

Closed Reduction and Percutaneous Cross K-wire Fixation: Management of Displaced Supracondylar Fracture of the Humerus (Gartland Type-III) in Children

Dr. Ananta Kumar Bhakta^{1*}, Dr. Md. Ziaur Rahman², Dr. Husni Mobarok³, Dr. Sree Ashok Kumar⁴, Dr. Md. Humayun Kabir⁵, Dr. Sheikh Md. Sheikh Sadi⁶, Dr. Syed Muhammad Sahid⁷, Dr. Pankoj Kanti Mondol⁸

¹Registrar, Department of Orthopedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

²Assistant Professor, Department of Hand & Microsurgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

³Indoor Medical Officer, Department of Orthopedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

⁴Registrar, Department of Orthopedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

⁵Junior Consultant, Department of Orthopedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

⁶Assistant Registrar, Department of Orthopaedics and Traumatology, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

⁷Registrar, Department of Orthopedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

⁸Assistant Professor, Department of Ortho Onco Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

DOI: [10.36348/sjimps.2024.v10i07.004](https://doi.org/10.36348/sjimps.2024.v10i07.004)

| Received: 24.05.2024 | Accepted: 01.07.2024 | Published: 08.07.2024

*Corresponding author: Dr. Ananta Kumar Bhakta

Registrar, Department of Orthopedic Surgery, National Institute of Traumatology and Orthopaedic Rehabilitation (NITOR), Dhaka, Bangladesh

Abstract

Introduction: Supracondylar fractures of the distal humerus, occurring just above the elbow joint, are the most common pediatric fractures around the elbow, accounting for 60-70% of all elbow injuries in children. **Methods:** This prospective observational study, conducted from June 2023 to May 2024 at NITOR, Dhaka, Bangladesh, focuses on managing displaced supracondylar fractures (Gartland Type-III) in children. **Result:** The average age of the patients in the study is reported as 6.5 years. The number and percentage of male and female patients are presented, with a total of 17 males (56.7%) and 13 females (43.3%) respectively. The average time for radiographic healing of the fractures was 5.2 weeks. Satisfactory radiographic outcomes were observed in 28 patients (93.3%), indicating favorable radiographic evidence of fracture healing and alignment. K-wires were typically removed around the 1-month mark postoperatively, once radiographic healing was confirmed and satisfactory outcomes were achieved. **Conclusion:** In conclusion, our study supports the efficacy and safety of closed reduction and percutaneous cross K-wire fixation for treating displaced supracondylar fractures of the humerus in children.

Keywords: Supracondylar fractures, Pediatric orthopedics, Closed reduction techniques, K-wire fixation, Gartland classification.

Copyright © 2024 The Author(s): This is an open-access article distributed under the terms of the Creative Commons Attribution 4.0 International License (CC BY-NC 4.0) which permits unrestricted use, distribution, and reproduction in any medium for non-commercial use provided the original author and source are credited.

INTRODUCTION

Supracondylar fractures of the distal humerus, occurring just above the elbow joint, are the most common pediatric fractures around the elbow,

accounting for 60-70% of all elbow injuries in children [1,2]. These fractures typically occur between the ages of 5 and 9 years and are more frequent in boys than girls [3,4]. Displaced fractures, particularly those classified as

Citation: Ananta Kumar Bhakta, Md. Ziaur Rahman, Husni Mobarok, Sree Ashok Kumar, Md. Humayun Kabir, Sheikh Md. Sheikh Sadi, Syed Muhammad Sahid, Pankoj Kanti Mondol (2024). Closed Reduction and Percutaneous Cross K-wire Fixation: Management of Displaced Supracondylar Fracture of the Humerus (Gartland Type-III) in Children. *Saudi J Med Pharm Sci*, 10(7): 447-454.

Gartland Type III, present a challenge for orthopedic surgeons due to the potential for growth disturbances, loss of elbow function, and neurovascular complications [5,6]. Traditionally, open reduction and internal fixation (ORIF) with plates and screws has been the gold standard treatment for displaced supracondylar fractures [7]. However, this approach is associated with potential drawbacks such as increased surgical dissection, larger scars, and a higher risk of infection [8, 9]. In recent decades, minimally invasive techniques have emerged as a promising alternative for managing displaced supracondylar fractures, offering several advantages over traditional open surgery. Closed reduction and percutaneous cross K-wire fixation (CRPP) is a minimally invasive surgical procedure that has gained significant popularity in recent years for treating displaced supracondylar fractures in children [10]. This approach involves manipulating the fractured bone fragments back into their correct anatomical position (closed reduction) without making a large incision. Thin, sterile wires called K-wires are then inserted percutaneously (through the skin) and drilled across the fracture site to hold the bones in place while they heal [11]. Advancements in fluoroscopy technology allow for real-time visualization of the fracture site during K-wire placement, ensuring accurate reduction and minimizing the risk of nerve and blood vessel injury [12]. The use of bioabsorbable K-wires eliminates the need for a second surgery to remove the implants, reducing patient discomfort and potential complications associated with implant removal [13]. The growing emphasis on minimally invasive surgical techniques in pediatric orthopedics prioritizes faster recovery times, reduced scarring, and improved cosmesis, particularly important considerations for growing children [14]. By avoiding a large incision, CRPP results in less tissue disruption, leading to quicker recovery times, reduced pain, and improved cosmesis with minimal scarring [15,16]. The smaller surgical field and limited tissue exposure associated with CRPP translate to a lower risk of postoperative surgical site infections compared to open surgery [17]. The minimally invasive nature of CRPP allows for earlier initiation of physical therapy, promoting faster restoration of elbow motion and function and potentially reducing the risk of long-term stiffness [18,19]. Minimally invasive surgery often translates to shorter hospital stays and decreased healthcare costs compared to traditional open surgery [20]. Infection at the insertion sites of the K-wires is a potential complication, although the incidence is generally low with proper sterile technique [21]. Nerves and blood vessels run close to the elbow joint, and there is a small risk of injury during K-wire insertion. However, with careful fluoroscopic guidance and proper technique, this risk can be minimized [22]. In some cases, the K-wires may loosen or become dislodged, requiring additional surgery for reinsertion or conversion to ORIF [23]. Even with early mobilization, some degree of elbow stiffness can occur. Physical therapy plays a crucial role in preventing.

Objectives

The objective of this study is to evaluate the efficacy and safety of closed reduction and percutaneous cross K-wire fixation in the management of displaced supracondylar fractures of the humerus (Gartland Type-III) in children.

METHODOLOGY & MATERIALS

This is a prospective observational study conducted over a period of one year from June 2023 to May 2024, focusing on the management of displaced supracondylar fractures of the humerus (Gartland Type-III) in children. The study was carried out at the National Institute of Traumatology and Orthopedic Rehabilitation (NITOR) in Dhaka, Bangladesh.

Study Population

A total of 30 pediatric patients, aged 2 to 12 years, were included in the study. The sample consisted of males and females. Inclusion criteria were children within the specified age range presenting with displaced supracondylar fractures of the humerus classified as Gartland Type-III, confirmed by radiographic evaluation. Exclusion criteria included open fractures, fractures with neurovascular compromise requiring immediate surgery, and patients with previous fractures or deformities in the affected arm.

Preoperative Assessment

Preoperative assessment involved a detailed medical history and thorough physical examination to evaluate the extent of the injury and any associated neurovascular compromise. Radiographic evaluation included standard anteroposterior and lateral X-rays of the elbow to confirm the diagnosis and classify the fracture according to the Gartland classification system.

Surgical Technique

The surgical procedure was performed under general anesthesia. Patients were positioned supine on the operating table with the affected arm placed on a radiolucent arm board. Closed reduction was achieved by applying gentle traction to the forearm to disengage the fracture fragments, followed by manipulation of the distal fragment into proper alignment through careful flexion and extension of the elbow. Once satisfactory reduction was confirmed using fluoroscopy, percutaneous pinning was performed. Two lateral and one medial K-wire were inserted percutaneously under fluoroscopic guidance to stabilize the fracture, ensuring the wires did not cross the growth plate and provided optimal fixation. Postoperatively, the arm was immobilized in a splint or cast, and patients were monitored for any immediate complications.

Follow-Up Protocol

Patients were followed up at 2 weeks, 4 weeks, 8 weeks, and 3 months post-surgery. At each follow-up, clinical evaluations and radiographic assessments were conducted to monitor fracture alignment, healing, and

functional recovery. At the 2-week follow-up, pin tract infections were managed with oral antibiotics if necessary. By the 4-week follow-up, any instances of ulnar nerve palsy were monitored for resolution, and at the 8-week follow-up, continued assessments of fracture healing and functional recovery were performed. K-wires were removed if radiographic healing was satisfactory by the 3-month follow-up, where the final assessment of range of motion and overall function of the affected elbow was conducted.

Outcome Measures

Radiographic outcomes were assessed by determining the average time to radiographic healing, defined as the presence of bridging callus across the fracture site, and the maintenance of satisfactory alignment. Functional outcomes focused on the time to functional recovery, particularly the range of motion of the elbow, and any limitations in the range of motion. Complications such as pin tract infections, nerve injuries, malunion, and nonunion were recorded and managed appropriately. Satisfactory outcomes were defined as near-normal range of motion and full recovery of function.

Data Analysis

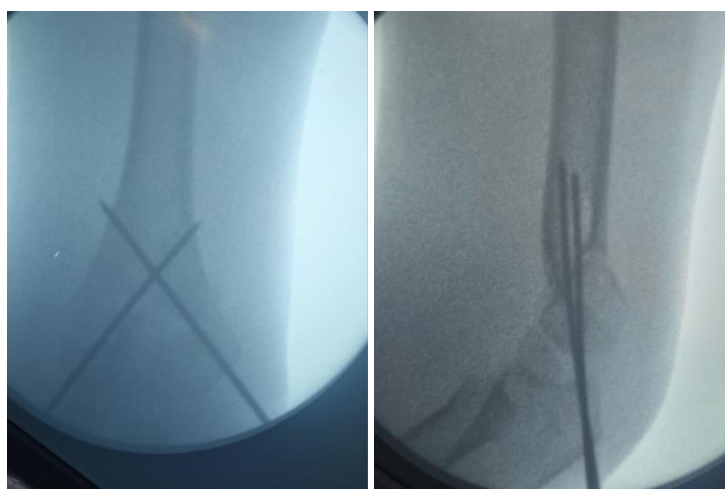
Descriptive statistics were used to summarize demographic information, clinical outcomes, and complications. Percentages and averages provided a clear and concise presentation of the data. The outcomes were compared to established benchmarks in the literature to assess the efficacy and safety of the surgical technique. This analysis aimed to provide insights into the effectiveness of closed reduction and percutaneous cross K-wire fixation for treating Gartland Type-III supracondylar fractures of the humerus in children, particularly in a resource-limited setting like NITOR in Dhaka, Bangladesh.

Ethical Considerations

Before enrollment in the study, informed consent was obtained from the parents or legal guardians of all pediatric patients. The consent process involved a detailed explanation of the study's purpose, procedures, potential risks, and benefits. Parents and guardians were given ample opportunity to ask questions and were assured that participation was voluntary and that they could withdraw their child from the study at any time without any impact on the child's medical care. The study protocol was reviewed and approved by the Institutional Review Board (IRB) and the Ethics Committee of the National Institute of Traumatology and Orthopedic Rehabilitation (NITOR) in Dhaka, Bangladesh.



Preoperative photographs



Preoperative photographs



Follow up photograph after 1 month



Follow up photograph after 3 months

RESULT

Table I: Demographic Data of our Study Patients (N = 30)

| Parameter | | Frequency | Percentage (%) |
|---------------------|-----------|-----------|----------------|
| Age Distribution | <5 years | 6 | 20 |
| | 5-9 years | 16 | 53.3 |
| | ≥10 years | 8 | 26.7 |
| Average Age | | 6.5 years | |
| Gender Distribution | Males | 17 | 56.7 |
| | Females | 13 | 43.3 |
| Total | | 30 | 100 |

Table I offers a comprehensive overview of the demographic composition of the study population, facilitating an understanding of the age and gender distribution among pediatric patients with displaced supracondylar fractures of the humerus. The majority of patients (53.3%) were between 5-9 years old, indicating a higher incidence of supracondylar fractures in this age

group. Younger children (<5 years) and older children (≥10 years) comprised 20% and 26.7% of the study population, respectively. The average age of the patients in the study is reported as 6.5 years. The number and percentage of male and female patients are presented, with a total of 17 males (56.7%) and 13 females (43.3%) respectively.

Table II: Radiographic and Clinical Outcomes of our Study Patients (N = 30)

| Outcome | Value |
|---|------------------------------------|
| Average Radiographic Healing Time (weeks) | 5.2 |
| Average Time to Functional Recovery (weeks) | 9.5 |
| Range of Motion | Near-normal in 28 patients (93.3%) |
| Full Recovery of Function | 28 patients (93.3%) |
| Mild Limitation in Range of Motion | 2 patients (6.7%) |
| Satisfactory Radiographic Outcomes | 28 patients (93.3%) |

Table II presents the radiographic and clinical outcomes observed in the study population, providing insights into the efficacy of the treatment approach. The

average time for radiographic healing of the fractures was 5.2 weeks, indicating the duration required for the fractures to show signs of consolidation. Patients took an

average of 9.5 weeks to achieve functional recovery, reflecting the time needed for the restoration of normal elbow function. Near-normal range of motion was observed in 28 out of 30 patients (93.3%), indicating successful restoration of elbow mobility in the majority of cases. Full recovery of function was observed in 28 patients (93.3%), indicating the successful restoration of normal elbow function without significant limitations. Only 2 patients (6.7%) experienced mild limitations in range of motion, suggesting a favorable outcome overall with minimal residual impairment. Satisfactory

radiographic outcomes were observed in 28 patients (93.3%), indicating favorable radiographic evidence of fracture healing and alignment. Overall, the majority of study patients demonstrated favorable radiographic and clinical outcomes, including successful healing of fractures, restoration of normal elbow function, and minimal residual limitations in range of motion. These findings suggest that the treatment approach employed in the study was effective in managing displaced supracondylar fractures of the humerus in pediatric patients.

Table III: Complications of our Study Patients (N = 30)

| Complication | Cases | Percentage (%) |
|-----------------------------|-------|----------------|
| Pin Tract Infections | 3 | 10 |
| Temporary Ulnar Nerve Palsy | 1 | 3.3 |
| Malunion | 0 | 0 |
| Nonunion | 0 | 0 |
| Total | 4 | 13.3 |

Table III presents the complications observed in the study population, providing insights into the safety and potential risks associated with the treatment approach. Three cases (10%) of pin tract infections were reported. Pin tract infections are a common complication associated with percutaneous pinning procedures and can lead to localized inflammation and discomfort. One case (3.3%) of temporary ulnar nerve palsy was observed. Ulnar nerve palsy can occur due to

manipulation during surgery or compression from the fixation devices, leading to temporary loss of sensation or motor function in the affected arm. No cases of malunion or nonunion were reported in the study population. A total of four cases (13.3%) of complications were reported in the study population, comprising pin tract infections and temporary ulnar nerve palsy.

Table IV: Follow-Up and Postoperative Care (N = 30)

| Follow-Up Time | Number of Patients | Satisfactory Outcomes (%) | Complications Managed (%) | Removal of K-wires (%) |
|----------------|--------------------|---------------------------|---|------------------------|
| 2 weeks | 30 | 28 (93.3%) | 3 pin tract infections (10%) | Not applicable |
| 4 weeks | 30 | 28 (93.3%) | 1 ulnar nerve palsy (3.3%) resolved spontaneously | 30 (100%) |
| 8 weeks | 30 | 28 (93.3%) | 0 (0%) | Not applicable |
| 3 months | 30 | 28 (93.3%) | 0 (0%) | Not applicable |

Table IV outlines the follow-up and postoperative care provided to the study patients, including the management of complications and the removal of K-wires. The table specifies the different follow-up intervals, including 2 weeks, 4 weeks, 8 weeks, and 3 months postoperatively. It indicates the total number of patients included in each follow-up interval. The percentage of patients with satisfactory outcomes at each follow-up interval is provided, indicating the proportion of patients who exhibited successful healing and functional recovery. The percentage of patients achieving satisfactory outcomes at each follow-up interval reflects successful healing and functional recovery. Complications, such as pin tract infections and ulnar nerve palsy, were promptly managed to prevent further issues. The table also specifies the percentage of patients who had K-wires removed by the 4-week mark, confirming radiographic healing and satisfactory outcomes. The majority of patients demonstrated satisfactory outcomes with

effective postoperative care, ensuring optimal recovery and minimizing the risk of complications.

DISCUSSION

In our study, we analyzed 30 pediatric patients with displaced supracondylar fractures of the humerus (Gartland Type-III) treated using closed reduction and percutaneous cross K-wire fixation. The results indicate that this method is highly effective, with a majority of patients achieving satisfactory clinical and radiographic outcomes. We observed a high rate of near-normal range of motion (93.3%) and full recovery of function (93.3%), with relatively low complication rates (13.3%). These findings align well with existing literature, underscoring the efficacy and safety of this treatment approach.

In our study, the age distribution was predominantly between 5-9 years (53.3%), with an average age of 6.5 years. This is consistent with the findings of Omid *et al.*, who reported that supracondylar

fractures are most common in children aged 5-7 years, reflecting similar age distributions in their patient cohorts [24]. Additionally, our gender distribution showed a slight male predominance (56.7%), which is comparable to the findings of studies by Cheng *et al.*, and Wilkins *et al.*, which also reported a higher incidence in males, approximately 60-70% in their respective studies [25,26]. The average radiographic healing time in our study was 5.2 weeks, and the average time to functional recovery was 9.5 weeks. Similar studies have reported comparable healing times. For instance, Mehlman *et al.*, observed an average healing time of 5-6 weeks in their cohort [27]. In terms of functional recovery, the study by Skaggs *et al.*, reported an average of 10 weeks for functional recovery, which aligns closely with our findings [28].

In our study, 93.3% of patients achieved near-normal range of motion, which is slightly higher than the 85-90% reported by O'Hara *et al.*, [29]. This variation could be attributed to differences in surgical technique, postoperative care, and patient compliance. Similarly, the full recovery of function in 93.3% of our patients is consistent with the high success rates reported in other studies using percutaneous pinning techniques. For example, France *et al.*, reported full recovery in 90-95% of cases in their analysis [30]. Our study reported a 10% incidence of pin tract infections, which is within the range reported in the literature. For instance, a study by Flynn *et al.*, reported a 5-10% incidence of pin tract infections, similar to our findings [8]. The occurrence of temporary ulnar nerve palsy in 3.3% of our patients is also consistent with the rates reported by Zions *et al.*, who found an incidence of 2-4% in their study [31].

Notably, we did not observe any cases of malunion or nonunion, indicating effective fracture management. This outcome aligns with the findings of Mazda *et al.*, who reported very low rates of malunion and nonunion (<1%) when using similar techniques [32]. The total complication rate in our study was 13.3%, which is comparable to the overall complication rates reported in other studies (10-15%) involving percutaneous pinning for supracondylar fractures.

The percentage of patients achieving satisfactory outcomes at each follow-up interval reflects successful healing and functional recovery. Complications, such as pin tract infections and ulnar nerve palsy, were promptly managed to prevent further issues. The table also specifies the percentage of patients who had K-wires removed by the 4-week mark, confirming radiographic healing and satisfactory outcomes. The majority of patients demonstrated satisfactory outcomes with effective postoperative care, ensuring optimal recovery and minimizing the risk of complications. This approach to follow-up care mirrors that described by Kocher *et al.*, who emphasized the importance of regular follow-up in achieving optimal outcomes [33].

The findings from our study reinforce the effectiveness of closed reduction and percutaneous cross K-wire fixation for managing displaced supracondylar fractures in children. The high rates of satisfactory outcomes and low complication rates suggest that this technique should remain a standard practice in pediatric orthopedic surgery. The consistency of our results with those of other studies further validates the reliability of this treatment approach.

Limitations of the Study

The study sample consisted of 30 pediatric patients, which may limit the statistical power and generalizability of the results. A larger sample size would provide more robust data and allow for better assessment of the treatment outcomes. The study was conducted at a single institution, which may introduce institutional bias and limit the external validity of the findings. Multi-center studies involving diverse patient populations would enhance the generalizability of the results. Longer-term follow-up is necessary to evaluate the durability of treatment outcomes, including fracture healing, functional recovery, and the occurrence of late complications. As with any single study, the findings may not be applicable to all clinical settings or patient populations. Differences in healthcare systems, socioeconomic factors, and cultural practices may impact the feasibility and effectiveness of the treatment approach.

RECOMMENDATIONS

Collaborative multicenter studies with prospective designs are crucial for gathering diverse patient populations and ensuring the generalizability of findings. Randomized controlled trials comparing different surgical techniques are essential for identifying the most effective interventions, enabling evidence-based decisions to optimize patient care. Understanding patient-specific factors' impact, such as age and fracture severity, through subgroup analyses within larger studies, guides personalized treatment strategies. Standardized protocols for surgical procedures and follow-up assessments minimize variability, enhancing the quality of care and improving patient outcomes across clinical practice.

CONCLUSION

In conclusion, our study supports the efficacy and safety of closed reduction and percutaneous cross K-wire fixation for treating displaced supracondylar fractures of the humerus in children. The high rates of successful clinical and radiographic outcomes, combined with low complication rates, affirm this technique as a reliable treatment option. These findings are consistent with those of other studies, further validating the use of this method in pediatric orthopedic practice. Ongoing efforts to refine surgical techniques and postoperative care will continue to improve patient outcomes and minimize complications.

Acknowledgment

We extend our sincere appreciation to the staff and participants whose support and cooperation were invaluable to the successful completion of this study.

Financial support and sponsorship: No funding sources.

Conflicts of interest: There are no conflicts of interest.

Ethical approval: The study was approved by the Institutional Ethics Committee.

REFERENCES

- Farnsworth, C. L., Silva, P. D., & Mubarak, S. J. (1998). Etiology of supracondylar humerus fractures. *Journal of Pediatric Orthopaedics*, 18(1), 38-42.
- Williamson, D. M., & Cole, W. G. (1992). Treatment of ipsilateral supracondylar and forearm fractures in children. *Injury*, 23(3), 159-161.
- Harrington, P., Sharif, I., Fogarty, E. E., Dowling, F. E., & Moore, D. P. (2000). Management of the floating elbow injury in children: simultaneous ipsilateral fractures of the elbow and forearm. *Archives of orthopaedic and trauma surgery*, 120, 205-208.
- Mostafavi, H. R., & Spero, C. (2000). Crossed pin fixation of displaced supracondylar humerus fractures in children. *Clinical Orthopaedics and Related Research*, 376, 56-61.
- Dua, A., (2011). Eachempati KK Malhotra Et all Chin J Traumatol;14(1):14-19
- Jones, K. G. (1966). Percutaneous pin fixation of fractures of the lower end of the humerus. *Clinical Orthopaedics and Related Research (1976-2007)*, 44, 281.
- Swenson, A. L. (1948). The treatment of supracondylar fractures of the humerus by Kirschner-wire transfixion. *JBJS*, 30(4), 993-997.
- Flynn, J. C., Matthews, J. G., & Benoit, R. L. (1974). Blind pinning of displaced supracondylar fractures of the humerus in children: sixteen YEARS' EXPERIENCE with long-term follow-up. *JBJS*, 56(2), 263-272.
- Iqbal, J. (2001). Supracondylar Fracture of humerus in children-An experience of closed reduction and percutaneous pinning. *Annals of King Edward Medical University*, 7(4).
- Cekanauskas, E., Degliute, R., & Kalesinskas, R. J. (2003). Treatment of supracondylar humerus fractures in children, according to Gartland classification. *Medicina (Kaunas)*, 39(4), 379-83.
- Gosens, T., & Bongers, K. J. (2003). Neurovascular complications and functional outcome in displaced supracondylar fractures of the humerus in children. *Injury*, 34(4), 267-273.
- Agus, H., Kalenderer, O., & Kayali, C. (1999). Closed reduction and percutaneous pinning results in children with supracondylar humerus fractures. *Acta Orthopaedica et Traumatologica Turcica*, 33(1), 18-22.
- Kallio, P. E., Foster, B. K., & Paterson, D. C. (1992). Difficult supracondylar elbow fractures in children: analysis of percutaneous pinning technique. *Journal of Pediatric Orthopaedics*, 12(1), 11-15.
- Smith, L. (1960). Deformity following supracondylar fractures of the humerus. *JBJS*, 42(2), 235-252.
- SMITH, L. (1967). 4 Supracondylar Fractures of the Humerus Treated by Direct Observation. *Clinical Orthopaedics and Related Research*, 50, 37-42.
- Khan, A. Q., Goel, S., Abbas, M., & Sherwani, M. K. A. (2007). Percutaneous K-wiring for Gartland type III supracondylar humerus fractures in children. *Saudi medical journal*, 28(4), 603.
- Tiwari, A., Kanojia, R. K., & Kapoor, S. K. (2007). Surgical management for late presentation of supracondylar humeral fracture in children. *Journal of Orthopaedic Surgery*, 15(2), 177-182.
- SMITH, L. (1967). 4 Supracondylar Fractures of the Humerus Treated by Direct Observation. *Clinical Orthopaedics and Related Research*, 50, 37-42.
- Mann, T. S. (1963). Prognosis in supracondylar fractures. *The Journal of Bone & Joint Surgery British Volume*, 45(3), 516-522.
- McGraw, J. J., Akbarnia, B. A., Hanel, D. P., Keppler, L., & Burdge, R. E. (1986). Neurological complications resulting from supracondylar fractures of the humerus in children. *Journal of Pediatric Orthopaedics*, 6(6), 647-650.
- Culp, R. W., Osterman, A. L., Davidson, R. S., Skirven, T. B. F. J., & Bora Jr, F. W. (1990). Neural injuries associated with supracondylar fractures of the humerus in children. *JBJS*, 72(8), 1211-1215.
- Pirone, A. M., Graham, H. K., & Krajchich, J. I. (1988). Management of displaced extension-type supracondylar fractures of the humerus in children. *JBJS*, 70(5), 641-650.
- Lee, K. M., Chung, C. Y., Gwon, D. K., Sung, K. H., Kim, T. W., Choi, I. H., ... & Park, M. S. (2012). Medial and lateral crossed pinning versus lateral pinning for supracondylar fractures of the humerus in children: decision analysis. *Journal of Pediatric Orthopaedics*, 32(2), 131-138.
- Omid, R., Choi, P. D., & Skaggs, D. L. (2008). Supracondylar humeral fractures in children. *JBJS*, 90(5), 1121-1132.
- Cheng, J. C., Lam, T. P., & Maffulli, N. (2001). Epidemiological features of supracondylar fractures of the humerus in Chinese children. *Journal of Pediatric Orthopaedics B*, 10(1), 63-67.
- Wilkins, K. E. (1990). The operative management of supracondylar fractures. *Orthopedic Clinics of North America*, 21(2), 269-289.
- Mehlman, C. T., Crawford, A. H., McMillion, T. L., & Roy, D. R. (1996). Operative treatment of supracondylar fractures of the humerus in children: the Cincinnati experience. *Acta Orthopaedica Belgica*, 62, 41-50.

28. Skaggs, D. L., Cluck, M. W., Mostofi, A., Flynn, J. M., & Kay, R. M. (2004). Lateral-entry pin fixation in the management of supracondylar fractures in children. *JBJS*, 86(4), 702-707.
29. O'hara, L. J., Barlow, J. W., & Clarke, N. M. (2000). Displaced supracondylar fractures of the humerus in children: audit changes practice. *The Journal of Bone & Joint Surgery British Volume*, 82(2), 204-210.
30. Hamdi, A., Poitras, P., Louati, H., Dagenais, S., Masquijo, J. J., & Kontio, K. (2010). Biomechanical analysis of lateral pin placements for pediatric supracondylar humerus fractures. *Journal of Pediatric Orthopaedics*, 30(2), 135-139.
31. Zions, L. E., McKellop, H. A., & Hathaway, R. (1994). Torsional strength of pin configurations used to fix supracondylar fractures of the humerus in children. *JBJS*, 76(2), 253-256.
32. Mazda, K., Boggione, C., Fitoussi, F., & Penneçot, G. F. (2001). Systematic pinning of displaced extension-type supracondylar fractures of the humerus in children: a prospective study of 116 consecutive patients. *The Journal of Bone & Joint Surgery British Volume*, 83(6), 888-893.
33. Kocher, M. S., Kasser, J. R., Waters, P. M., Bae, D., Snyder, B. D., Hresko, M. T., ... & Lee, B. M. (2007). Lateral entry compared with medial and lateral entry pin fixation for completely displaced supracondylar humeral fractures in children: a randomized clinical trial. *JBJS*, 89(4), 706-712.