Acta Orthop. Belg., 2015, **81**, 384-391

ORIGINAL STUDY

Shaft-Condylar Angle for surgical correction in neglected and displaced lateral humeral condyle fracture in children

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Purpose : **To assess the outcome after using the Shaft-Condylar angle (SCA) as intraoperative reference for sagittal plane correction in displaced lateral humeral condyle fractures in children presented 3-weeks after injury.**

Methods : **Ten children, with delayed presentation of a displaced lateral humeral condyle fracture and undergoing surgery during 1999-2011, were reviewed. The goal was to obtain a smooth articular surface with an intraoperative SCA of nearly 40° and nearest-anatomical carrying angle. They were allocated into two groups according to the postoperative SCA [*Good-reduction group* (SCA = 30-50°), and *Bad-reduction group* (SCA < 30°, > 50°)] and the final outcomes were then compared.**

Results : **All fractures united without avascular necrosis. The *Good-reduction group* (n = 7) showed a significant improvement in final range of motion and functional outcome compared to the *Bad-reduction group* (n = 3) ($p = 0.02$). However, there was no significant difference in pain, carrying angle and overall outcome between both groups.**

Conclusion : **SCA is a possible intraoperative reference for sagittal alignment correction in late presented displaced lateral humeral condyle fractures.**

Keywords : lateral condylar fracture ; fracture distal humerus in children ; shaft-condylar angle ; neglected fracture ; displaced fracture.

INTRODUCTION

Neglected displaced lateral condylar fracture of the humerus in children is a rare traumatic injury with only a small number of case series in literature (*1,3,4,7,9,15,16,18,21,23*). Furthermore, treatment of this condition remains one of the controversial and difficult problems in pediatric elbow fractures. Conservative treatment potentially yields poor functional outcome while surgical treatment also carries significant risks of postoperative complications such as avascular necrosis (AVN) of the lateral humeral condyle and residual postoperative deformity.

Earlier studies reported on the difficulty in surgical management caused by anatomical distortion from the callus, fibrous scar and the indistinction of

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No benefits or funds were received in support of this study. The authors report no conflict of interests.

bony edges (*4,5,7,8,10,11,14,19,20,23*). Beside this, the risk of vascular impairment of the lateral condyle fragment due to extensive dissection of the posterior soft tissue attachment has also been reported, particularly in the treatment between 3 and 6 weeks after injury (*4,10,11*). Nevertheless, possibly due to the improvement in surgical techniques, several recent studies showed satisfactory outcomes with open reduction and internal fixation (ORIF) in the late presented cases (*1,3,6,8,9,12,15,18,21,22*).

Although the aforementioned studies supported better outcome of the surgical treatment, the operative intervention in late presented displaced lateral humeral condylar fractures is still a very challenging procedure because it needs to restore the small and hardly identifiable displaced fragment to a nearly anatomical position in the situation of a limited exposure of the lateral condylar fragment. Therefore, the previously recommended goal of fracture reduction is not to create perfect anatomical reduction, but to achieve an acceptable reduction by using some intraoperative references such as articular surface continuity, contralateral carrying angle, and intraoperative range of motion (*15,21*). Nevertheless, through our knowledge, these previously recommended intraoperative references only concern the coronal plane correction by using the carrying angle without attention to the deformity in the sagittal plane (*3,9,15,16,18,21*). Therefore, we adopted an additional intraoperative assessment technique using the shaft condylar angle (SCA) (Fig. 1) (*13*), measured by image intensifier, to facilitate the deformity correction in the sagittal plane and evaluate the optimal sagittal plane deformity alignment. This report aimed to evaluate the long-term outcome of neglected and displaced lateral condylar fractures of the humerus in children after surgery with attempted sagittal plane deformity correction, and to correlate the clinical outcome with postoperative SCA.

MATERIALS AND METHODS

Between 1999 and 2011, ten children with a displaced (more than 4 mm.) lateral condylar fracture of the humerus presented longer than 3 weeks after the initial injury were recruited. All patients had pain and stiffness at the affected elbows. An ORIF with Kirschner wires, was performed by either the first author (n = 9) or the second author (n = 1). The aims of the surgical restoration were to obtain a nearly 40-degree SCA (Fig. 2), a nearly anatomical carrying angle and smooth articular surface continuity without extensive dissection of the posterior soft tissue attachment. This study had been reviewed and approved by our institutional board review, based on the Declaration of Helsinki. Informed consent, for publication of individual clinical details, was obtained from the parents or guardians of all patients who participated in this study, before the surgery was scheduled.

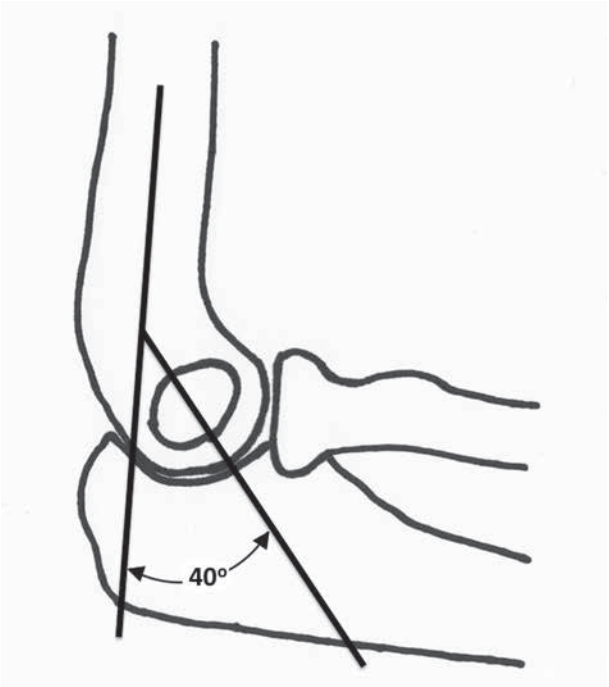

Fig. 1. — Schematic picture showing the shaft-condylar angle (SCA) measurement on lateral radiographs of the elbow. SCA angle is the angle between the axis of distal humerus shaft and axis of the distal humeral condyle.

Clinical examination was performed in all cases. Pain and range of motion of the injured elbow were recorded. The carrying angle on the normal side was measured with a goniometer and then used as the reference for the deformity correction in the coronal plane.

Pre-operative radiographs were used to evaluate the degree and type of displacement according to Jakob *et al* (*11*), and Wadsworth (*20*). The fractures were also classified using Badelon's criteria (*2*). The inclusion criteria were the cases with displacement in both antero-posterior and lateral radiographs of more than 4 millimeters with or without rotation of the distal fragment.

The lateral approach was used in all cases. The fascia overlying the extensor tendon was incised, and the exten-

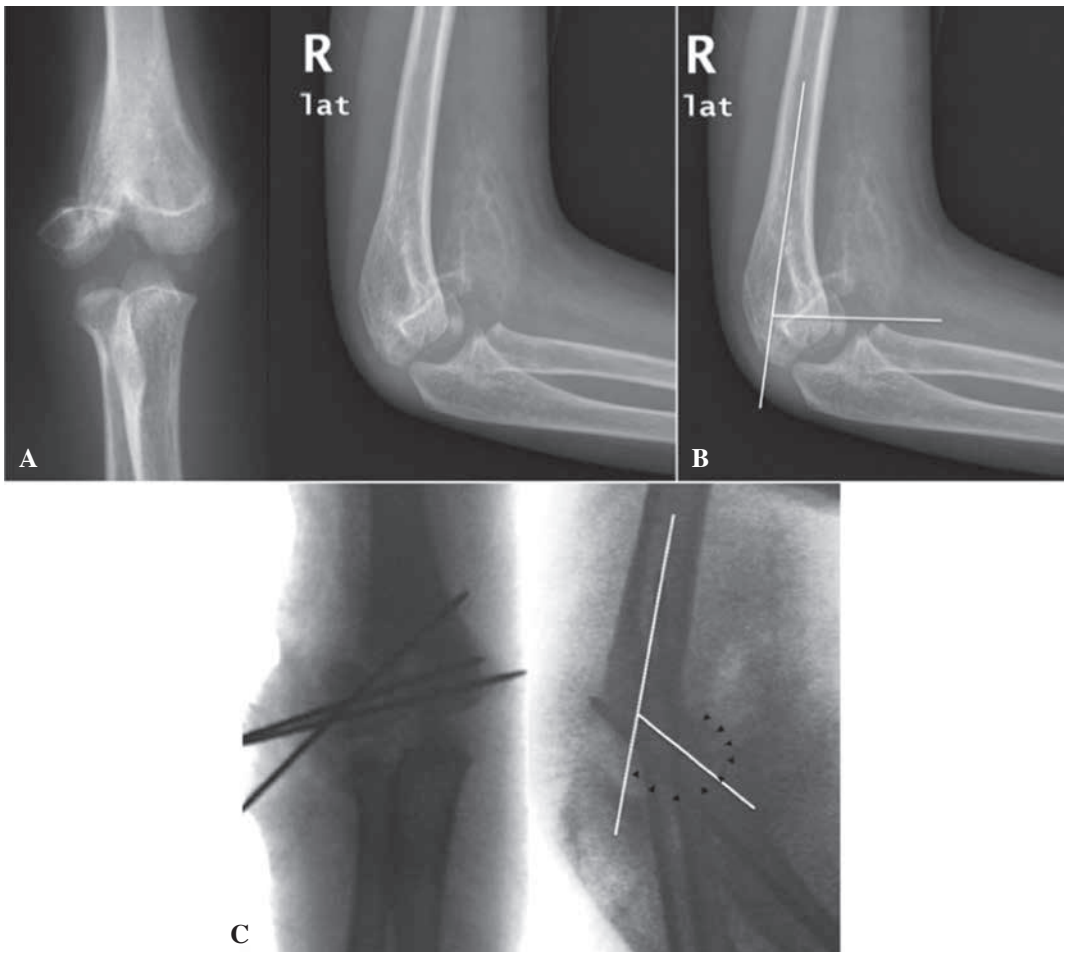

Fig. 2. — A case example of late-presented lateral humeral condyle fracture (LHCFx) in a 6-year-old boy 16 weeks after injury. A. preoperative radiographs show displaced non-union LHCFx with myositis ossificans formation anteriorly, B. Preoperative shaft-condylar angle (SCA) measured 105 degree, and C. Intraoperative SCA was used as a guide to reduce the fracture into nearly anatomical position (48 degree).

sor muscles were identified and retracted. The first step was to identify the fracture site and articular surface. Because of the anatomical distortion, the fibrous scar and callus on the anterior surface of the distal humerus were carefully removed in order to clearly visualize the fracture site and articular surface. As a rule, the posterior soft tissue attachment of the condylar fragment was preserved in all cases.

The second step was preparation of the lateral condylar fragment for reduction. This included identification of the condylar surface and mobilisation of the fragment by dissecting the soft tissue scar attached to the displaced lateral condyle without removing the posterior soft tissue envelope. As all of the fractures were presented late, the whole articular surface of the condylar fragment was always covered with a fibrous membrane that must be carefully removed. The round contour, as well as the articular surface of the lateral condyle in all cases, was found to be preserved. At the third step, the condylar fragment was re-aligned, approximated, and temporarily fixed to the distal humerus with a Kirschner wire by using references as a smooth continuity of the articular surface and the nearest normal carrying angle. At this stage, the position of the lateral condylar fragment and the quality of reduction were verified by using the SCA measured from the true lateral view on the fluoroscope. The ultimate goal was that this angle should be near 40 degrees as much as possible. Then the definitive

fixation was done by using at least 2 Kirschner wires depending on the stability of the fragment. After wound closure, the elbow was immobilised with a long arm slab.

Postoperatively, the patients were allowed for active wrist and shoulder range of motion exercises and then followed up periodically in the first six weeks for bone union. The Kirschner wires and slab were removed at the fourth week postoperatively.

All of the patients were followed up for at least a 2-year period and the examination of the elbow was performed and recorded in every appointment session. The patients and parents were asked about the level of pain and their satisfaction. The examination included inspection for the appearance of the lateral prominence of the affected elbow, palpation to identify the area of tenderness, measurement of the carrying angle on both sides, range of motion of the elbow and neurological examination. Pain, range of motion, carrying angle, and neurological status were then classified according to the criteria of Dhillon *et al* (*4*) and a clinical score was awarded as excellent, good, fair, and poor.

Radiographs at each follow up period were analysed for the SCA, the lateral spur and overgrowth, the fishtail deformity and the evidence of AVN. The SCA was measured by the first and the second author from the true lateral radiograph where the condyle or capitulum was clearly seen and not concealed by the part of the olecranon. The average angle between the two measurements was used. Then the SCA was classified into 2 categories : *good reduction* (30-50 degrees), and *bad reduction* (less than 29.5 degrees or more than 50.5 degrees) (Fig. 3).

The analysis was carried out using Statistical Package for Social Science (SPSS version 17.0 for windows ; Chicago, IL, USA). Continuous data were presented as mean and range. Categorical data were presented as proportion. Fisher's exact test was used to compare the outcomes between good reduction group and bad reduction group. A *p*-value of less than 0.05 was considered as significant.

RESULTS

Ten patients with displaced (more than 4 mm) lateral condylar fracture of the humerus more than 3 weeks after initial injury included seven boys and three girls. The average age was 4.5 years (range 1.75-10.5 years). Six fractures (60%) involved the right elbow and four (40%) the left elbow. The average time from the injury to surgery was 8.8 weeks (range 3-17 weeks). The average duration of follow-up was 3.7 years (range 2-11 years). All fractures were displaced more than 4 mm. and classified as Badelon type IV. Nine cases (90%) were classified as Salter & Harris type II and one (10%) as type IV. Preoperative evaluation showed severe limitation of elbow movement in all patients (Table I).

The clinical and radiographic examination on follow up showed union at the fracture sites in all cases. No AVN was observed. Postoperative pain was observed in one case (10%, No. 5), which occasionally occurred after performing heavy activity. Postoperative range of motion was improved in all cases. Six patients (60%, No. 1, 2, 3, 8, 9, and 10) had full flexion and extension of the affected elbow while the other four cases (40%, No. 4, 5, 6, and 7) had remarkable improvement. Pronation and supination were full in all cases. The carrying angle compared with the normal side was increased in six cases (60%). Radiographs demonstrated physeal growth arrest in all. The other four cases (40%) had the same carrying angle as compared to the normal side. No varus deformity was observed. Six cases (60%) showed a lateral prominence on examination, classified as a large bony prominence in 2 cases (20%) and slight prominence in 4 cases (40%). Another 4 cases showed a normal appearance. The average of the SCA at follow-up radiographs was 47.7 degrees (range 38-62 degree) (Table I).

They were allocated into two groups according to the postoperative SCA [*Good-reduction group* (SCA = 30-50°), and *Bad-reduction group* (SCA < 30°, > 50°). Regarding postoperative SCA, 7 patients (70%, No. 1, 2, 3, 5, 8, 9, and 10) were allocated into the *Good reduction* group and 3 patients (30%, No. 4, 6, 7) into the *Bad reduction* group. After grading by Dhillon's criteria, the *Good reduction* group (n = 7) showed excellence in pain and range of motion in 6 cases or 86%, 29% excellence in carrying angle (n = 2), 86% excellence in functional grading (n = 6), and 29% excellence in overall grading (n = 2). The *Bad reduction* group (n = 3) revealed 100% excellence in pain (n = 3), 67% excellence in carrying angle with 0% excellence in range of motion, functional and overall grading (n = 0). The *Good reduction* group demonstrated significant improvement in range of motion and functional grading outcome compared to the

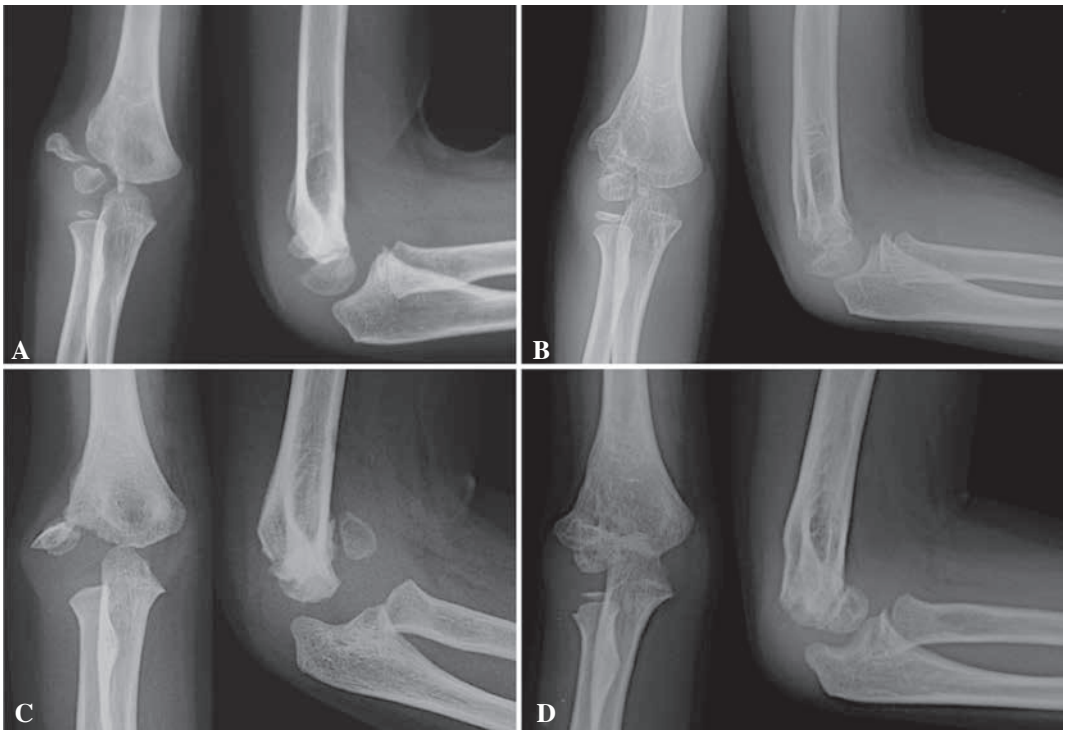

Fig. 3. — Good and bad case examples. A-B. Good reduction case example of lateral humeral condyle fracture (LHCFx) 14 weeks after injury in a 4-year-old boy (case no.2) : preoperative (A) and 4-year postoperative radiographs (B) with shaft-condylar angle (SCA) as 42 degrees, C-D. Bad reduction case example of LHCFx 16 weeks after injury in a 4-year-old boy (case no. 6) : preoperative (C) and at 5-year postoperative radiographs (D) with SCA of 54 degrees.

Bad reduction group ($p = 0.022$ and 0.017 respectively). However, there was no significant difference in pain, carrying angle and overall grading outcome ($p = 0.54$, 0.31, and 0.33 respectively) (Table II).

DISCUSSION

Late presentation of displaced lateral humeral condylar fractures is uncommon and considered as one of the problematic pediatric injuries due to the difficulty in surgical management and risk of postoperative complications. Recently, several studies demonstrated a significant improvement in postoperative outcome and advocated some surgical techniques in order to preserve vascularity of the lateral condyle fragment and create intraoperative acceptable reduction (*1,3,16-18*). Nonetheless, the aforementioned techniques did not provide a clear reference for deformity correction in the sagittal plane and studies had also not proven the correlation between the sagittal plane malalignment and the postoperative functional outcome. Therefore, the aim of this study was to evaluate the clinical outcome after using the SCA as reference for the sagittal plane correction and the correlation between the SCA and postoperative functional outcome.

Intraoperative problems in the late presented lateral humeral condyle fracture of the humerus include : 1. Anatomical distortion from the fibrous scar and callus needed to be carefully removed in order to clearly visualise the fracture site and articular surface. 2. Need of preserving the posterior soft tissue attachment of the lateral condyle. 3. Mobilisation and reduction of the lateral condylar fragment into the nearest normal anatomy.

The previous recommended references for reduction are carrying angle, articular surface continuity

Table I. — Patient's preoperative characteristics and postoperative outcome

No.	Injury Age (yr)	Time to Surgery (wk)	F.U. (yr)	Pain	ROM*		Carrying angle*		Lat. prom	SCA*
					Preop	Post-op	Normal	Fracture side (post-op)		
1	3.25	5	11	N	0-60	0-140	10	18	no	50
2	4.25	14	4.5	N	30-90	0-140	6	12	yes	42
3	1.75	4	3.5	N	30-90	0-140	5	8	no	40.5
4	10.5	6	2.5	N	80-95	40-125	8	10	sl	62
5	3.25	16	2	Oc	70-90	0-120	5	5	sl	40
6	4.25	16	5.5	N	40-100	10-140	8	8	yes	54
7	6.75	17	2	N	70-90	20-130	5	18	sl	60
8	3.75	3	3	N	30-90	0-140	5	5	no	42
9	2.5	4	3	N	30-95	0-140	6	6	no	48.5
10	4.75	3	2	N	30-80	0-140	7	10	sl	38

F.U., follow up ; ROM, range of motion ; Preop, preoperative ; Post-op, postoperative ; Lat. prom, lateral prominence ; SCA, shaft-condylar angle.

* : the value measured as degree ; N : no pain ; Oc : pain presented occasionally.

and congruity, as well as the use of position with the greatest intraoperative range of motion (*15,21*). However, in our experience, using intraoperative motion as a guide for the sagittal plane reduction may be impossible in late presented lateral condylar fracture cases with already a stiff elbow as demonstrated in our patients. This elbow stiffness in this condition is caused by fibrous scar contracture and intra-articular fibrosis which requires dissection, especially in the patients with a markedly displaced fracture. Moreover, this reduction technique depends on surgical experience and needs multiple attempts of temporary fixation to test and verify the maximum range of motion gained, which is harmful to the small lateral condylar fragment and affects to the final stability after definite fixation.

Use of intraoperative SCA under fluoroscopy has many advantages. First, the quality of reduction is more reliable because of using an easier measurable and well-known method. Secondly, the extensive soft tissue dissection around the lateral condylar fragment is not necessary. This is because the quality of the sagittal plane deformity reduction under direct visualisation is replaced by the imaging device, and therefore, the surgical exposure could be limited resulting in less soft tissue trauma. Thirdly, multiple attempts of temporary fixation should be avoided by this proposed technique and result in better vascularity preservation and final stability.

The result from this study showed that this modified intraoperative reference is reliable in that the mean SCA in all cases was 47.7 degree, close to the intraoperative reduction goal (40 degree). The *good reduction group* (SCA 30-50 degree) also demonstrated a significant correlation with better range of motion and functional grading outcome (Table II). Specifically, the SCA of more than 50 degree was directly associated with some limitation of elbow extension (Table I). This might be explained by the excessive anterior or forward tilting of the fragment resulting in an anatomical block of the elbow extension. Additionally, the incidence of having no AVN in our series also supported the advantage of limited soft tissue dissection and vascularity preservation with this technique.

Our data was comparable with the result of previous studies on late presented lateral humeral condylar fractures in children (*1,3,16-18*) and showed that the surgical management in this group of patients is possible and can be performed, as late as 3 weeks after fracture, with satisfactory results (Table I).

Nevertheless, our study also has some limitations. First, our sample size is small because the incidence of this type of injury is rare and we included

Table II. — The correlation between final outcome variables, rating by Dhillon's criteria, and the shaft-condylar angle (SCA)

Clinical outcome variables	Rating by Dhillon criteria				*p*-value◆
	Excellent	Good	Fair	Poor	
Pain					
Good reduction (n = 7)	6	1	0	0	0.54
Bad reduction (n = 3)	3	0	0	0	
Range of motion					
Good reduction (n = 7)	6	1	0	0	0.022*
Bad reduction (n = 3)	0	1	2	0	
Carrying angle					
Good reduction (n = 7)	2	5	0	0	0.31
Bad reduction (n = 3)	2	1	0	0	
Functional grading					
Good reduction (n = 7)	6	0	1	0	0.017*
Bad reduction (n = 3)	0	1	2	0	
Overall grading					
Good reduction (n = 7)	2	4	1	0	0.33
Bad reduction (n = 3)	0	2	1	0	

◆ : *p*-value calculated from Fisher exact test ; * : significant difference with $p < 0.05$.

only patients with severe displacement. There is need for a larger study population in order to find correlation between the SCA and other clinical outcomes, such as pain or overall grading outcome, or find the possible latest time for surgery. Secondly, the exact pathophysiology of a large SCA and limited elbow extension is still inconclusive. Therefore, a study with a larger population and dynamic advanced imaging might be required to identify the cause of this finding.

CONCLUSION

Surgical management in neglected and displaced lateral condylar fractures of the humerus in children is a good treatment option. The satisfactory outcome is obtained by meticulous surgical technique, preserving vascularity and reducing the fragment into the nearest anatomical position. From our result, we recommended using the shaft-condylar angle (SCA), as one of the intraoperative references, for reduction in order to achieve a good range of motion and functional outcome.

REFERENCES

1. **Agarwal A *et al.*** Management of neglected lateral condyle fractures of humerus in children : A retrospective study. *Indian J Orthop* 2012 ; 46 (6) : 698-704.
2. **Badelon O *et al.*** Lateral humeral condylar fractures in children : a report of 47 cases. *Journal of pediatric orthopedics* 1988 ; 8 (1) : 31-34.
3. **Bae KC *et al.*** Surgical Treatment of Late Presented Displaced Lateral Condylar Fracture of the Humerus in Children. *J Korean Orthop Assoc* 2008 ; 43 (1) : 24-29.
4. **Dhillon KS, Sengupta S, Singh BJ.** Delayed management of fracture of the lateral humeral condyle in children. *Acta orthopaedica Scandinavica* 1988 ; 59 (4) : 419-424.
5. **Flynn JC, Richards JF, Jr.** Non-union of minimally displaced fractures of the lateral condyle of the humerus in children. *The Journal of bone and joint surgery. American volume* 1971 ; 53 (6) : 1096-1101.
6. **Flynn JC, Richards JF, Jr, Saltzman RI.** Prevention and treatment of non-union of slightly displaced fractures of the lateral humeral condyle in children. An end-result study. *The Journal of bone and joint surgery. American volume* 1975 ; 57 (8) : 1087-1092.
7. **Fontanetta P, Mackenzie DA, Rosman M.** Missed, maluniting, and malunited fractures of the lateral humeral condyle in children. *The Journal of trauma* 1978 ; 18 (5) : 329-35.
8. **Foster DE, Sullivan JA, Gross RH.** Lateral humeral condylar fractures in children. *Journal of pediatric orthopedics* 1985 ; 5 (1) : 16-22.

9. **Gaur SC, Varma AN, Swarup A.** A new surgical technique for old ununited lateral condyle fractures of the humerus in children. *The Journal of trauma* 1993 ; 34 (1) : 68-69.
10. **Hardacre JA *et al.*** Fractures of the lateral condyle of the humerus in children. *The Journal of bone and joint surgery. American volume* 1971 ; 53 (6) : 1083-1095.
11. **Jakob R *et al.*** Observations concerning fractures of the lateral humeral condyle in children. *The Journal of bone and joint surgery. British volume* 1975 ; 57 (4) : 430-436.
12. **Jeffery CC.** Non-union of the epiphysis of the lateral condyle of the humerus. *The Journal of bone and joint surgery. British volume* 1958 ; 40-B (3) : 396-405.
13. **Kasser JR, Beaty JH.** *The Elbow Region : General Concepts in the Pediatric Patient*. In : *Rockwood & Wilkins' Fractures in Children*. Beaty JH, Kasser JR (eds). 2006, Lippincott Williams & Wilkins, Philadelphia, pp 529-541.
14. **Maylahn DJ, Fahey JJ.** Fractures of the elbow in children ; review of three hundred consecutive cases. *J Am Med Assoc* 1958 ; 166 (3) : 220-228.
15. **Roye DP, Jr, Bini SA, Infosino A.** Late surgical treatment of lateral condylar fractures in children. *Journal of pediatric orthopedics* 1991 ; 11 (2) : 195-199.
16. **Saraf SK, Khare GN.** Late presentation of fractures of the lateral condyle of the humerus in children. *Indian J Orthop* 2011 ; 45 (1) : 39-44.
17. **Sathyamoorthy P *et al.*** Development and validation of an elbow score. *Rheumatology (Oxford)* 2004 ; 43 (11) : 1434-1440.
18. **Shimada K *et al.*** Osteosynthesis for the treatment of non-union of the lateral humeral condyle in children. *The Journal of bone and joint surgery. American volume* 1997 ; 79 (2) : 234-240.
19. **Speed JS, Macey HB.** Fractures of the humeral condyles in children. *The Journal of Bone & Joint Surgery* 1933 ; 15 (4) : 903-919.
20. **Wadsworth TG.** Injuries of the capitular (lateral humeral condylar) epiphysis. *Clinical orthopaedics and related research* 1972 ; 85 : 127-142.
21. **Wattenbarger JM, Gerardi J, Johnston CE.** Late open reduction internal fixation of lateral condyle fractures. *Journal of pediatric orthopedics* 2002 ; 22 (3) : 394-398.
22. **Wilson PD**, Fracture of the lateral condyle of the humerus in childhood. *The Journal of Bone & Joint Surgery* 1936 ; 18 (2) : 301-318.
23. **Zionts LE, Stoltz MR.** Late fracture of the lateral condyle of the humerus : A trauma case study. *Orthopedics* 1984 ; 7 (3) : 540-545.