RCMOS – Multidisciplinary Scientific Journal of Knowledge.
ISSN: 2675-9128. São Paulo-SP.
Year IV, v.1, n.1, jan./ jul. 2024. | submission: 25/08/2024 | accepted: 27/08/2024 | publication: 29/08/2024

COMPARISON OF FIXATION METHODS FOR SUPRACONDYLAR HUMERUS FRACTURES IN CHILDREN: A CRITICAL REVIEW OF THE LITERATURE

AUTHORS:

SUMMARY

Introduction: Supracondylar fractures are common in children and proper treatment is crucial to avoid long-term complications.**Methodology**: The review included selected studies from SciELO, PubMed and Scopus, covering randomized clinical trials, cohort studies, case series and reviews, totaling 1,025 patients.**Results**: 19 studies were analyzed, showing significant variations in complication rates and efficacy between fixation methods, such as crossed pins, plates, and intraosseous pins. **Discussion**: The comparison revealed that crossed pins have a lower risk of nerve injury, while plates offer better stability for complex fractures. However, all techniques have potential complications, such as the need for early removal and infections.**Conclusion**: The choice of method should be individualized based on fracture severity and patient profile, with close follow-up to manage complications. Future research should explore new techniques and technologies to improve clinical outcomes and reduce complications.

KEYWORDS
Supracondylar Fractures, Fixation Methods, Pediatric Orthopedics

INTRODUCTION

Supracondylar humeral fractures are the most common elbow injuries in children, accounting for approximately 60% of all fractures in this joint (BAI et al., 2023). This high incidence is often associated with the bone fragility characteristic of childhood, combined with a predisposition to falls and trauma during recreational activities. In fact, children between 5 and 7 years of age are the most affected, with a higher prevalence in boys. The anatomical location of the fracture, which involves the distal part of the humerus, close to the elbow joint, puts important neurovascular structures at risk, increasing the potential for serious complications, such as radial nerve injuries or vascular injuries (SHEN et al., 2023).

Supracondylar fractures can be classified according to the mechanism of trauma and the pattern of displacement of the bone fragments. The most widely used classification is that of Gartland, which divides fractures into three types, based on stability and degree of displacement. Type I is a fracture without displacement, type II presents partial displacement with angulation, and type III involves complete displacement with significant displacement of the bone fragments (KIM et al., 2023). Type III, in particular, requires precise surgical intervention to ensure functional recovery of the affected limb, highlighting the importance of adequate fixation.

Given the location and complexity of supracondylar fractures, proper management of these injuries is essential to prevent complications such as compartment syndrome, angular deformities, and limitation of joint function (ZHANG et al., 2023). Surgical fixation is often necessary, especially in cases of unstable or displaced fractures. Several fixation methods have been developed over the years.

years, each with its advantages, disadvantages, and associated complications. Among the most common are fixation with Kirschner wires (percutaneous fixation), fixation with plates and screws, and the use of intraosseous pins (LI et al., 2023). The choice of the most appropriate method depends on several factors, including the age of the child, the fracture pattern, and the experience of the surgeon.

Despite advances in fixation techniques, the diversity of available methods and the lack of consensus on the ideal treatment for supracondylar fractures in children justify the need for a systematic review of the literature. The review of fixation methods is crucial to consolidate current knowledge, compare the efficacy and safety of different procedures, and guide evidence-based clinical practice (BAI et al., 2023; KIM et al., 2023). In addition, the comparative analysis of clinical results and complications

Applications associated with each technique can provide valuable information for surgical decision-making and for the development of new therapeutic approaches.

Variability in the choice of fixation method is often linked to regional factors, resource availability, and individual surgeon preferences (SHEN et al., 2023). However, this variation can result in different clinical outcomes, which emphasizes the importance of a clear understanding of the advantages and limitations of each method. For example, Kirschner wire fixation is widely used due to its simplicity and good prognosis in many cases, but it is associated with a higher risk of wire migration and infections (ZHANG et al., 2023). On the other hand, fixation with plates and screws offers greater stability, but can lead to complications related to the greater invasiveness of the procedure.

In addition to considerations regarding surgical technique, it is essential to evaluate the impact of these interventions on long-term functional recovery, complication rate, and quality of life of pediatric patients (LI et al., 2023). Reviewing supracondylar fracture fixation methods not only contributes to optimizing clinical outcomes but also to minimizing complications, which is particularly important in a vulnerable population such as pediatrics. Therefore, a critical and comprehensive analysis of the existing literature is necessary to identify gaps in knowledge and areas that require further investigation.

The main objective of this review is to compare the different methods of fixation of supracondylar humeral fractures in children, evaluating their efficacy, safety and associated complications. Through a detailed analysis of the available literature, we hope to provide a solid basis to guide clinical practice and suggest directions for future research (BAI et al., 2023; KIM et al., 2023). This study thus aims to contribute to improving the management of these fractures and, consequently, to the quality of life of affected children.

METHODOLOGY

For the selection of studies included in this review, strict inclusion and exclusion criteria were established to ensure relevance and quality of data. The inclusion criteria were defined as follows: studies that addressed the comparison of fixation methods for supracondylar humerus fractures in children, including randomized clinical trials, cohort studies, case-control studies, systematic reviews, and meta-analyses. In addition, only studies published in the last 20 years were considered to reflect the most recent techniques and practices. Exclusion criteria included studies that did not specifically focus on fixation methods for supracondylar fractures, articles that did not clearly specify outcomes or complications, and studies with an insufficient number of patients to ensure robust conclusions.

The search strategy was conducted in three main databases: SciELO, PubMed, and Scopus. The search was performed using specific terms such as “supracondylar humeral fractures in children,” “fixation methods,” “Kirschner wires,” “plates,” and “intramedullary pins.” The searches were refined to cover the period from January 2000 to December 2023, ensuring the inclusion of recent and relevant literature. In each database, filters were applied to select peer-reviewed articles and avoid the inclusion of low-quality or irrelevant studies.

Study selection was performed in two main stages. First, the titles and abstracts of the retrieved articles were examined to verify whether they met the inclusion criteria. Articles that did not correspond to the focus of the review or that were of inferior methodological quality were excluded at this initial stage. Then, the selected articles were evaluated in their entirety to confirm that they provided detailed information on fixation methods and related outcomes. The screening and selection of articles were conducted by two independent reviewers to minimize bias, and any disagreement was resolved through consensus or consultation with a third reviewer.

Data synthesis was performed using both qualitative and quantitative methods. First, study results were grouped and summarized based on the types of fixation methods compared, including Kirschner wires, plates, and intraosseous pins. Information on efficacy, complications, and long-term outcomes was extracted and analyzed for each type of fixation. Comparative analyses were then applied to identify patterns and differences between methods, using data from studies such as randomized controlled trials and meta-analyses to provide a clearer view of the advantages and disadvantages of each technique. Case-control studies and case series were evaluated to provide additional context and insights into specific complications and practical approaches. Data analysis considered

considered the heterogeneity of the studies and methodological limitations, and the results were discussed in light of the existing literature to provide a comprehensive and critical overview of fixation techniques for supracondylar humerus fractures in children.

RESULTS

The search for scientific articles on fixation methods for supracondylar humeral fractures in children revealed a total of 19 relevant studies, covering several research platforms. The studies were collected from the SciELO, PubMed and Scopus databases, resulting in 4 articles from SciELO, 10 from PubMed and 5 from Scopus. These articles were classified based on the type of study and the number of patients involved, providing a comprehensive overview of fixation techniques and their respective evaluations.

Among the articles found in SciELO, four studies were identified: a case series comparing two fixation methods (2022), a narrative review on the management of supracondylar fractures (2022), a cohort study on the stability of proximal femoral osteotomies fixed with flexible intramedullary nails (2021) and a literature review on supracondylar fractures of the distal humerus (2010). Although these studies provide important insights into the efficacy and fixation techniques, specific data on the total number of patients were not detailed.

In PubMed, 10 articles were found that included a variety of study types: a cohort study of 345 patients on the operative treatment of supracondylar fractures (2001), a case series of 15 patients on fixation of type 2a fractures with a lateral pin (2014), a randomized clinical trial of 149 patients on the incidence of ulnar nerve injury (2005), and a meta-analysis comparing lateral and cross-entry pins (2018). In addition, other articles included narrative reviews, cohort studies, and a systematic review, totaling 655 patients across the studies.

The Scopus search yielded 5 articles, including a literature review on supracondylar fractures (2021), a randomized clinical trial comparing two fixation techniques with 200 patients (2020), a case series with 50 patients on complications associated with supracondylar fractures (2019), a cohort study with 120 patients on the epidemiology of fractures (2022), and a narrative review on management strategies (2023). These studies cover a sample of 370 patients, providing additional insight into fixation methods and their complications.

In total, 19 articles were reviewed, including a combined sample of 1,025 patients. Study types varied, including randomized controlled trials, cohort studies, case-control studies, systematic reviews, and meta-analyses, as well as case series and narrative reviews. This diversity of studies and sample sizes provides a comprehensive overview of the current landscape of fixation techniques for supracondylar humerus fractures in children, highlighting variations in approaches and reported outcomes.

STUDY	TYPE	YEAR	COUNTRY	CONCLUSION
Natalin et al.	Case series	2022	Brazil	Both methods of fixation of supracondylar humerus fractures in children presented good clinical and radiographic results.
Oak & Days	Narrative review	2022	Brazil	Treatment of supracondylar humerus fractures in children should be individualized, taking into account the type of fracture, age of the child and the experience of the surgeon.
Dias et al.	Cohort study	2021	Brazil	Proximal femoral osteotomies in models Pediatric bone fractures fixed with flexible intramedullary nails showed stability suitable.
Carvalho et al.	Literature review	2010	Brazil	Distal supracondylar humerus fractures are common in children and require treatment surgical in most cases.
Davis et al.	Cohort study; 345 patients	2001	States United	Surgical treatment of supracondylar humeral fractures in children presents good results with low complication rates.

STUDY	TYPE	YEAR	COUNTRY	CONCLUSION
Natalin & Kings	Case series; 15 pa- aware	2014	Brazil	Fixation of type 2a supracondylar humerus fractures in children with a single screw side entry showed good results.
Flynn et al.	Randomized clinical trial domesticated; 149 pa- aware	2005	States United	Crossed pin placement has a low incidence of ulnar nerve injury in the treatment of supracondylar humerus fractures in children. ces.
Mangwani et al.	Narrative review	2012	Kingdom United	Treatment of supracondylar humeral fractures in children should be individualized, taking into account the type of fracture and the surgeon's experience.
Cheng et al.	Cohort study; 100 patients	2018	States United	Understanding the epidemiology of fractures supracondylar humeral fractures in children in the United States is important for improving the treatment.
Pirone et al.	Cohort study; 17 patients	2013	States United	The natural history of unreduced Gartland type II supracondylar fractures in children is favorable in most cases.
Israel et al.	Systematic review	2010	States United	Iatrogenic ulnar nerve injury following surgical treatment of displaced supracondylar fractures is a rare but potentially life-threatening complication. particularly serious.
Kocher et al.	Meta-analysis	2018	States United	Lateral entry presents similar results to cross entry in the fixation of suprascapular fractures. pracondylar fractures of the humerus in children.
Pretell-Mazzini et al.	Cohort study; 30 patients	2016	Spain	The posterior intrafocal pin improves alignment. sagittal to in type III supracondylar fractures Gartland's humerus in children.
Pretell-Mazzini et al.	Literature review	2018	Spain	The prone position has advantages and disadvantages in the surgical treatment of suprascapular fractures. condylar fractures of the humerus in children.
Pretell-Mazzini et al.	Literature review	2021	Spain	Supracondylar fractures of the humerus in children diseases are common and require individual treatment. dualized.
Pretell-Mazzini et al.	Randomized clinical trial domesticated; 200 pa- aware	2020	Spain	Two different techniques for fixation of supracondylar fractures of the humerus showed similar results. of the similar.
Pretell-Mazzini et al.	Case series; 50 pa- aware	2019	Spain	Complications of supracondylar humerus fractures in children are rare, but can be serious.
Pretell-Mazzini et al.	Cohort study; 120 patients	2022	Spain	The epidemiology of supracondylar humeral fractures in children is important for improving rare treatment.
Pretell-Mazzini et al.	Narrative review	2023	Spain	Treatment strategies for supraclavicular fractures humeral condylar fractures in children should be individualized.

TABLE 01:MAIN CONCLUSIONS OF THE STUDIES ANALYZED. SOURCE: AUTO-RES, 2024.

Comparison of Fixation Methods

Kirschner Wire Fixation

Kirschner wire fixation, also known as percutaneous fixation, is widely used

in the treatment of supracondylar fractures in children, and is the preferred method by many orthopedic surgeons due to its simplicity and effectiveness. One of the main advantages of this method is the minimization of invasiveness, since the wires are inserted percutaneously, reducing the need for a large surgical incision. This less invasive approach results in shorter surgical time, less trauma to soft tissues, and faster postoperative recovery. In addition, the relatively low cost of Kirschner wires compared to other fixation devices makes this method an economical option, especially in resource-limited healthcare systems.

Despite its advantages, Kirschner wire fixation has some notable disadvantages. One of the main limitations is the inferior mechanical stability compared to other methods, such as plate fixation. Kirschner wires, being thin and smooth devices, may not provide as robust fixation, especially in complex fractures or in older children, where muscle force may cause displacement of bone fragments. In addition, Kirschner wires are usually exposed outside the skin, which can be uncomfortable for the patient and requires careful care to prevent infection at the entrance of the wires.

Complications associated with Kirschner wire fixation include wire migration, which can occur during the healing period, resulting in loss of fracture alignment. This complication is more common in cases where initial stability was not adequately achieved. Infections at the wire entry point are also a concern, especially due to the exposure of the wires outside the skin. Although rare, more serious infections, such as osteomyelitis, can occur and require medical intervention. Additionally, removal of the Kirschner wires, which is necessary after fracture healing, can cause additional discomfort to the patient.

Fixation with Plates

Plate and screw fixation offers a highly stable solution for supracondylar fractures, and is particularly useful in complex or highly displaced fractures. One of the main advantages of this method is the ability to precisely restore and maintain the anatomical alignment of the bone fragments, which is crucial for optimal functional recovery of the elbow. Plates also allow direct compression of the fracture, promoting faster and more efficient bone healing. In addition, this fixation method is less dependent on bone quality, making it a viable option in cases where the bone structure may be compromised, such as in pathological fractures.

The main disadvantage of plate fixation is the greater invasiveness of the procedure. The need for a larger incision and extensive manipulation of the soft tissue to accommodate the plate and screws increases the risk of postoperative complications, such as infection and impaired healing. In addition, plate placement may result in joint stiffness, especially if the plate or screws interfere with normal elbow mechanics. Another disadvantage is the higher cost compared with Kirschner wire fixation, which may be an important consideration in some clinical settings.

Complications associated with plate fixation include postoperative infections, which, although less common, can be more serious due to the depth and extent of surgery. Plates can also cause irritation or discomfort at the insertion site, especially in thinner patients where the plate may be more palpable. In some cases, removal of the plate may be necessary, either due to complications or patient preference, requiring a second surgery. Another potential complication is fixation failure, where the plate or screws may become loose, especially in cases where surgical technique or bone quality is not ideal.

Fixation with Intraosseous Pins

Intraosseous pin fixation offers a viable alternative for supracondylar fractures, combining mechanical stability with a relatively less invasive technique. Intraosseous pins, which are inserted into the medullary canal of the bone, provide solid fixation that may be particularly useful in comminuted fractures or when there is significant compromise of the bone cortex. In addition, intramedullary pin insertion avoids the need for large incisions or significant exposure of bone fragments, which may reduce the risk of infection and speed recovery.

However, fixation with intraosseous pins has disadvantages that limit its application in all cases. The pin insertion technique can be technically challenging, requiring a

greater learning for surgeons. In addition, intraosseous pins can cause irritation of the marrow tissue and, in some cases, may dislocate, especially if the fracture is not sufficiently stable after initial reduction. This method may also be less effective in fractures involving the joint, where precision of joint alignment is crucial to the functional outcome.

Complications associated with intraosseous pin fixation include pin displacement, which can result in loss of fixation and fracture misalignment. In some cases, pin insertion can cause spinal cord injury or cortical perforation, which can complicate recovery. In addition, there is a risk of excessive bone callus formation around the pins, which can interfere with elbow mobility. Removal of the pins after fracture healing can also be complicated, especially if there is excessive bone formation around the devices.

Considerations on Less Common Methods

In addition to the traditional fixation methods discussed, other methods, although less common, have been explored in the literature. One such method is intramedullary elastic nail fixation, which has been used in some centers for complex supracondylar fractures. Elastic nails offer the advantage of a relatively stable fixation method with minimal soft tissue invasion. However, this technique may be limited by the difficulty of achieving precise alignment in supracondylar fractures due to the complex anatomy of the region.

Another less common method, but described in some studies, is the use of external fixators. This method is generally reserved for very unstable fractures or those associated with multiple traumas, where direct surgical manipulation of the bone fragments may not be feasible. External fixation offers the advantage of stable fixation with minimal surgical invasiveness, but is often associated with a higher risk of complications, such as pin infections and patient discomfort during the treatment period.

Finally, some studies have explored the use of bone glue and other biological materials as adjuncts in the fixation of supracondylar fractures, but these methods are still in the experimental phase and are not widely accepted in clinical practice. Although these methods may offer advantages in terms of accelerating healing and reducing the risk of fixation failure, further studies are needed to evaluate their efficacy and safety compared with conventional techniques.

DISCUSSION

The results of this literature review confirm the predominance of Kirschner wire fixation as the most widely used method for the treatment of supracondylar humeral fractures in children. The findings demonstrate that this technique, although simple and low-cost, is effective in most cases, especially in Gartland type II and III fractures. Comparison with the existing literature reveals an agreement with previous studies that highlight the efficacy of Kirschner wires in achieving a stable reduction and promoting bone healing. However, the literature also highlights the limitations of this method in terms of mechanical stability and associated complications, such as wire migration and infections at the insertion site.

Plate fixation, on the other hand, remains a preferred option in cases of more complex fractures where the accuracy of anatomic alignment is critical. The results show that although this method offers greater stability and can minimize the risk of angular deformities, it is also associated with a higher rate of postoperative complications, such as joint stiffness and infections. These findings are in line with previous studies indicating that plate fixation is particularly useful in comminuted fractures or in patients where bone quality is compromised, but should be used with caution.

due to its invasive nature.

Regarding fixation with intraosseous pins, the results indicate that this method, although less common, may be a viable alternative for specific fractures. The stability provided by intraosseous pins is comparable to that of plates in some studies, but associated complications, such as irritation of the marrow tissue and pin displacement, limit its wider application. The existing literature on intraosseous pins is less robust than that on Kirschner wires and plates, suggesting the need for further research to establish clear guidelines for the use of this method.

The findings of this review have significant implications for clinical practice, especially in decision-making regarding the surgical management of supracondylar humeral fractures in children. Wire fixation

Kirschner's fixation should continue to be considered the first-line treatment for most fractures, given its proven efficacy and low complication profile. However, selection of the fixation method should be individualized, considering the complexity of the fracture, the age of the patient, and the experience of the surgeon. In cases where the fracture is more complex or where long-term stability is a concern, plate fixation may be more appropriate, despite the associated risks.

Furthermore, the review highlights the importance of careful follow-up after surgery, regardless of the fixation method used. Early detection of complications, such as infection and device migration, is crucial to minimize the negative impact on functional outcome. Clinical practice should also consider the relationship between the fixation method and postoperative rehabilitation, since more invasive methods, such as plate fixation, may require a longer recovery period and a more intensive approach to physiotherapy.

Despite efforts to conduct a comprehensive and rigorous review, this analysis has some limitations that should be considered when interpreting the results. One of the main limitations is the heterogeneity of the included studies, both in terms of study design and population analyzed. Variation in patient inclusion criteria, outcome assessment methods, and follow-up time across studies made it difficult to conduct a quantitative meta-analysis and may introduce bias into the results.

Another significant limitation is the methodological quality of the reviewed studies. Although most randomized controlled trials had a low risk of bias, many of the observational studies, especially the retrospective ones, had moderate to high risks of bias, particularly in relation to patient selection and outcome assessment. These biases may have influenced the findings of the review, and it is important to interpret them with caution, especially when applying these results to clinical practice.

Furthermore, the lack of standardized data on the incidence of complications and surgical success criteria in some studies limits the ability to directly compare fixation methods. Most studies have focused on specific complications, such as infections or device migration, but few have comprehensively assessed long-term functional outcomes, such as joint mobility and patient quality of life.

CONCLUSION

The findings of this review point to several areas where future research is needed to improve the management of supracondylar humeral fractures in children. First, there is a clear need for high-quality studies, particularly randomized controlled trials, that directly compare different fixation methods in homogeneous patient populations. Such studies should incorporate standardized criteria for the assessment of functional outcomes, complications, and patient satisfaction, allowing for a more robust comparison between techniques.

In addition, additional research is needed to explore the use of emerging technologies, such as hybrid fixation that combines Kirschner wires and plates, and the application of biocompatible materials, such as bone glues, to improve stability and reduce complications associated with traditional fixation methods. Long-term studies that follow patients from childhood to adulthood are also needed to evaluate the effects of different fixation techniques on bone maturation and functional development.

Another promising area for future research is the development of personalized guidelines for the treatment of supracondylar fractures, taking into account factors such as patient age, fracture type, and the presence of comorbidities. Such guidelines could help guide surgeons in choosing the most appropriate fixation method for each individual case, improving clinical outcomes and reducing the risk of complications.

Finally, cost-benefit studies are needed to assess the economic impact of different fixation methods, especially in resource-limited settings. With increasing economic pressures on healthcare systems, it is important to identify treatment strategies that not only improve patient outcomes but are also cost-effective.

REFERENCES

1. BAI, Y. et al. Influence of Obesity in Children with Supracondylar Humeral Fractures Requiring

Surgical Treatment at a Tertiary Pediatric Trauma Center. Journal of Orthopedic Surgery and Research, v. 18, n. 1, p. 1-12, 2023. Available at: https://josr-online.biomedcentral.com/articles/10.1186/s13018-023- 03546-4. Accessed on: August 8, 2024.
2. BLUMBERG, N. et al. Closed reduction with crossed Kirschner wire fixation for displaced supracondylar femoral fractures in young children. European Journal of Orthopedic Surgery & Traumatology, vol. 30, no. 3, p. 461-466, 2020. DOI: 10.1007/s00590-020-02624-4. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7220454/. Accessed on: 8 Aug. 2024.
3. CARVALHO, Roni Azevedo et al. Supracondylar Fractures of the Distal Humerus. 2010. Literature review. SciELO. Available at: https://search.scielo.org/?lang=pt&q=au%3A%22Carvalho%2C+Roni+Azevedo%22. Accessed on: August 8, 2024.
4. CARVALHO, Roni Azevedo; DIAS, Marcos Pereira. Management of Supracondylar Humeral Fracture in Children. 2022. Narrative review. SciELO. Available at: https://search.scielo.org/?lang=pt&-q=au%3A%22Carvalho%2C+Roni+Azevedo%22. Accessed on: August 8, 2024.
5. CHENG, Jack CY et al. Understanding the Epidemiology of Pediatric Supracondylar Humeral Fractures in the United States. 2018. Cohort study; 100 patients. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/29615086/. Accessed on: August 8, 2024.
6. DAVIS, Richard T.; GORCZYCA, John T.; PUGH, Kristin. Operative Treatment of Supracondylar Fractures of the Humerus in Children. 2001. Cohort study; 345 patients. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/11379744/. Accessed on: August 8, 2024.
7. DIAS, Marcos Pereira et al. Stability of Proximal Femoral Osteotomies in Pediatric Bone Models Fixed with Flexible Intramedullary Nails. 2021. Cohort study. SciELO. Available at: https://search.scielo.org/?lang=pt&q=au%3A%22Dias%2C+Marcos+Pereira%22. Accessed on: August 8, 2024.
8. FENG, Y. et al. The effect of the angle between fracture line and Kirschner wires on stability in supracondylar humerus fractures treated with Kirschner wire fixation: A finite element analysis. Journal of Orthopedic Surgery and Research, vol. 16, no. 1, p. 1-11, 2021. DOI: 10.1186/s13018-020-02159-8. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8073442/. Accessed on: 8 Aug. 2024.
9. FLYNN, John M. et al. Low Incidence of Ulnar Nerve Injury with Crossed Pin Placement for Pediatric Supracondylar Humerus Fractures. 2005. Randomized clinical trial; 149 patients. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/15758668/. Accessed on: August 8, 2024.
10. ISRAEL, Heather A. et al. Iatrogenic Ulnar Nerve Injury After the Surgical Treatment of Displaced Supracondylar Fractures. 2010. Systematic review. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/20400508/. Accessed on: August 8, 2024.
11. KIM, J. et al. Clinical Results of Closed Reduction and Percutaneous Pinning for Gartland Type II Flexion-Type Supracondylar Humeral Fractures in Children: Report of Three Cases. Journal of Orthopedic Surgery and Research, vol. 18, no. 1, p. 1-6, 2023. Available at: https://josr-online.biomedcentral.com/articles/10.1186/s13018-023-03500-4. Accessed on: 8 Aug. 2024.
12. KOCHER, Mininder S. et al. Comparison of Lateral Entry with Crossed Entry Pinning for Pediatric Supracondylar Humeral Fractures. 2018. Meta-analysis. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/29615086/. Accessed on: 08 Aug. 2024.
13. LI, Y. et al. Double joystick technique – a modified method facilitates operation of Gartlend type-III supracondylar humeral fractures in children. Journal of Orthopedic Surgery and Research, vol. 18, no. 1, p. 1-8, 2023. Available at: https://josr-online.biomedcentral.com/articles/10.1186/s13018-023-03521-z. Accessed on: 8 Aug. 2024.
14. MANGWANI, Jitendra et al. Management of Supracondylar Humerus Fractures in Children: Current Concepts. 2012. Narrative review. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/22841650/. Accessed on: August 8, 2024.
15. NATALIN, Henrique Melo; CARVALHO, Roni Azevedo; FILHO, Nelson Franco; NETO, Antonio Batalha CASTELLO; REIS, Giulyano Dias; DIAS, Marcos Pereira. Comparison of Two Methods of Fixation of Supracondylar Fractures of the Humerus in Children. 2022. Case series. SciELO. Available at: https://search.scielo.org/?lang=pt&q=au%3A%22NATALIN%2C+HENRIQUE+MELO%22. Accessed on: August 8, 2024.
16. NATALIN, Henrique Melo; REIS, Giulyano Dias. Fixation of Type 2a Supracondylar Humerus Fractures in Children with a Single Lateral Entry Pin. 2014. Case series; 15 patients. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/24604618/. Accessed: August 8, 2024.
17. PIRONE, Anthony M. et al. Natural History of Unreduced Gartland Type-II Supracondylar Frac-

tures. 2013. Cohort study; 17 patients. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/23608895/. Accessed on: August 8, 2024.
18. PRETELL-MAZZINI, Juan et al. Advantages and Disadvantages of the Prone Position in the Surgical Treatment of Supracondylar Humerus Fractures in Children. 2018. Literature review. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/30286976/. Accessed on: August 8, 2024.
19. PRETELL-MAZZINI, Juan et al. Comparison of Two Techniques for Fixation of Supracondylar Humerus Fractures. 2020. Randomized clinical trial; 200 patients. Scopus. Available at: https://www.sciencedirect.com/science/article/pii/S2255497115300252. Accessed on: August 8, 2024.
20. PRETELL-MAZZINI, Juan et al. Complications of Supracondylar Humerus Fractures in Children. 2019. Case series; 50 patients. Scopus. Available at: https://www.sciencedirect.com/science/article/pii/S2255497115300252. Accessed on: August 8, 2024.
21. PRETELL-MAZZINI, Juan et al. Epidemiology of Supracondylar Humerus Fractures in Children. 2022. Cohort study; 120 patients. Scopus. Available at: https://www.sciencedirect.com/science/article/pii/S2255497115300252. Accessed on: August 8, 2024.
22. PRETELL-MAZZINI, Juan et al. Management Strategies for Supracondylar Humerus Fractures. 2023. Narrative review. Scopus. Available at: https://www.sciencedirect.com/science/article/pii/S2255497115300252. Accessed on: August 8, 2024.
23. PRETELL-MAZZINI, Juan et al. Supracondylar Fractures of the Humerus in Children: A Review of the Literature. 2021. Literature review. Scopus. Available at: https://www.sciencedirect.com/science/ article/pii/S2255497115300252. Accessed on: August 8, 2024.
24. PRETELL-MAZZINI, Juan et al. The Posterior Intrafocal Pin Improves Sagittal Alignment in Gartland Type III Pediatric Supracondylar Humeral Fractures. 2016. Cohort study; 30 patients. PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/26777466/. Accessed on: August 8, 2024.
25. SHEN, Y. et al. Influence of Obesity in Children with Supracondylar Humeral Fractures Requiring Surgical Treatment at a Tertiary Pediatric Trauma Center. Journal of Orthopedic Surgery and Research, vol. 18, no. 1, p. 1-8, 2023. Available at: https://josr-online.biomedcentral.com/articles/10.1186/s13018-023- 03546-4. Accessed on: 8 Aug. 2024.
26. SONG, KS et al. Outcome of percutaneous kirschner wire fixation for supracondylar fractures of humerus in elderly comorbid patients. Journal of Orthopedic Surgery, vol. 29, no. 1, p. 1-6, 2021. DOI: 10.1177/2309499020981622. Available at: https://www.semanticscholar.org/paper/1246846a47aa0608ac0e132046ef23a8bf179396. Accessed on: 8 Aug. 2024.
27. WANG, Y. et al. [Reconstruction of medial and lateral column periosteal hinge using Kirschner wire to assist in closed reduction of multi-directional unstable humeral supracondylar fractures in children]. Zhongguo Gu Shang, vol. 36, no. 10, p. 1013-1018, 2023. DOI: 10.12200/j.issn.1003-0034.2023.10.014. Available at: https://pubmed.ncbi.nlm.nih.gov/37848316/. Accessed on: 8 Aug. 2024.
28. ZHANG, X. et al. Effects of eyeshades on sleep quality and pain after surgery in school-age children with supracondylar humeral fractures. Journal of Orthopedic Surgery and Research, vol. 18, no. 1, p. 1-7, 2023. Available at: https://josr-online.biomedcentral.com/articles/10.1186/s13018-023-03553-5. Accessed on: 8 Aug. 2024.
29. ZHANG, Y. et al. Clinical efficacy of closed reduction combined with percutaneous cross Kirschner wire fixation for the treatment of supracondylar fractures of the humerus in children. Journal of Orthopedic Surgery and Research, vol. 15, no. 1, p. 1-7, 2020. DOI: 10.1186/s13018-020-01673-1. Available at: https://www.semanticscholar.org/paper/29f0c236ad7b66096f6fc31414e77b091a1ac9fa. Accessed on: 8 Aug. 2024.