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Methods of percutaneousfixation of fragments in supracondylar humerus fractures in children and adolescents

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The aim of this study is to conduct a meta-analysis and evaluate the clinical efficacy and safety of crossed and lateral fixation of fragments in supracondylar humerus fractures in children and adolescents. Methods. A comprehensive literature search was conducted in the PubMed and EMBASE databases from 2015 to December 2023 using the following search terms: "supracondylar fractures of distal humerus in pediatric patients", "treatment", "methods of fixation", "pinning configuration", "biomechanical analysis of pin placement". According to the inclusion and exclusion criteria, the literature sources of anatomic-biomechanical and clinical studies related to the use of crossed and lateral fixation of fragments in the case of supracondylar fractures of the humerus in children and adolescents were selected and analyzed. The review was prepared in accordance with the recommendations of the "Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines." Results. A comparison of results from experimental studies investigating the degree of stabilization achieved in the crossed and lateral configurations of fixation structures reveals conflicting conclusions due to the heterogeneity of designs implemented. The principal limitation of lateral fixation is the increased risk of failure of fixation. The outcomes of clinical trials (Flynn criteria) demonstrate that both types of fracture fixation yield equivalent clinical outcomes. One disadvantage of crossed fixation is the risk of iatrogenic ulnar nerve damage, while another disadvantage is the increased complexity of the surgical technique. Conclusions. The results of anatomical and biomechanical studies indicate that cross-fixation provides more rigid fixation of fragments in supracondylar humerus fractures in children and adolescents. Nevertheless, clinical outcomes based on radiological and functional data (including Flynn's score) demonstrate no significant distinction between the two types of fixation configurations. However, they do indicate a notable risk of iatrogenic ulnar nerve damage in cross fixation, which justifies the necessity to utilise a mini-open technique in the medial fixation construct.

Мета. Провести метааналіз та оцінити клінічну ефективність і безпечність застосування перехрещеної та латеральної фіксації відламків у разі надвиросткових переломів плечової кістки в дітей та підлітків. Методи. Здійснено пошук літератури в базах даних PubMed та EMBASE з 2015 до грудня 2023 року використовуючи такі терміни: «supracondylar fractures of distal humerus in pediatric patients», «treatment», «methods of fixation», «pinning configuration», «biomechanical analysis of pin placement». За критеріями включення та виключення відібрано та проаналізовано джерела літератури анатомо-біомеханічних і клінічних досліджень, які стосуються застосування перехрещеної та латеральної фіксації відламків у разі надвиросткових переломів плечової кістки в дітей та підлітків. Огляд підготовлено згідно з рекомендаціями «Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines». Результати. Порівняльний аналіз даних експериментальних досліджень ступеня стабілізації відламків у разі перехрещеної та латеральної конфігурації фіксуючих конструкцій вказує на протиріччя висновків, які зумовлені неоднорідністю дизайнів під час їхнього проведення. Головним недоліком латерального способу є підвищений ризик втрати фіксації. Під час застосування (Flynn критерії) виявлено, що обидва типи стабілізації перелому забезпечують рівнозначні клінічні результати. Недоліком використання перехресного кріплення є ятрогенне ушкодження ліктьового нерва. Висновки. Перехрещена фіксація за результатами анатомо-біомеханічних досліджень забезпечує більш жорстке кріплення відламків у разі надвиросткових переломів плечової кістки в дітей та підлітків. Проте клінічні результати, які базуються на рентгенологічних і функціональних показниках (включаючи бали за критерієм Флінна), указують на відсутність істотної різниці між двома типами конфігурації фіксації. Утім констатують суттєві ризики ятрогенного ушкодження ліктьового нерва за перехрещеної фіксації, що обгрунтовує необхідність застосування мініВідкритої техніки в разі застосування медіальної фіксуючої конструкції. Ключові слова. Надвиросткові переломи в дітей та підлітків, лікування, методи фіксації, конфігурація фіксації, біомеханічні дослідження, метааналіз.

Key words. Supracondylar fractures of distal humerus in pediatric patients, treatment, methods of fixation, pinning configuration, biomechanical analysis of pin placement, meta-analysis

Introduction

Fractures of the distal epimetaphysis of the humerus in children and adolescents are one of the most common injuries, accounting for 16 to 50 % of bone fractures in general and 50–80 % of all intra-articular injuries of the upper extremity. Among the injuries of this localization, supracondylar (3–18 %) and transcondylar fractures (57.5–70 %) prevail, mainly in children aged 6–7 years (range: from 1 year 4 months to 12 years 4 months). Age at injury has a bimodal pattern with the first peak at approximately 1 year of age and the second at 4–5 years of age. With age, the proportion of such fractures decreases, and their types change [1, 2].

There are several systems for describing supracondylar fractures in children and adolescents, but the most used in daily clinical practice is the classification of J. J. Gartland [3], which was consistently modified by Wilkins et al. [4]. Later, Leitch and his colleagues expanded J. J. Gartland's classification and introduced type IV — a multidirectional unstable fracture in both flexion and extension with complete loss of contact of both the anterior and posterior cortical layers [5].

Modern tactics of treatment of supracondylar fractures in pediatric practice, depending on the type of injury, are given enough attention, but there are a number of debatable issues [6, 7]. One of them, deserving special attention, is the configuration of the location of the internal fixation structures, which has been the subject of debate for the last decades. The two most common designs for fixation of supracondylar fractures in children and adolescents today are with crossed wires and with the use of 2 or 3 lateral wires with their divergence in the coronal plane [8].

The prerequisite for the development and implementation of lateral fixation (LF) of fragments, as opposed to the transverse method, is to reduce the risk of iatrogenic damage to the ulnar nerve during the insertion of a medial wire or pin.

Crossed fixation (CF) provides a stable biomechanical structure, which is characterized by more significant torsional and bending stiffness compared to lateral fixation, although it increases the risk of injury to the ulnar nerve [9].

Therefore, establishing the advantages and disadvantages of these fastening methods is an urgent issue of modern orthopedics in pediatric practice in the case of supracondylar fractures of the humerus.

Purpose: to conduct a meta-analysis and evaluate clinical effectiveness and safety of the use of crossed and lateral fixation of fragments in supracondylar fractures of the humerus in children and adolescents.

Material and methods

The review was prepared in accordance with the recommendations of the "Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines" [10]. A literature search was conducted in PubMed and EMBASE databases from 2015 to December 2023, using the following terms: "supracondylar fractures of distal humerus in pediatric patients", "treatment", "methods of fixation", "pinning configuration", "biomechanical analysis of pin placement". References of reviews and studies selected by two reviewers independently were also searched manually. Relevant articles were included after reading the full text and determining the necessary parameters.

Inclusion criteria: 1) type II–IV according to Hartland supracondylar fractures in children and adolescents; 2) use of closed/open reposition with percutaneous, mini-open or open fixation technique; 3) medial-lateral crossed and lateral method of fixation; 4) anatomical and biomechanical studies of these methods; 5) articles with level I–IV evidence; 6) duration of observation not less than one year; 7) studies involving more than 10 patients; 8) sources in foreign languages.

Exclusion criteria: 1) type I according to Hartland supracondylar fractures in children and adolescents; 2) reviews, theses or articles with insufficient data; 3) non-standardized, new (combined) methods of fixation.

According to the given factors, two independent researchers screened the search results by title, abstract, and full text. The obtained data included: first author, year of publication, level of evidence, study design, type of fracture, number and age of patients, fixation technique, results of anatomical and biomechanical studies.

Meta-analysis was performed using the RStudio software (Fig. 1), the Meta package for generating risk ratios for categorical outcomes, mean difference for continuous outcomes, and 95% confidence intervals (CI).

Results

The obtained results of anatomical and biomechanical studies of crossed and lateral fixations in the case of supracondylar fractures in children and adolescents are shown in Table 3.

EZR statistical package was used to make forest diagrams (Figs. 2–6) of meta-analysis results, using

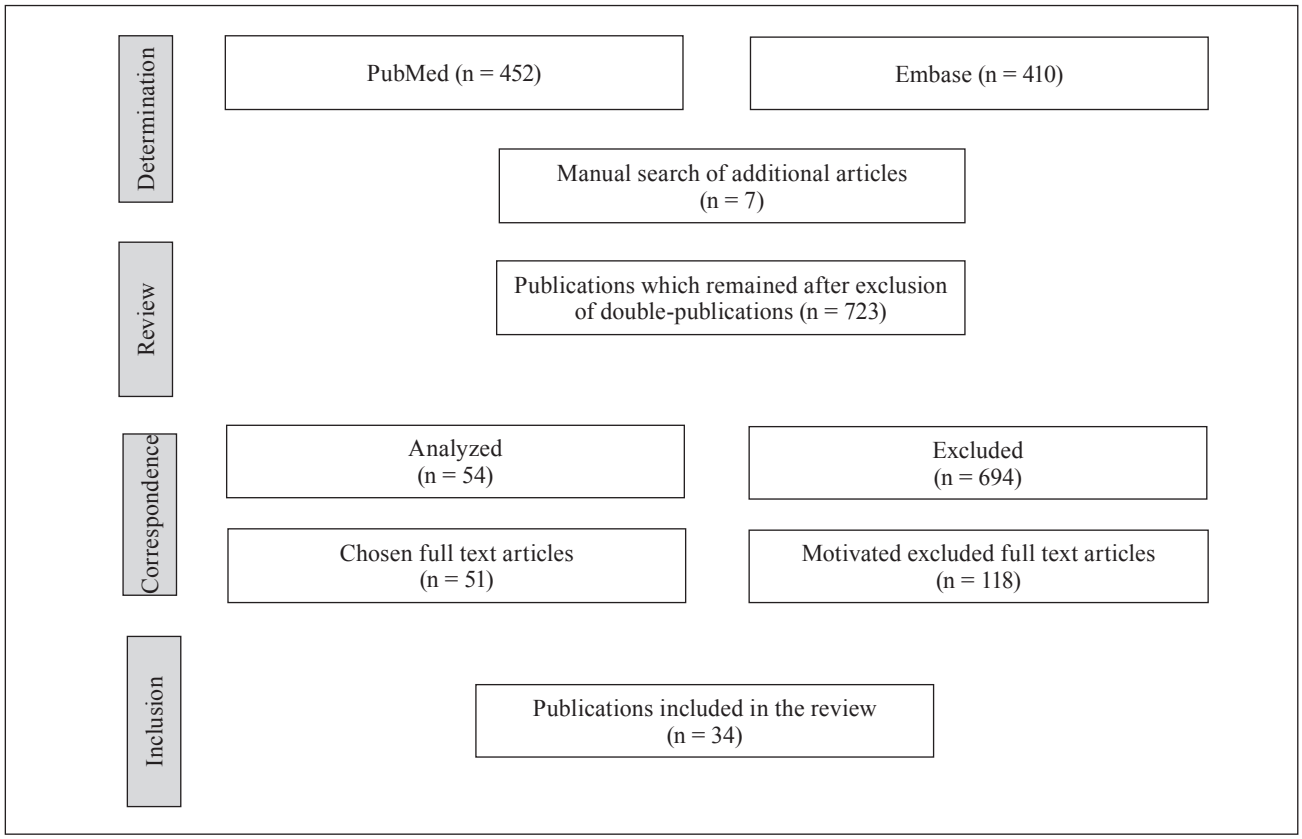

Fig. 1. Block diagram of the selection of articles for the study

Table 1

Articles regarding anatomical and biomechanical studies of fixation methods

Author, year, country	Characteristics of models	Method of fixation
Allieu Kamara. et al., 2018, People's Republic of China [11]	Transverse fractures of different levels	CF with Kirchner wires, lateral external fixation, elastic stable intramedullary nails (ESIN)
Chuang Liu et al., 2020, People's Republic of China [12]	Transverse, medial and lateral oblique fractures	CF with Kirchner wires, lateral external fixation, elastic stable intramedullary nails (ESIN)
Allieu Kamara et al., 2021, People's Republic of China [13]	Transverse fractures of different levels	PF and multi-planar LF
Ahmet Oztermeli et al., 2023, Turkey [14]	Transverse fractures	CF and multi-planar LF with two and three wires
Melissa Wallace et al., 2019, USA [15]	Transverse fractures	Coronal and sagittal placement of pins of different diameters
Alexander M. Bitzer et al., 2021, USA [16]	Transverse fractures	CF and multi-planar LF with two and three wires
Marcos Ceita Nunes et al., 2019, Brasil, [17]	Transverse fractures	CF and multi-planar LF
Hanim A. et al., 2021, Malaysia, [18]	Transverse fractures	CF and multi-planar LF, intersection points
Witit Pothong et al., 2021, Thailand, [19]	Transverse fractures	LF
Serhat Durusoy et al., 2021, Turkey [20]	Transverse fractures	CF
Wei Wang et al., 2020, People's Republic of China [21]	Transverse fractures	CF and LF, ESIN
Xiang-Fei Liu et al., 2020, People's Republic of China [22]	Transverse fractures	CF and LF

the average values of the stiffness indicators of both structures with different numbers of wires (N/mm).

Treatment outcomes in children and adolescents with supracondylar fractures are shown in Table 4.

A comparative analysis of the results of treatment of patients with supracondylar fractures of the humerus using CF and LF is shown in Table 5. Data processing showed that the law of distribution differed from the normal one ($p < 0.01$), therefore, such indicators as the median and 95% CI were used to present the data.

The analysis proves that there was no significant difference between the two groups regarding the range of motion and, accordingly, the final functional outcome.

Discussion

The assessment of anatomical and biomechanical studies revealed that the disadvantage of LF is an increased risk of loss of reposition, which can lead to deformation in the form of *cubitus varus*, and subsequently to the need for surgical correction due to lower biomechanical stability compared to CF [11, 12, 18, 21].

However, the location and number of fixing means are of essential importance for ensuring stability under LF.

The optimal fixation that provides the best rigidity is the use of 3 lateral pins that diverge in the coronal and sagittal planes, as opposed to crossed and 3 lateral pins that diverge only in the coronal plane.

Three side pins in both divergent and parallel configurations provide sufficient stability without significant difference. The divergent type of sagittal structures provides the greatest rigidity under different loads in comparison with other types. The advantage of the divergent sagittal configuration can be

Table 2

Articles with clinical results of treatment of patients using various methods of fixation

Author, year, country	Type of fracture Gartland J. J.	Method of fixation		Study design
		crossed	lateral	
Erdinç Acar et al., 2020, Turkey [23]	III	16	16	Retrospective
Henrigue Melo Natalin et al., 2021, Brazil [24]	III	19	24	Randomized
Kumar Prashant et al., 2016, India [25]	III	31	31	Randomized
Hossam Abubeih et al., 2019, Egypt [26]	III	34	34	Randomized
Afaque S. F. et al., 2020, India [27]	III	40	37	Randomized
Naik L. G. et al., 2017, India [28]	III	29	28	Prospective
Arun K. N. et al., 2018, India [29]	III	30	38	Prospective
Palange N. et al., 2019, India [30]	III	15	15	Randomized
Othman M. K.et al., 2020, India [31]	III	15	15	Prospective
Naveen P. R. et al., 2017, Iraq [32]	II, III	20	20	Prospective
Ahmad M. Radaideh et al., 2022, Jordan [33]	III	34	67	Retrospective
Francisco Eguia et al., 2020, Jordan [34]	III	49	93	Prospective
Justyna Napora et al., 2022, Poland [35]	III	62	13	Retrospective
Pesenti S. et al., 2017, France [36]	III, IV	33	58	Retrospective

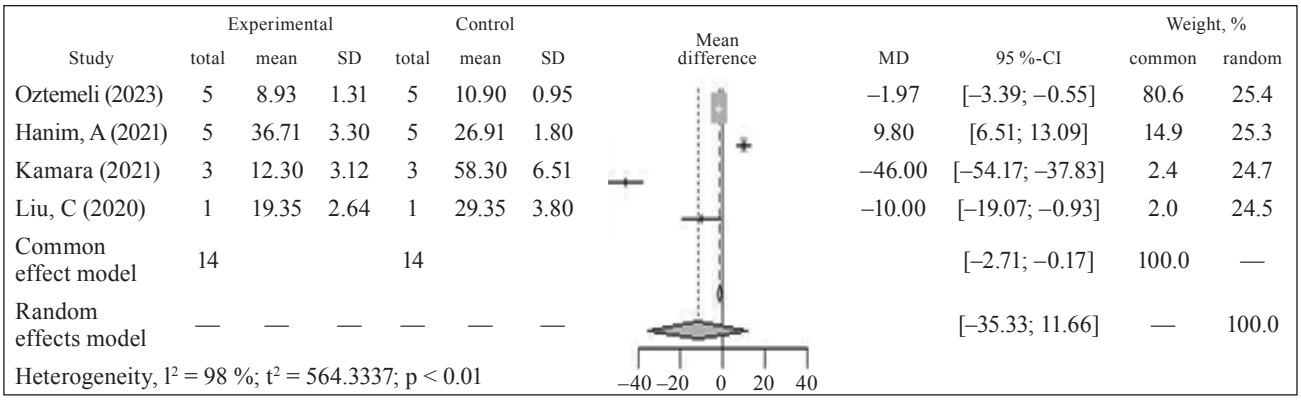

Fig. 2. Comparison of structure stiffness in bending load (N/mm) in LF and CF with 2 Kirchner wires

Table 3

Results of anatomical and biomechanical studies of crossed and lateral fixation

Author, year	Characteristics of the study	Conclusion
Allieu Kamara. et al., 2018 [11]	Transverse fractures were simulated at three levels: high, medium, and low, which were fixed using Kirchner wires, lateral external fixation, and ESIN, respectively. Tested during varus/valgus loading, extension/flexion, external/internal rotations	ESIN provides the best overall stability. Two lateral and one medial pins are the most stable CF
Chuang Liu et al., 2020 [12]	Transverse, medial and lateral oblique fractures, which were fixed with crossed and lateral external configurations. Tested during varus/valgus loading, extension/flexion, external/internal rotations	The best stability against translational forces in lateral oblique, medial oblique and transverse fractures is provided by ESIN, LF and CF, respectively. CF is superior to ESIN and LF in stabilizing all three fracture types against torsional forces. 2-medial and 1-lateral design provides the best stability
Allieu Kamara et al., 2021 [13]	Different models of crossed and divergent-lateral bracing with two or three pins were simulated on a transverse type of fracture and tested in six loading directions	CF and LF are more stable against torsional and translational forces, respectively, while 3-cross pins were more stable against all forces. A third pin from the ulnar fossa significantly increased the stability of the 2-lateral pins
Ahmet Oztermeli et al., 2023 [14]	Four pin configuration techniques were tested: crossed pins, 2 lateral pins, 3 lateral pins and combined technique for transverse fractures	Varus and flexion load values are statistically lower in the LF group compared to the CF group. There was no difference between the groups in terms of valgus load ($p > 0.05$)
Melissa Wallace et al., 2019 [15]	Five-pin configurations were designed to test coronal and sagittal patterns of 1.6-diameter pin placement; 2.0 and 2.4 mm	The larger diameter of the pin provides better fixation rigidity. The use of 3 lateral and 1 medial pins was not statistically different from 2 lateral and 1 medial pins
Alexander M. Bitzer et al., 2021 [16]	16 specimens with 3 lateral pins diverging in the coronal and sagittal planes and 16 specimens with a CF configuration. The fracture plane is transverse	Better design stiffness using 3 lateral pins that diverge in the coronal and sagittal planes compared to crossed and 3 lateral pins that only diverge in the coronal plane
Marcos Ceita Nunes et al., 2019 [17]	72 transverse fracture models that were fixed using parallel Kirchner wires and lateral intramedullary coconfiguration. Each group was tested for varus/valgus loading, extension/flexion, external/internal rotation	Fixation with one intramedullary and one lateral pin provides greater stability compared to fixation with two lateral constructs, considering loading during extension/flexion
Hanim A. et al., 2021 [18]	A transverse fracture in the middle of the ulnar fossa was simulated and fixed with two 1.6 mm pins with stability testing in extension/flexion, valgus/varus, internal/external rotation	In CF, the central intersection point was found to be the stiffest configuration for both linear and rotational forces, compared to the lateral, superior, and medial intersection points
Witit Pothong et al., 2021 [19]	Four pin configurations were studied: sagittal; crossed sagittal; divergent sagittal; parallel sagittal. All of them were bicortical with medial and lateral fixation. Testing was done for extension/flexion, varus/valgus, and during rotational efforts	The divergent configuration of the sagittal pin provides the greatest stiffness of the structure under various loads compared to others. The advantage of the divergent sagittal pin configuration can be explained by the maximum pin spread distance at the fracture site and the pin angle locking mechanism
Serhat Durusoy et al., 2021 [20]	The study was conducted on models of distal humerus fracture with cross-fixation with a combination of different angles (30°, 45° and 60°).	Increasing the insertion angle of both the medial and lateral pin increases stabilization and reduces displacement, especially against rotational deforming forces
Xiang-Fei Liu et al., 2020 [21]	The supracondylar fracture model was fixed in a transverse and lateral configuration in the direction of extension/flexion and varus/valgus displacement and internal/external rotation.	Among the 2-pin configurations, the crossed ones provided greater stability against rotational forces in excess of 2585 Nmm/°. The third added pins increased stability in all directions. Extension/flexion and varus/valgus and internal/external rotation stresses were 198 N/mm, 395 N/mm and 6,251 Nmm/°

Study	Experimental total	Experimental mean	Experimental SD	Control total	Control mean	Control SD	MD	95 %-CI	Weight, % common	Weight, % random
Oztemeli (2023)	5	11.95	1.58	5	8.93	1.31	3.02	[1.22; 4.82]	53.9	23.4
Nunes (2019)	6	22.90	4.00	6	17.10	1.20	5.80	[2.46; 9.14]	15.6	19.5
Hanim, A (2021)	5	36.74	5.70	5	26.91	2.30	9.83	[4.44; 15.22]	6.0	14.1
Kamara (2021)	3	10.78	2.24	3	12.30	3.12	–1.52	[–5.87; 2.83]	9.2	16.7
Liu, C (2020)	1	23.31	3.90	1	19.35	2.64	3.96	[–5.27; 13.19]	2.0	7.6
Kamara, A (2019)	2	7.30	2.00	2	6.40	1.70	0.90	[–2.74; 4.54]	13.2	18.7
Common effect model	22			22			3.18	[1.86; 4.50]	100.0	—
Random effects model	—	—	—	—	—	—	3.44	0.41; 6.46]	—	100.0
Heterogeneity, $I^2 = 65$ %; $t^2 = 9.3167$; $p = 0.01$										

Mean difference

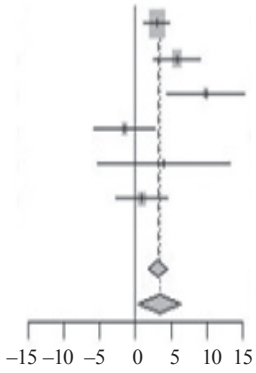

Fig. 3. Comparison of structure stiffness in bending load (N/mm) in lateral fixation with 3 wires and lateral fixation with 2 Kirchner wires

Study	Experimental total	Experimental mean	Experimental SD	Control total	Control mean	Control SD	MD	95 %-CI	Weight, % common	Weight, % random
Nunes (2019)	6	30.70	4.90	6	19.00	3.40	11.70	[6.93; 16.47]	27.4	20.1
Hanim, A (2021)	5	51.48	6.30	5	27.57	2.80	23.91	[17.87; 29.95]	17.1	20.0
Kamara (2021)	3	12.73	2.40	3	65.30	7.10	–52.57	[–61.05; –44.09]	8.7	19.8
Liu, C (2020)	1	5.18	0.90	1	14.67	3.80	–9.49	[–17.14; –1.84]	10.7	19.9
Kamara, A (2019)	2	9.10	1.50	2	11.34	2.60	–2.24	[–6.40; 1.92]	36.1	20.1
Common effect model	17			17			0.91	[–1.59; 3.41]	100.0	—
Random effects model	—	—	—	—	—	—	–5.61	[–31.04; 19.82]	—	100.0
Heterogeneity, $I^2 = 98$ %; $t^2 = 831.1541$; $p < 0.01$										

Mean difference

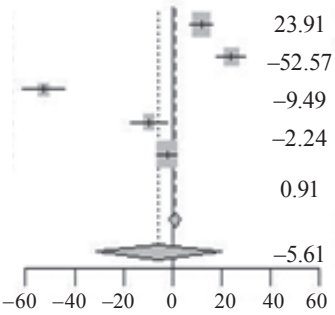

Fig. 4. Comparison of structure stiffness in extensional load (N/mm) in lateral fixation with 3 wires and crossed fixation with 2 Kirchner wires

Study	Experimental total	Experimental mean	Experimental SD	Control total	Control mean	Control SD	MD	95 %-CI	Weight, % common	Weight, % random
Oztemeli (2023)	5	33.81	2.49	5	10.90	0.95	22.91	[20.57; 25.25]	5.4	15.4
Nunes (2019)	6	30.70	4.90	6	28.70	3.50	2.00	[–2.82; 6.82]	1.3	15.2
Hanim, A (2021)	5	71.00	8.90	5	58.68	7.10	12.32	[2.34; 22.30]	0.3	14.7
Kamara (2021)	3	190.30	18.40	3	260.30	24.20	–70.00	[–104.10; –35.60]	0.0	9.6
Liu, C (2020)	1	14.81	1.80	1	30.23	5.10	–15.42	[–26.02; –4.82]	0.3	14.6
Kamara, A (2019)	2	14.30	1.30	2	22.20	3.80	–7.90	[–13.47; –2.33]	1.0	15.2
Pothong, W (2021)	15	7.13	0.97	15	8.01	0.57	–0.88	[–1.45; –0.31]	91.7	15.4
Common effect model	37			37			0.37	[–0.18; 0.91]	100.0	—
Random effects model	—	—	—	—	—	—	–4.70	[–22.17; 12.77]	—	100.0
Heterogeneity, $I^2 = 99$ %; $t^2 = 516.0042$; $p < 0.01$										

Mean difference

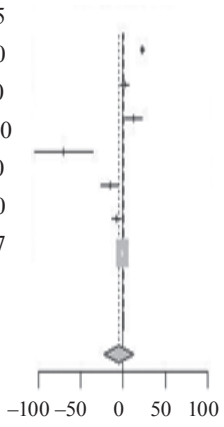

Fig. 5. Comparison of structure stiffness in varus load (Nmm/°) in lateral fixation with 3 wires and crossed fixation with 2 Kirchner wires

explained by the maximum distance of the pin spread at the fracture site and the pin angle locking mechanism [13–17, 19].

Clinical results of the examination of patients based on radiological and functional data (including scores according to the Flynn criterion) indicate the absence

Table 4

Results of treatment of supracondylar fractures in children and adolescents

Author	Flynn criteria				Conclusion
	E (%)	G (%)	S (%)	US (%)	
Erdinç Acar et al., 2020, Turkey [22]	93.40	6.60	—	—	Both types of fracture fixation showed equivalent clinical results
Henrigue Melo Natalin et al., 2021, Brazil [23]	68.40* 79.10**	26.40* 16.70**	5.20* 4.20**	— —	Both types of fixation showed similar clinical results
Kumar Prashant et al., 2016, India [24]	74.19* 83.87**	25.82* 16.12**	— —	— —	LF provides similar functional results and almost the same mechanical stability compared to medial-lateral fixation. Iatrogenic injury of the ulnar nerve 6.25 %.
Hossam Abubeih et al., 2019, Egypt [25]	73.60* 79.40**	17.60* 11.80**	5.90* 5.90**	2.90* 2.90**	There was no significant difference in complications and degree of fixation for LF and CF. If each method follows the same standardized operative technique, their percutaneous fixation results will be the same in terms of safety and efficacy
Afaque S. F. et al., 2026, India [26]	70.30* 86.00**	18.90* 37.50**	10.8* 2.50**	— —	In the final result, there was no difference between CF and LF groups in terms of radiological and clinical outcomes. Two patients of group I developed delayed ulnar neuritis (5%), which completely resolved during further observation
Naik L. G. et al., 2017, India [27]	78.60	17.90	—	3.50	No significant difference in functional and radiological outcomes was observed between both methods
Arun K. N. et al., 2018, India [28]	80.00* 71.10**	16.70* 21.00**	3.38* 7.90**	— —	There was no statistically significant difference between both methods
Palange N. et al., 2019, India [29]	66.67* 60.00**	26.67* 26.70**	6.66* 13.30**	— —	No statistical difference was found between the two techniques, but there is a high risk of ulnar nerve injury in CF
Othman M. K. et al., 2020, India [30]	66.60* 60.00**	6.70* 13.30**	26.70* 26.70**	— —	No statistical difference was found between the two techniques in clinical outcomes. Injury to the ulnar nerve in CF was noted in two patients (13.3 %)
Naveen P. R. et al., 2017, Iraq [31]	75.00* 80.00**	20.00* 15.00**	5.00* 5.00**	— —	The two fixation techniques provide the same functional clinical results
Ahmad M. Radaideh et al., 2022, Jordan [32]	62.10* 62.50**	35.50* 36.10**	3.40* 1.40**	— —	LF and CF configuration in supracondylar fractures of the humerus in children provides the same functional and radiological results
Justyna Napora et al., 2022, Poland [33]	80.00	17.40	1.30	1.30	Despite the debate in the literature regarding the two types of fixation, both methods provide excellent clinical and functional results

Notes: E — Excellent; G — Good; S — Satisfactory; US — Unsatisfactory; * — LF; ** — CF.

of a significant difference between the two types of fixations — crossed and lateral [29–33].

In our opinion, the risks of loss of reposition after LF (proven by experimental studies) are leveled due to external immobilization, which is used during both types of fixation.

A significant disadvantage of medial-lateral fixation is a higher risk of iatrogenic damage to the ulnar nerve (from 5 to 13%) [26, 30]. Its injury rate can be significantly reduced with the mini-open technique, which consists of making a small incision on the medial epicondyle and visualizing the ulnar nerve before inserting a medial pin. This method makes it possible to reduce nerve damage to 2.2% [34].

The performed analysis has certain limitations. First, the methodological quality of the experimental

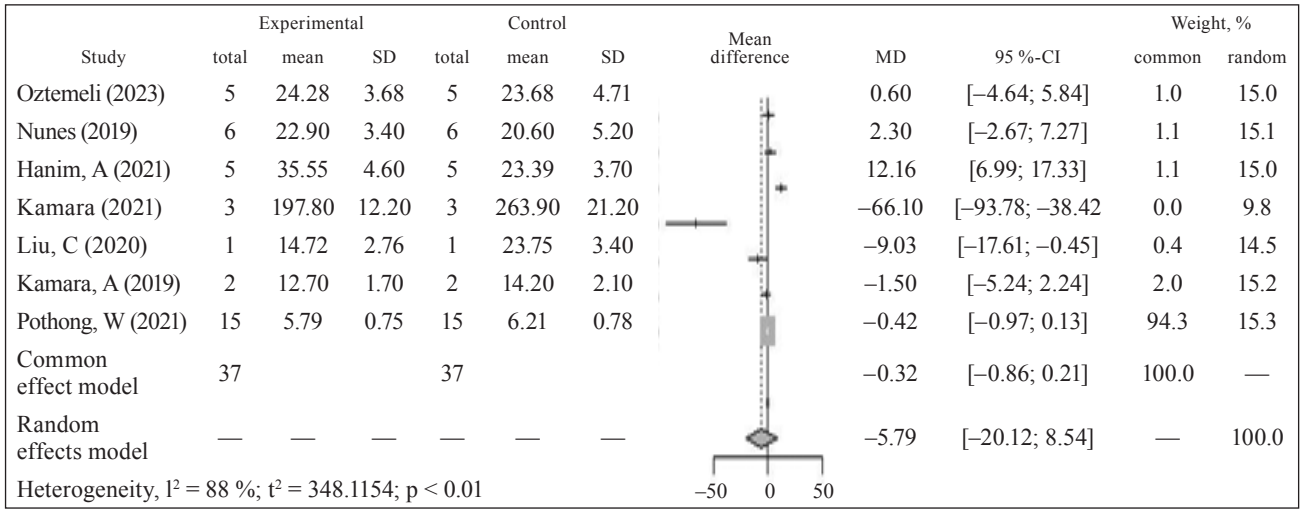

Fig. 6. Comparison of structure stiffness in valgus loading (Nmm/°) in lateral fixation with 3 wires and crossed fixation with 2 Kirchner wires

Table 5

Comparative analysis of the results of treatment using CF and LF according to the Flynn criteria

Result	Median		95 % CI	
	CF	LF	CF	LF
Excellent	73.89	74.85	66.67–80.00	60.00–80.00
Good	18.40	17.65	16.70–26.40	13.30–26.70
Satisfactory	5.20	5.20	3.38–10.80	1.40–13.30
Unsatisfactory	2.90	—	1.30–3.50	—

studies is low: several types of fractures and fixation by certain configurations of stabilizing structures are given. However, the stability of lateral and crossed fixations depends on the point of introduction and the plane of location of the fixing structures, as well as on the angle between them [18, 19]. It is not possible to monitor these important parameters due to their absence, inconsistency of statistical data, therefore the results are not reliable enough. Second, there is high clinical heterogeneity with respect to fracture type and number of fixation constructs, which affects clinical outcomes. Thus, according to the modified Hartland classification, type II fractures can be divided into IIA and IIB, respectively, however, IIA is rotationally stable compared to IIB, which creates a certain bias in the analysis for loss of reduction function.

Conclusions

Cross-fixation based on the results of anatomical and biomechanical studies provides more rigid fixation of fragments in the case of supracondylar fractures of the humerus in children and adolescents. However, clinical results based on radiological and functional data (Flinn score) indicate no significant difference between crossed and lateral types of fixation. At the same time, significant risks of iatrogenic damage to the ulnar nerve during cross fixation are noted, which justifies the need to use a mini-open technique during medial fixation construction.

Conflict of interest. The authors declare no conflict ofinterest.

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METHODS OF PERCUTANEOUSFIXATION OF FRAGMENTS IN SUPRACONDYLAR HUMERUS FRACTURES IN CHILDREN AND ADOLESCENTS

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