0.93 for measurement 1 and 2, respectively) are comparable to this data. Nevertheless, these results underline the fact that a standardized and validated system for measuring fracture displacement of humeral medial epicondyle fractures is needed. As a prerequisite, however, the normal anatomical location of the medial humeral epicondyle should be defined and displacement should be measured as the maximum distance between the fragment and its normal location *(10,14)*. Gottschalk and coworkers recommend standardized 45 degrees oblique radiographs to improve intraobserver and interobserver reliability *(15)*. Nevertheless, these views were not included in the standard radiographic examinations of humeral medial epicondyle fractures in our Department and were therefore not available for the present study.

Another interesting finding of the present study is the considerable variability of treatment recommendations between the different raters. In another available report, Hughes and colleagues have performed a discrete choice experiment with a convenience sample of 13 paediatric orthopedic surgeons reviewing 60 cases of medial epicondyle

fractures *(16)*. The surgeons were queried whether they would treat the injury operatively or non-operatively. 54% of the surgeons preferred ORIF (open reduction and internal fixation) over conservative treatment for the included 60 scenarios; for every millimeter increase in displacement, the surgeons tended to ORIF by a factor of 0.09 *(16)*. Comparable to our results, there was also substantial variation among the surgeons when treating the fractures and the decision to operate was significantly based on the degree of displacement and if there was a concomitant elbow dislocation *(16)*.

The present examination, however, has only focused on displacement and the raters were not informed whether or not there was a concomitant elbow dislocation. Therefore, we are not able to examine whether other factors, besides concomitant elbow dislocation, such as trauma mechanism, elbow stability and expected high-level physical over-head activity – which all have been discussed as indications for operative treatment *(17)* – influence the surgeon´ treatment recommendation.

A possible limitation of the present study is the inclusion of a relatively small number of patients and its retrospective design. Nevertheless, all 57 radiographs were measured a second time by all six reviewers. Additionally, the defined disagreement level of 2 mm is arbitrary and was chosen to be able to compare our results to formerly published studies *(10)*. The strengths of this study include the number of investigators, including four paediatric surgeons with different level of training and two paediatric radiologists as well as the implementation of the intrarater and interrater variability of the treatment recommendations.

CONCLUSION

The results of the present study confirm other reports describing that even experienced examinators have a high level of disagreement in the displacement measurement and treatment recommendation of medial epicondyle fractures *(10,16)*. Therefore, both validated and standardized measurement tools as well as a clear threshold for reduction and fixation of displaced medial epicondyle fractures in paediatric and adolescent patients are needed and subject for future studies.

REFERENCES

1. Fuss FK. The ulnar collateral ligament of the human elbow joint. Anatomy, function and biomechanics. J Anat. 1991;175:203-212.
2. Firth AM, Marson BA, Hunter JB. Paediatric medial humeral epicondyle fracture management: 2019 approach. Curr Opin Pediatr. 2019;31(1):86-91.
3. Gottschalk HP, Eisner E, Hosalkar HS. Medial epicondyle fractures in the pediatric population. J Am Acad Orthop Surg. 2012;20(4):223-232.
4. Pathy R, Dodwell ER. Medial epicondyle fractures in children. Curr Opin Pediatr. 2015;27(1):58-66.
5. Beck JJ, Bowen RE, Silva M. What's new in pediatric medial epicondyle fractures? J Pediatr Orthop. 2018; 38(4):e202-e206.
6. Hines RF, Herndon WA, Evans JP. Operative treatment of medial epicondyle fractures in children. Clin Orthop Relat Res. 1987(223):170-174.
7. Lee HH, Shen HC, Chang JH, Lee CH, Wu SS. Operative treatment of displaced medial epicondyle fractures in children and adolescents. J Shoulder Elbow Surg. 2005;14(2):178-185.
8. Farsetti P, Potenza V, Caterini R, Ippolito E. Long-term results of treatment of fractures of the medial humeral epicondyle in children. J Bone Joint Surg Am. 2001;83(9):1299-1305.
9. Josefsson PO, Danielsson LG. Epicondylar elbow fracture in children. 35-year follow-up of 56 unreduced cases. Acta Orthop Scand. 1986;57(4):313-315.
10. Pappas N, Lawrence JT, Donegan D, Ganley T, Flynn JM. Intraobserver and interobserver agreement in the measurement of displaced humeral medial epicondyle fractures in children. J Bone Joint Surg Am. 2010;92(2):322-327.
11. Landin LA, Danielsson LG. Elbow fractures in children. An epidemiological analysis of 589 cases. Acta Orthop Scand. 1986;57(4):309-312.
12. Haxhija EQ, Mayr JM, Grechenig W, Hollwarth ME. [treatment of medial epicondylar apophyseal avulsion injury in children]. Oper Orthop Traumatol. 2006;18(2):120-134.
13. Axibal DP, Ketterman B, Skelton A, et al. No difference in outcomes in a matched cohort of operative versus nonoperatively treated displaced medial epicondyle fractures. J Pediatr Orthop B. 2019;28(6):520-525.
14. Klatt JB, Aoki SK. The location of the medial humeral epicondyle in children: Position based on common radiographic landmarks. J Pediatr Orthop. 2012;32(5):477-482.
15. Gottschalk HP, Bastrom TP, Edmonds EW. Reliability of internal oblique elbow radiographs for measuring displacement of medial epicondyle humerus fractures: A cadaveric study. J Pediatr Orthop. 2013;33(1):26-31.

16. Hughes M, Dua K, O'Hara NN, et al. Variation among pediatric orthopaedic surgeons when treating medial epicondyle fractures. J Pediatr Orthop. 2017.

17. Lawrence JT, Patel NM, Macknin J, et al. Return to competitive sports after medial epicondyle fractures in adolescent athletes: Results of operative and nonoperative treatment. Am J Sports Med. 2013;41(5):1152-1157.