Upper Extremity Injuries in Different Age Groups - A Common Paediatric Bone Injury and a Common Adult Soft Tissue Injury on the Upper Extremity

PhD Thesis

Doctoral School of Pharmacological and Pharmaceutical Sciences, Medical School, University of Pécs, Pécs

Head: Erika Pintér, MD, PhD, DSc

Translational Medicine Programme leader: Péter Hegyi, MD, PhD, DSc, MA

Mátyás Vajda, MD

Institute for Translational Medicine, Medical School, University of Pécs, Pécs, Hungary

Centre for Musculoskeletal Surgery, Saint George University Teaching Hospital of Fejér County, Székesfehérvár, Hungary

Supervisors

Gergő Józsa, MD, PhD

Institute for Translational Medicine, Medical School, University of Pécs, Pécs, Hungary

Division of Paediatric Surgery, Traumatology, Urology and Paediatric Otolaryngology, Department of Pediatrics, Medical School, University of Pécs, Pécs, Hungary

Ákos Zahár, MD, PhD, FACS

Centre for Musculoskeletal Surgery, Saint George University Teaching Hospital of Fejér County, Székesfehérvár, Hungary

PÉCS, 2025

Table of Contents

1. Preface

This dissertation represents the results of the work of a PhD applicant who got involved in more than one project in his field of study. Since his interest lies in the subspeciality of shoulder and elbow surgery, he chose to explore the entire anatomical region in order to gain a complex view and thorough understanding of this topic.

2. Background

Upper extremity injuries are a leading cause of hospital visits, affecting up to 18.6% of injury-related admissions. These injuries significantly impact functionality and quality of life due to the upper limb's role in fine motor tasks, load bearing, and daily activities. Shoulder and elbow injuries are particularly relevant due to their anatomical complexity and high incidence, especially in sports, older and paediatric populations.

2.1. Anatomical and Functional Significance of the Shoulder and Elbow

2.1.1. Shoulder

The shoulder complex includes the clavicle, scapula, and humerus, several joints (glenohumeral, acromioclavicular, sternoclavicular), ligaments, and muscles. The rotator cuff and deltoid facilitate movement and stability. The long head of the biceps tendon (LHBT) is an important stabilizer and depressor of the humeral head, although its precise in vivo role remains debated. Movements at the shoulder include abduction, adduction, flexion, extension, and internal and external rotation. These motions occur primarily at the glenohumeral joint but require coordinated activity across all shoulder components to achieve the complex movements necessary for daily functions and athletic activities. Due to the demands of strength, endurance, and flexibility placed on the shoulder in daily activities, it frequently becomes a site of musculoskeletal issues and pathology.

2.1.2. Elbow

The elbow consists of the humerus, radius, and ulna, forming the ulnohumeral, radiocapitellar, and proximal radioulnar joints. The medial and lateral collateral ligaments contribute to elbow stability, while four muscle groups facilitate flexion, extension, and forearm rotation. Four nerves—the median, radial, musculocutaneous, and ulnar— traverse the elbow's anatomy and often display anatomical variations. The brachial artery features many branches in the arm, creating extensive collateral circulation around the elbow. This robust blood supply means that injuries to the brachial artery at the elbow does not always result in distal ischemia. The elbow joint works in tandem with the shoulder to position the hand accurately. Given the shoulder's wide range of motion across all three axes, the demand for elbow mobility is reduced. Movements at the elbow include flexion-extension through the ulnohumeral joint and pronation-supination through the proximal radioulnar joint.

2.2. Overview of Pathologies

2.2.1. LHBT Injuries

The LHBT is susceptible to a variety of pathologies including tenosynovitis, tendinopathy, partial or complete tears, and instability. These can result from repetitive strain, trauma, or age-related degeneration. Symptoms typically include anterior shoulder pain, cramping, and functional impairment, particularly during overhead or rotational movements. In patients undergoing rotator cuff repair, LHBT abnormalities are found in 36% to 82% of cases, indicating a strong correlation.

2.2.2. Supracondylar humerus fractures (SCHFs)

Supracondylar humerus fractures (SCHFs) are the most common paediatric elbow fractures, particularly affecting children aged 4–7. The injury usually occurs due to falls on an outstretched arm. Extension-type fractures dominate, while flexion-type fractures, though less common, may affect older children. The Gartland classification is commonly used to guide treatment: Type I fractures are non- or minimally displaced (<2 mm). Type II injuries are displaced (>2 mm) but retain an intact posterior cortex or hinge (IIA), with the possibility of additional malrotation (IIB). Types III and IV involve complete displacement, with a disrupted posterior hinge characterizing Type III, and multidirectional instability indicating Type IV. Type IV is typically an intraoperative diagnosis. Radiographic evaluation and neurovascular assessment are critical in initial diagnosis.

2.3. Diagnostic Methods and Tools for Shoulder and Elbow Injuries

Diagnostic options include physical examination, radiography, Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and ultrasound. These are essential for identifying pathological structures and selecting appropriate treatments.

2.4. Overview of Treatment Options for LHBT and SCHF Injuries

2.4.1. LHBT injuries

Conservative management is often the first step and includes rest, anti-inflammatory medication, and physiotherapy modalities like ultrasound, extracorporeal shockwave therapy, and strengthening exercises. Eccentric training and joint mobilization may improve function, while dry needling and steroid injections provide symptomatic relief.

Surgical intervention is indicated for persistent symptoms or structural abnormalities unresponsive to conservative care. The two main surgical options are tenotomy and tenodesis. Tenotomy involves releasing the tendon from its origin. It is quicker, requires fewer postoperative restrictions, and is commonly preferred for elderly or low-demand patients. However, it carries a higher risk of Popeye deformity (bulging of the biceps) and possible strength loss. Tenodesis involves reattaching the tendon, either in a suprapectoral or subpectoral position. This approach maintains the length-tension relationship and theoretically leads to better cosmetic and functional outcomes. Various fixation techniques include interference screws, suture anchors, and soft tissue fixation. Tenodesis is more complex and typically favoured in younger, active individuals.

2.4.2. SCHF Injuries

Conservative management is recommended for nondisplaced (Gartland I) fractures. Immobilization with a posterior splint or above-elbow cast for one to four weeks is standard. Pain control and monitoring for neurovascular compromise are critical during follow-up.

Surgical treatment is generally indicated for displaced fractures (Gartland II–IV), but the necessity for surgery in Type IIA fractures is debated. The standard procedure is closed reduction and percutaneous pinning with two or three Kirschner-wires (K-wires), but in rare cases intramedullary nailing or fixateur externe might be good alternatives. Lateral pinning avoids the risk of ulnar nerve injury, while crossed pinning offers greater rotational stability but increases the risk of iatrogenic nerve damage. Open reduction is necessary when closed reduction fails or in the presence of open fractures, vascular entrapment, or poor perfusion. A ventral incision is preferred as it provides access to potentially injured nerves or vessels, although radial, ulnar, and dorsal approaches are also viable. Vascular compromise, indicated by a pale or pulseless hand, may require exploration of the antecubital fossa and blood vessel reconstruction or bypass.

2.5. Potential Complications from LHBT and SCHF Injuries and Treatments

2.5.1. LHBT Injuries and Treatments

Complications following tenotomy include Popeye deformity leading to cosmetic dissatisfaction, biceps cramping pain, continued anterior shoulder pain, and strength loss. The most common complications occurring after tenodesis are residual pain, subjective weakness, Popeye deformity and implant failure. The choice of fixation method (implant vs. soft tissue) can influence revision rates. Implant-based techniques may require revision more often, while soft-tissue fixation is more prone to perceived weakness. Rare complications include infections, nerve injuries and humeral fractures.

2.5.2. SCHF Injuries and Treatments

Many complications arise from the trauma itself, rather than the interventions; however, iatrogenic complications can also occur.

Acute complications include nerve injuries, brachial artery injury, compartment syndrome, hardware irritation, and difficulty achieving or maintaining reduction. Infections are rare, typically superficial, are mostly manageable with oral antibiotics. Deep infections may involve the joint leading to further surgical explorations. Chronic complications, such as persisting elbow stiffness and malunion (leading to cubitus varus or valgus deformities) can also occur. Conservative treatment risks include improper bone healing, leading to deformity or functional impairment if the fracture is not adequately immobilized.

2.6. Long-term Outcomes

2.6.1. LHBT injuries

Both tenotomy and tenodesis generally offer excellent patient-reported outcomes. According to some studies tenodesis provides superior results in strength and aesthetics, particularly for high-demand patients, though other studies show comparable function across techniques. Outcome scoring systems used include the Constant score, American Shoulder and Elbow Surgeons (ASES) score, and Simple Shoulder Test (SST) score, each assessing various functional and pain parameters.

2.6.2. SCHFs

Satisfactory outcomes are expected with timely and appropriate intervention. Restoration of carrying angle and elbow range of motion to within 10 degrees of the unaffected limb predicts high satisfaction. However, nerve injuries and growth disturbances may lead to persistent pain or deformities.

2.7. Unique Aspects of Paediatric elbow Injuries

Children’s bones are less dense, more flexible, and possess a thick periosteum and active growth plates. These characteristics allow for some natural remodelling of fractures but make the skeletal system vulnerable to growth disturbances. The distal end of the humerus accounts for about 20% of the longitudinal growth of the humerus. Therefore, SCHFs have a relatively low remodelling capacity compared to many other regions, making proper alignment and stabilization especially important.

2.8. Aims

2.8.1. LHBT Injuries

Previous meta-analyses comparing tenotomy and tenodesis for LHBT surgeries have been inconclusive or included lower-quality cohort studies. Ongoing debate persists regarding which technique yields better long-term outcomes in strength and pain relief. Our study aimed to address these gaps, also evaluating cosmetic results—particularly Popeye deformity, which impacts patient satisfaction. Given the mixed results from clinical trials and limitations of prior meta-analyses, our goal was to conduct the most comprehensive comparison to date of tenodesis versus tenotomy in LHBT treatment.

2.8.2. SCHF in Children

Many studies on SCHFs involve small sample sizes and utilize retrospective data collection, which can introduce significant bias. Our research sought to analyse the characteristics of children with SCHF recorded in our registry. We compared their demographic distribution and the outcomes of the interventions they received with those reported in the international literature.

3. Studies

3.1. Comparing the results of tenotomy and tenodesis in long head of the biceps tendon (LHBT) surgeries

3.1.1. Materials and Methods

This study followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for systematic reviews and meta-analyses to ensure transparency and reproducibility. The protocol was registered on PROSPERO (CRD42021244613). There were no deviations from protocol.

3.1.1.1. Search strategy, inclusion, and exclusion criteria

We used the PICOTS framework to define our clinical question, focusing on patients undergoing LHBT surgery (P). Tenotomy (I) was compared with tenodesis (C) across outcomes (O) like pain scores, muscle strength, function scores (Constant, ASES, SST), operative time, and cosmetic results (e.g., Popeye deformity). Timing (T) for statistical analysis of each outcome was set when at least three studies reported the same outcome at the same time point. Outcomes not suitable for quantitative synthesis were included solely in the systematic review section. The study type (S) comprised randomized controlled trials (RCTs). A systematic search was conducted on November 28, 2020, in five major databases (MEDLINE (via PubMed), Embase, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, and Scopus) using the terms “bicep* AND teno*”. We excluded reviews, meta-analyses, non-RCT studies, non-comparative reports, distal biceps tears, biomechanical, cadaver, and animal studies.

3.1.1.2. Selection and data extraction

We used EndNote X9 to manage study selection. Two reviewers (M.V., L.S.) independently screened titles, abstracts, and full texts, resolving disagreements by consensus. Cohen’s kappa was calculated to assess inter-rater agreement. Reference lists were also screened for additional studies. Data were extracted into a predefined Excel sheet, including study and patient characteristics, surgical details, and outcomes. Strength values in Newtons were converted to kilograms when necessary, and strength indices were calculated if not reported.

3.1.1.3. Statistical analysis

For dichotomous outcomes, we calculated odds ratios (ORs) with 95% confidence intervals (CIs), applying continuity correction when necessary. For continuous data, we used weighted mean differences (WMDs), estimating missing values via Wan's method when required. A random effects model (DerSimonian and Laird) accounted for heterogeneity, assessed by I^2 values. Forest plots illustrated the results. Trial Sequential Analysis (TSA) was conducted when feasible to validate findings. Statistical comparisons were made only when three or more studies reported the same outcome at the same time point. Analyses were performed using Stata 16.0 and TSA software. We presented individual results from all included studies in the systematic review section to compare the two surgical methods transparently.

3.1.1.4. Risk of bias assessment and quality of evidence

We assessed risk of bias (RoB) using the Cochrane RoB 2 tool and evaluated evidence certainty with the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) system, categorizing results as high, moderate, low, or very low. Two independent reviewers (M.V. and L.S.) performed the assessments, resolving disagreements by consensus.

3.1.2. Results

3.1.2.1. Search and selection

We initially identified 5,450 records across five databases. Upon completing the selection process, we identified nine full-text articles eligible for the meta-analysis and eleven studies for inclusion in the systematic review section.

3.1.2.2. Characteristics of the studies included

Our meta-analysis included nine RCTs and 572 participants, with 293 in the tenotomy group and 279 in the tenodesis group. Two studies did not report outcomes at comparable time points, thus were only included in the systematic review section (eleven studies altogether). All studies involved patients with LHBT pathology. Nine of the eleven studies also included patients with concurrent rotator cuff tears, whereas two studies specifically excluded such patients. Tenotomy was performed arthroscopically in all studies. Tenodesis was also carried out arthroscopically, except in 31.5% of patients (17 out of 54) in the study of MacDonald et al., where an open subpectoral approach was used. The follow-up periods varied among the studies, generally ranging from 12 to 24 months, with some differences in the evaluation times for various outcomes.

3.1.2.3. Meta-analysis results

3.1.2.3.1. Post-operative function

At 6 months, elbow flexion strength in kg showed no significant difference (WMD: 2.82; $p = 0.237$; evidence graded as low). At 12 months, tenodesis showed significantly better flexion strength in kg (WMD: 3.67; $p = 0.06$; evidence graded as moderate) (Figure 1.). Forearm supination strength in kg at 12 months also favoured tenodesis (WMD: 0.36; $p = 0.012$; evidence graded as low). Constant scores from three studies showed no significant difference at 6 months (WMD: 0.78; $p = 0.634$; evidence graded as moderate) or at 12 months (WMD: 2.26; $p = 0.190$; evidence graded as low).

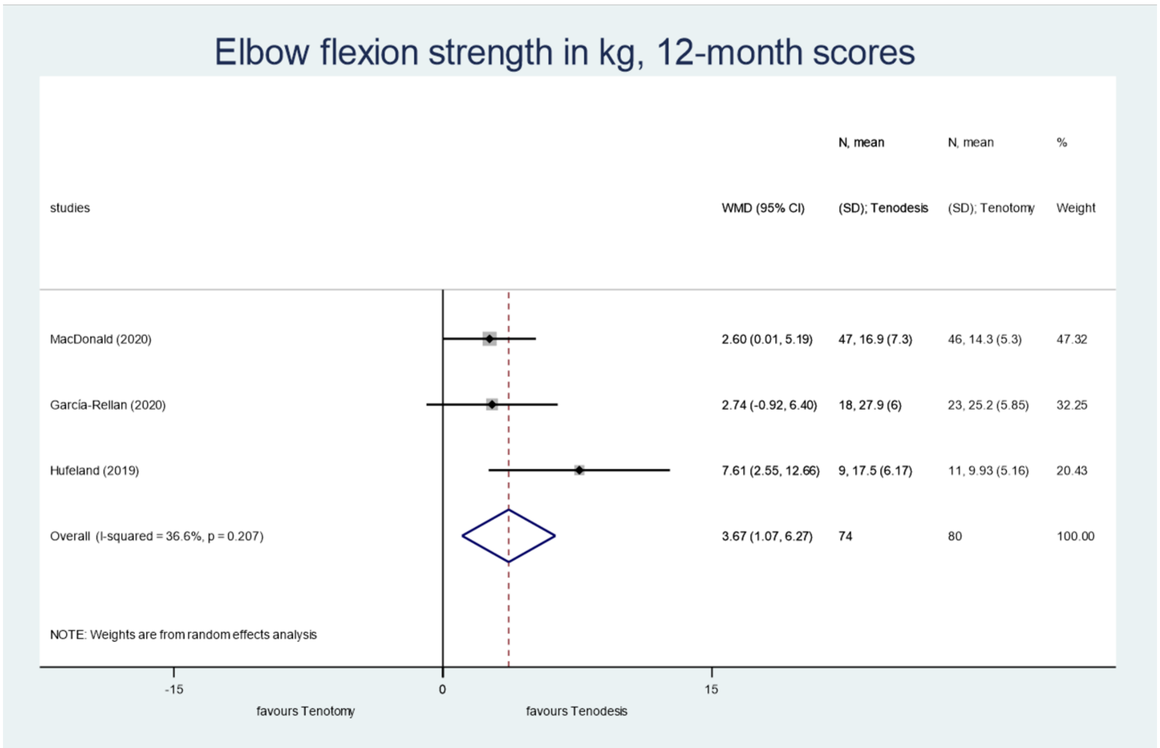

Figure 1. *A Forest plot of elbow flexion strength (kg) at 12-month follow-up. Black diamonds show individual study effects with 95% CIs (vertical lines). Grey square size indicates study weight. The blue diamond shows the overall effect with its CI.*

3.1.2.3.2. Post-operative pain

Three studies assessed 3-month VAS pain scores, showing a significant difference in favour of tenotomy (WMD: 0.99; $p < 0.001$; evidence graded as high) (Figure 2.), indicating earlier pain relief. No significant differences were found at 6 months (WMD: 0.05; $p = 0.724$; evidence graded as moderate), 12 months (WMD: 0.19; $p = 0.411$; evidence graded as very low), or 24 months (WMD:

0.01; p = 0.637; evidence graded as moderate). Bicipital cramping pain at 6 months also showed no significant difference (OR: 0.92; p = 0.943; evidence graded as moderate).

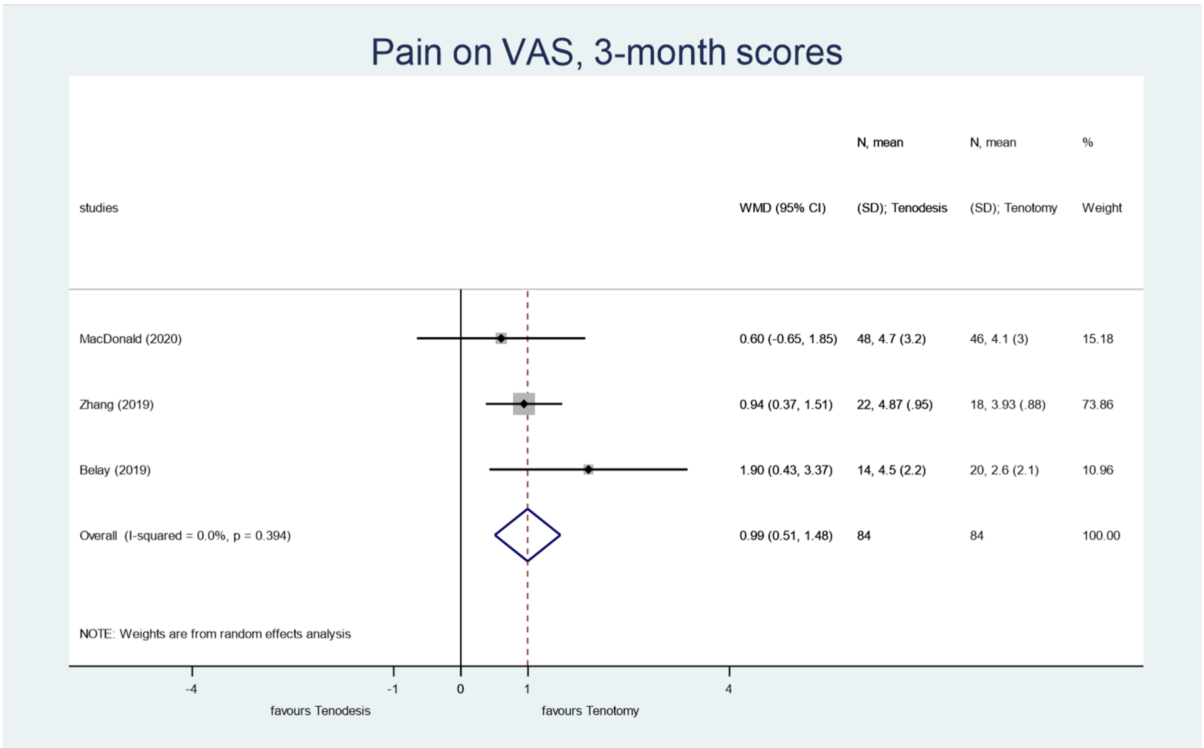

Figure 2. *A Forest plot representing the level of postoperative pain on the Visual Analog scale (VAS), comparing tenotomy and tenodesis, measured 3 months postoperatively.*

3.1.2.3.3. Popeye deformity

Three studies reported Popeye deformity at 24 months, showing a significant difference favouring tenodesis (OR: 0.19; p < 0.001; evidence graded as moderate) (Figure 3.).

3.1.2.3.4. Operative time

Operative time comparison showed no significant difference between tenotomy and tenodesis (WMD: 17.15; p = 0.080; evidence graded as very low).

3.1.2.3.5. TSA (Trial Sequential Analysis)

TSA was deemed conclusive in the following outcomes: 3-month pain levels on the VAS (the tenotomy method was superior to the tenodesis method, further clinical trials are not required), occurrence of Popeye deformity at the 24-month follow-up (the tenodesis method was superior to the tenodesis method, further clinical trials are not required).

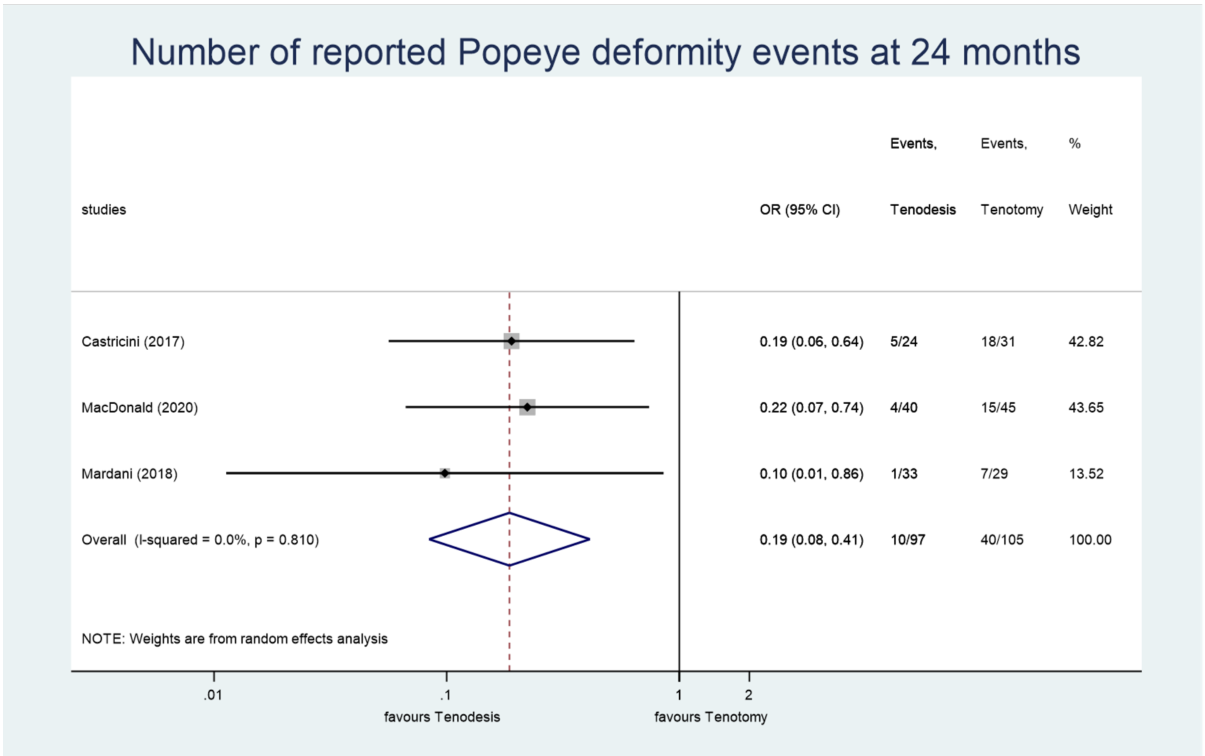

Figure 3. *A Forest plot representing the occurrence of Popeye deformity, comparing tenotomy and tenodesis, measured 24 months postoperatively.*

3.1.2.4. Systematic review results

Eight studies measured elbow flexion strength, six assessed forearm supination strength, and seven evaluated the Constant score. Five studies included the ASES score, while three reported on SST scores. Pain levels were reported by nine studies, the incidence of bicipital cramping pain was noted in six, and bicipital groove pain events were reported in three studies. All studies included data on Popeye deformity outcomes.

3.1.2.5. Risk of bias assessment and quality of evidence

The risk of bias assessment was performed for every outcome. Popeye deformity was reported across all studies. In this assessment, four studies were found to have a high risk of bias, six studies raised "some concerns", and one study was determined to have a low risk of bias. Lower grades were generally due to unclear randomization processes, lack of blinding, and missing trial protocols.

The results of the GRADE analysis for each outcome are presented in the results section.

3.1.3. Discussion

The biceps brachii is a key contributor to elbow flexion strength, making it a primary outcome in our analysis. While no significant difference was found at 6 months, tenodesis showed superior elbow flexion strength at 12 months. This contrasts with earlier meta-analyses. However, TSA suggests that more RCTs are needed to confirm 6-month outcomes, and even though the 12-month sample size was adequate, results remain inconclusive. Individual studies varied in timing, limiting further statistical comparison.

Forearm supination, another main function of the biceps, also showed better results for tenodesis at 12 months—contradicting previous findings. TSA again indicated the need for more trials, though study trends support a tenodesis advantage.

Constant scores showed no significant difference at either 6 or 12 months, but the systematic review suggested a trend favouring tenodesis. This reflects findings from earlier studies, which either saw small statistical differences without clinical significance or no difference at all.

VAS scores showed a significant pain reduction at 3 months in the tenotomy group, with TSA confirming the reliability of this result. No differences were observed at later follow-ups. Other meta-analyses or reviews also failed to detect a consistent advantage for either method over time.

While some prior studies reported more frequent cramping with tenotomy, our 6-month data did not show a significant difference, aligning with other analyses suggesting comparable rates between methods.

Popeye deformity was significantly more common after tenotomy, a result consistent with prior literature and confirmed by our analysis. TSA indicated no further trials are needed to establish this difference.

Although earlier reviews suggest tenotomy is quicker to perform, our analysis did not find a statistically significant difference in operative time between the two procedures. Given varied surgical contexts and conflicting TSA outcomes, further evidence is needed to clarify this point.

3.1.3.1. Strengths and Limitations

This meta-analysis of nine studies has several strengths, including a rigorous methodology and consistent outcome assessment timing. By including only randomized controlled trials, it represents high-level evidence. TSA confirmed the reliability of results for 3-month VAS pain and 24-month Popeye deformity outcomes.

However, some limitations were present, such as small sample sizes affecting TSA reliability for several outcomes. Differences in surgical indications, techniques, and rehabilitation protocols among studies also introduced variability. In some cases, statistical values had to be estimated from incomplete data. The TSA did not provide conclusive results for outcomes like 6-month elbow flexion strength, 12-month elbow flexion strength, 12-month forearm supination strength, 12-month Constant score, 12-month VAS pain levels, and operative time.

Further RCTs are needed to clarify these outcomes, with standardized assessment time points and a focus on biceps-specific measures like flexion and supination strength. Future studies may benefit from using dedicated scores such as the LHB score rather than broader shoulder assessment tools. Creating subgroups based on concurrent rotator cuff surgery or tenotomy variations could improve the specificity and relevance of future findings.

3.1.3.2. Conclusions

Our findings suggest that tenodesis is preferable to tenotomy due to its association with a lower incidence of Popeye deformity, improved postoperative biceps function, and comparable long-term pain outcomes.

3.2. The first analysis of a multicentre paediatric supracondylar humerus fracture (SCHF) registry by fracture type

3.2.1. Materials and methods

We used the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guideline to ensure transparent reporting of our observational study. The registry was approved by the Medical Research Council's Ethics Committee (35335-2/2018/EKU).

3.2.1.1. Data source and quality

Data that were prospectively collected into the Hungarian paediatric SCHF Registry were analysed retrospectively, which includes data from seven institutions about patients who underwent surgery between September 5, 2018, and March 25, 2021. To maintain high data quality, all information added to the registry underwent a four-tier quality assurance process conducted by both administrators and surgeons.

3.2.1.2. Categorization by fracture type

The operating surgeon classified fractures using anteroposterior and lateral radiographs. Since Gartland IV requires intraoperative confirmation, only three types were included: IIA (single-plane displacement with remaining fragment contact), IIB (rotational displacement with partial contact), and III (complete displacement). Outcomes were analysed by comparing these three groups.

3.2.1.3. Analysed endpoints

We statistically analysed multiple parameters across the three groups, including age, sex, BMI, injury type, initial radial pulse and oxygen saturation, and hand function outcomes. Additional factors assessed were antibiotic use, surgeon experience, reduction methods, type of open reduction, fixation techniques, pin number and size, analgesic use, operative time, and complications. Complications—such as infections, wound healing problems, swelling, movement loss, vascular/nerve injury, bone healing problems, or compartment syndrome—were classified as early (before discharge) or late (during follow-up). Time to pin removal was also recorded.

3.2.1.4. Statistical analysis

Data from the registry were compiled in Excel and analysed using R (version 4.0.2). Categorical variables were tested with Chi-Squared or Fisher's Exact test, followed by Fisher's pairwise tests with False Discovery Rate (FDR) correction when significant. Continuous variables were analysed with the Kruskal-Wallis test and Dunn's post hoc test, using Holm-Šídák correction. A p-value <0.05 was considered significant, except for Dunn's test (<0.025). Of 217 patients, 214 were included; three were excluded due to missing fracture classification, making representativeness analysis unnecessary.

3.2.2. Results

3.2.2.1. Preoperative data summary

The dataset included 217 patients, with a mean age of 6.52 years—6.08 for females and 7.03 for males. Of 214 classified cases, 31 were Gartland IIA, 121 IIB, and 62 III. Females made up 53.46% (116), and males 46.54% (101). A significant sex difference was found ($p=0.001$), especially between IIA and IIB (p=0.0008), with female/male ratios of 2.58/7.42 in IIA and 6.28/3.72 in IIB (Figure 4.). BMI data were available for 190 patients, with an average of 16.36 (Figure 4.). Among 214 cases, 195 (91.12%) were extension-type injuries and 19 (8.88%) were flexion-type.

Oxygen saturation was measured in 137 cases, averaging 97.83%. Gartland III had significantly lower values than IIB (96.78% vs. 98.19%, p=0.0110) (Figure 4.).

Radial pulse was documented in 215 cases: 196 (91.16%) palpable, 17 (7.91%) not palpable but with good microcirculation, and two (0.93%) with poor circulation (Figure 4.). Hand function was assessed in 204 cases: 138 (67.65%) had full function, 63 (30.88%) couldn't be objectively evaluated due to pain, and three had nerve dysfunction (0.49% each for the median, radial, and ulnar nerves).

Preoperative antibiotic use was documented in 210 patients: 190 (90.48%) received antibiotics—167 cefazolin (87.89%), 20 amoxicillin–clavulanic acid (10.53%), and 3 clindamycin (1.58%)—while 20 (9.52%) received none.

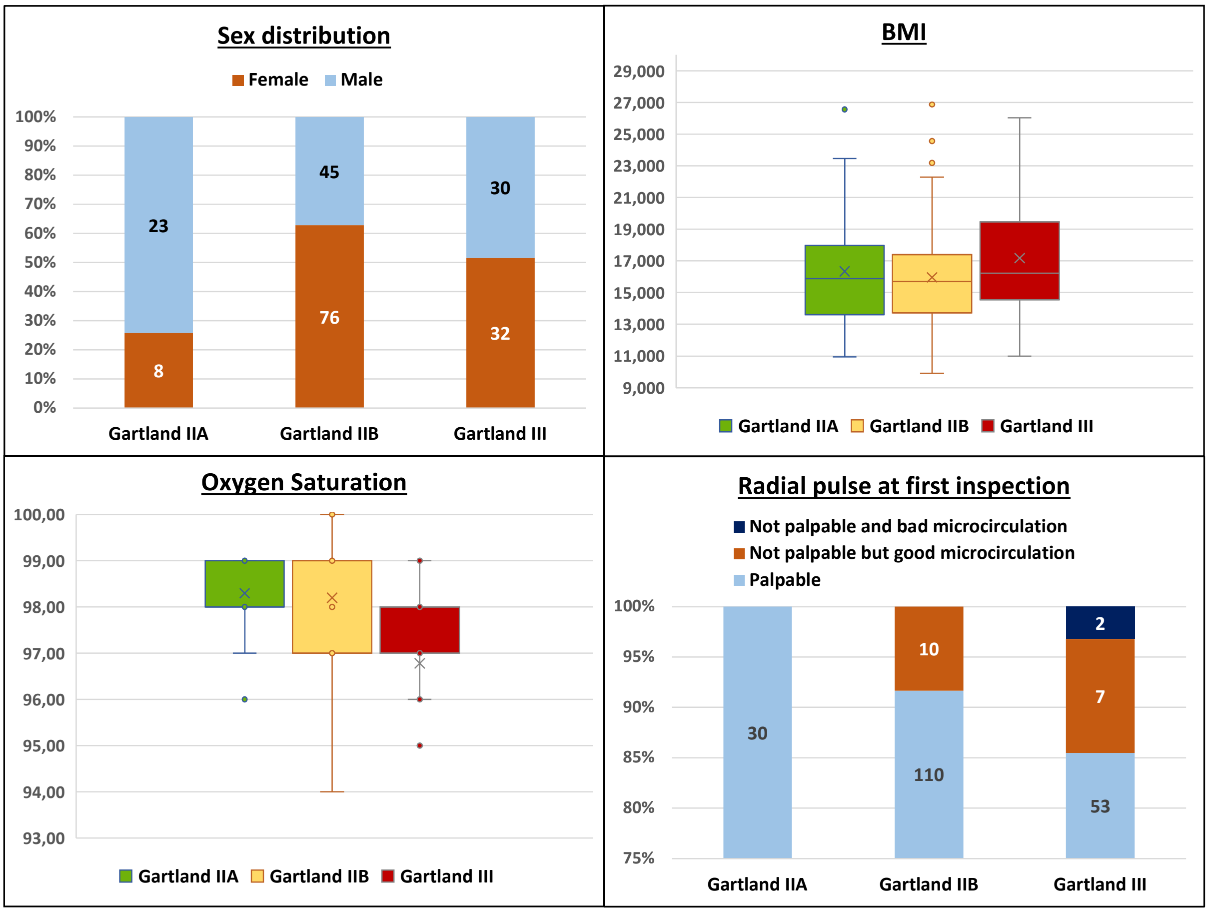

Figure 4. *Preoperative data by fracture type groups.*

Due to the small number of cases in certain subgroups, statistical analysis was not feasible for outcomes like radial pulse at the initial examination and results of hand function assessment.

There were no significant differences observed in age distribution (p=0.7934), BMI (p=0.2254), type of injury (flexion vs. extension) (p=0.5606), or preoperative antibiotic use (p=0.3533).

3.2.2.2. Operative data summary

Among 216 cases, surgeries were performed by senior specialists in 102 (47.22%), junior specialists in 59 (27.31%), and non-specialists in 55 (25.46%). Surgeon experience differed significantly (p=0.0228), though post-hoc tests did not pinpoint specific group differences (IIA/IIB: p=0.0955, IIA/III: p=0.0633, IIB/III: p=0.0955) (Figure 5.).

Fracture reduction methods were recorded for all 217 cases: 150 (69.12%) had closed reduction, five (2.3%) started closed but converted to open due to radial artery dysfunction, and nine (4.15%) for other reasons. Twenty-five (11.52%) used percutaneous tools, one (0.46%) used the joystick method, and 27 (12.44%) were primarily open reductions (Figure 5.).

Open reduction was required in 41 cases: 21 ventral (51.22%), 8 radial (19.51%), 6 ulnar (14.63%), 3 ventral + radial (7.32%), 2 ventral + ulnar (4.88%), and 1 combined ventral, radial, and ulnar (2.44%) (Figure 5.).

In 207 cases, fixation methods included pinning in 204 (97.6%), external fixateur in 3 (1.44%), and intramedullary fixation in 2 (0.96%). Of the pinning cases, two pins were used in 153 (75%), three in 35 (17.16%), four in 15 (7.35%), and five in one (0.49%). Pin diameter was reported in 194 patients: 2 mm in 129 (66.49%), 1.8 mm in 35 (18.4%), 1.5 mm in 24 (12.37%), and 2.2 mm in 6 (3.09%). No significant differences were found between groups (p=0.1556).

Intraoperative local analgesia was recorded in 216 patients: 109 (50.46%) received it and 107 (49.54%) did not, with no significant group differences (p=0.3404).

Operative time was documented in 207 cases, with a mean of 48.19 minutes (range: 10–300). Significant differences were observed between all groups (p<0.005), with average times of 29.3 minutes (IIA), 44.57 minutes (IIB), and 65.19 minutes (III) (Figure 5.).

Due to the low sample size in many subgroups, correct statistical comparisons were not possible for outcomes related to types of fracture reduction, open reduction, intraoperative fixation, and number of pins used.

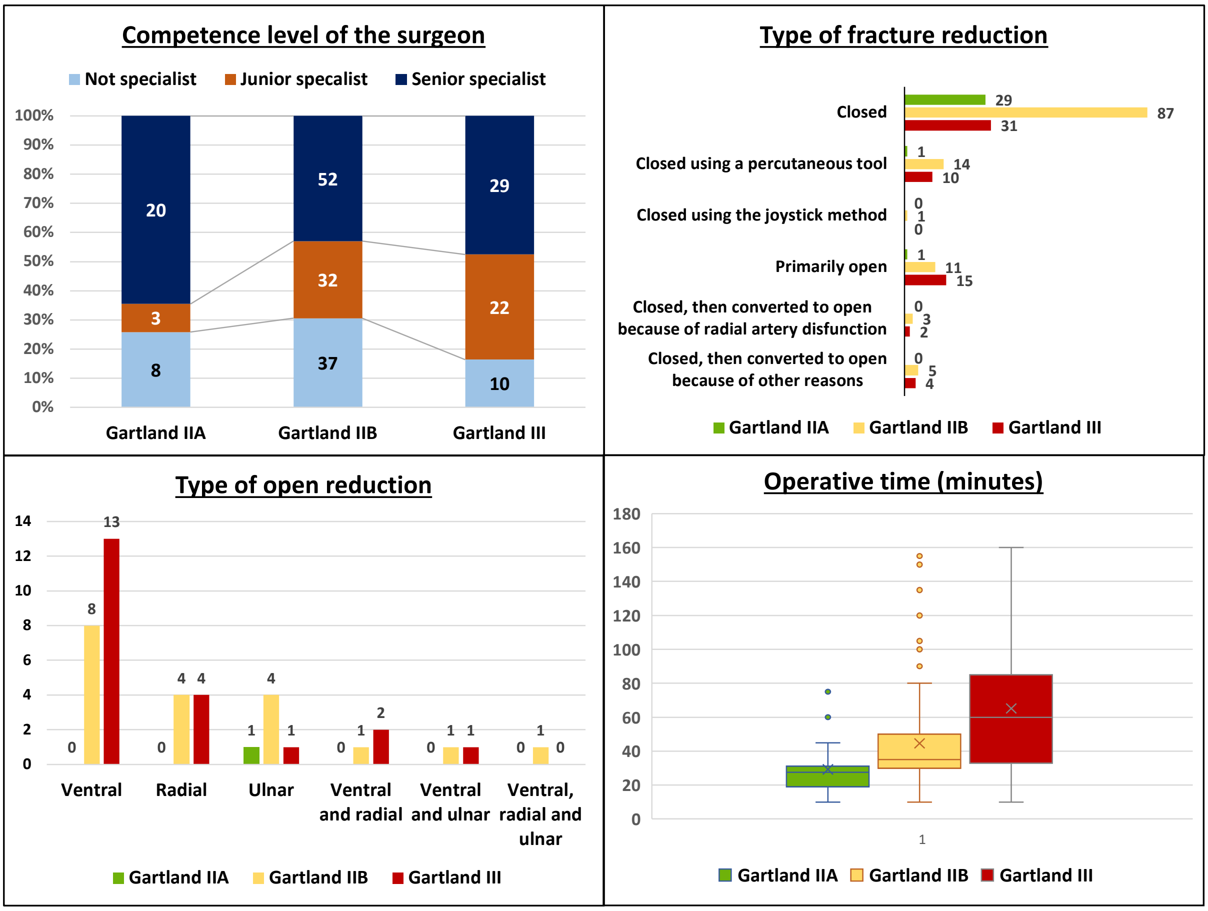

Figure 5. *Operative data by fracture type groups.*

3.2.2.3. Postoperative data summary

Postoperative fixation types were documented for all 217 patients: 168 (77.42%) received a dorsal cast with U-extension, 46 (21.2%) had a dorsal cast without extension, two (0.92%) had no orthotic device (both treated with fixateur externe), and one (0.46%) received an orthosis.

Postoperative analgesics were given in 202 of 211 cases (95.73%), and nine (4.27%) received none. Painkillers for home use were prescribed in 139 of 204 cases (68.14%), while 65 (31.86%) were not.

Antibiotic use after surgery was reported in 213 cases: 200 (93.9%) did not receive antibiotics, while 13 (6.1%) did.

Early complications were absent in 191 of 215 patients (88.48%) and present in 24 (11.52%), including 20 neurological (9.3%), three vascular (1.4%), and two bone-related (0.93%) (Figure 6.).

Late complications were reported in 37 of 204 cases (18.14%), while 167 (81.86%) had none. These included 17 neurological (8.33%), one vascular (0.49%), six bone-related (2.94%), six superficial infections (2.94%), one deep infection (0.49%), and three wound healing problems (1.47%). Additional issues included early pin removal in eight cases (3.92%), loss of movement in five (2.45%), swelling in two (0.98%), and one fever case (0.49%). No compartment syndrome was reported (Figure 6.).

No significant differences were found for pre- or postoperative antibiotic use (p=0.5981 and p=0.7353) or operative time (p=0.2448) in relation to infection. All seven patients with infections had received preoperative antibiotics but no postoperative antibiotics. Their operative times ranged from 20 to 45 minutes. No lasting effects were observed.

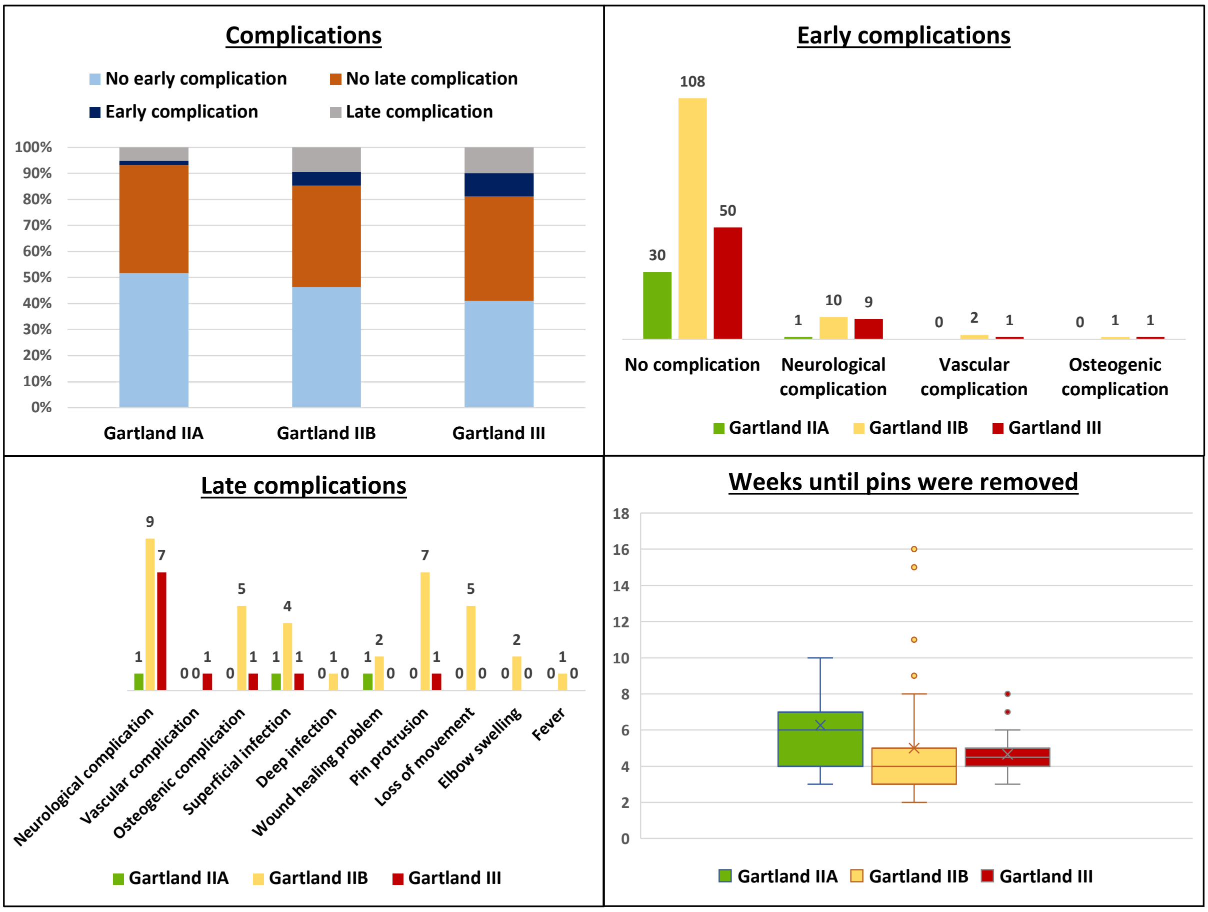

Figure 6. *Postoperative data by fracture type groups.*

The only significant difference in postoperative outcomes was time to pin removal ($p=0.0125$), particularly between Gartland IIA (mean: 6.27 weeks) and IIB (mean: 5.0 weeks, $p=0.0053$); the difference between IIA and III (mean: 4.66 weeks) was close to being significant ($p=0.0477$, with $p<0.025$ required for significance) (Figure 6.).

No significant group differences were found in early complications ($p=0.0988$), prescribed painkillers for home use ($p=0.384$), or late complications ($p=0.6403$).

Due to the low sample size in various subgroups, statistical analysis was not feasible for outcomes including the type of postoperative fixation, analgesia and antibiotic use, as well as specific early vascular, neurological, and bone-related complications.

3.2.3. Discussion

Using a prospective multicentre registry, we analysed pre-, intra-, and postoperative data of paediatric SCHF patients, categorized by Gartland type (IIA, IIB, III) based on anteroposterior and lateral radiographs.

Key findings include significantly lower oxygen saturation in more severe fractures, no significant BMI impact on fracture type, and longer pin retention in less severe cases. No significant differences were found in early or late complications across groups.

The average patient age was 6.52 years—older than in some studies, younger than in others. We observed a sex difference: Gartland IIA had more males, IIB more females, with no sex disparity in type III. Overall, 53.46% were female, consistent with varied reports in the literature.

BMI showed no significant correlation with fracture type, aligning with several studies, although some suggest higher BMI may relate to more severe fractures, complications or malrotation.

Oxygen saturation at first inspection was slightly but significantly lower in Gartland III (mean: 96.78%) compared to IIB (98.19%) and IIA (98.29%). While small, such differences may suggest vascular compromise in children, as even saturations above 95% have been associated with poor perfusion.

Operative times increased with fracture severity, which is consistent with data from the international literature.

While small subgroup sizes limited statistical comparison of reduction techniques, more open reductions were observed in complex fractures.

Local analgesic use showed no significant group difference, suggesting it may depend more on surgeon preference.

Notably, pin removal occurred later in Gartland IIA (mean: 6.27 weeks) than in III (4.66 weeks). This may reflect greater confidence in fixation stability for more complex cases or caution among less experienced surgeons. Gartland III fractures were less often treated by non-specialists, while IIA cases had more involvement from senior surgeons. Compared to international literature in our country we tend to retain pins for a longer time, especially in less severe fractures.

Although complication rates did not significantly differ between groups, there was a trend toward more complications in severe fractures, particularly neurological. Our 9.3% nerve injury rate matches other reports ranging from 9.5% to 11.3%, though some studies show higher or lower values.

Overall, these findings highlight the importance of tailored treatment strategies in paediatric SCHFs and support further research to refine surgical approaches based on fracture type and patient factors.

3.2.4. Limitations

Our main limitation is that the dataset was national, which may limit generalizability. Inconsistent reporting meant some outcomes included fewer patients. Although the overall sample size was large, subgroup analysis was hindered by small numbers. Follow-up times were not standardized, and patient-reported outcomes were not collected. As an observational study, causal relationships between interventions could not be determined.

3.2.5. Conclusions

Our study emphasizes the significance of initial oxygen saturation levels as potential indicators of fracture severity. It also stresses the need for detailed attention to neurological complications and the prolonged use of pins, thereby highlighting the importance of customized treatment strategies in paediatric SCHFs.

4. Publications and scientific metrics

4.1. First author publications

- **Vajda M**, Szakó L, Hegyi P, Erőss B, Görbe A, Molnár Zs, Kozma K, Józsa G, Bucsi L, Schandl K (2022) Tenodesis yields better functional results than tenotomy in long head of the biceps tendon operations - a systematic review and meta-analysis. Int Orthop 46:1037–1051. https://doi.org/10.1007/s00264-022-05338-9 (Q1, IF: 2.7)
- **Vajda M**, Lőrincz A, Szakó L, Szabó L, Kassai T, Zahár Á, Józsa G (2024) The first analysis of a multicentre paediatric supracondylar humerus fracture (SCHF) registry by fracture type. Arch Orthop Trauma Surg 145:39. https://doi.org/10.1007/s00402-024-05644-4 (Q1, IF: 2.0)

4.2. Co-author papers

- Leiner T, Nemeth D, Hegyi P, Ocskay K, Virág M, Kiss Sz, Rottler M, **Vajda M**, Váradi A, Molnár Zs (2022) Frailty and Emergency Surgery: Results of a Systematic Review and Meta-Analysis. Front Med (Lausanne) 9:811524. https://doi.org/10.3389/fmed.2022.811524 (Q1, IF: 3.9)

4.3. Metrics

- Number of publications related to the subject of the thesis: 2
  - Cumulative impact factor of publications related to the thesis: 4.7
  - Q1: 2, Q2: 0, Q3: 0, Q4: 0
- Number of total accepted articles: 3
  - Cumulative impact factor of the published articles: 8.6
  - Q1: 3, Q2: 0, Q3: 0, Q4: 0
- Number of citations according to MTM2 (as of 11.04.2025): 31
  - https://m2.mtmt.hu/gui2/?type=authors&mode=browse&sel=10098226&view=pubTable
- Number of citations according to Google Scholar (as of 11.04.2025): 38
  - https://scholar.google.com/citations?hl=en&user=xmhzhokAAAAJ&view_op=list_works&gmla=AGd7smGL-hAIhJWKfF7Rz36DdKkSR1bMXOa_MqZZo39SAneMD5zocbGGctKg68OFqNHElHsnWhhb6oe3A13AzwG4zPxNWq2GLyOmpA

5. PhD work and future perspectives

During my PhD, I completed Translational Medicine training and taught Pathophysiology at the University of Pécs, strengthening my teaching skills. I also enrolled patients in prospective registries and randomized clinical trials.

Currently, I'm contributing to the development of a rotator cuff registry. This involved reviewing existing registries, collaborating with an international team experienced in registry management, and consulting Hungarian shoulder surgery experts and registry developers. Together, we designed a comprehensive data collection form to track patient demographics, risk factors, symptoms, surgical details, complications, postoperative outcomes, shoulder scores (e.g., Constant, ASES), and return-to-work status.

Since 2017, I've been actively working in orthopaedics and traumatology as a resident. Looking ahead, I plan to implement the rotator cuff registry and continue integrating scientific research into clinical practice, aligning with my training in translational medicine.