Optimal management of physeal elbow injuries in the skeletally immature athlete remains undefined: a systematic review

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ABSTRACT

Importance Physeal elbow injury remains common for the youth athlete. In this patient population, the most effective treatment strategy for these injuries is not established.

Objective This systematic review aimed to synthesise current literature regarding treatment and outcomes of physeal elbow injuries in the skeletally immature athlete.

Evidence review A systematic literature review was completed using two databases (PubMed and ScienceDirect). Search terms included 'paediatric elbow injury', 'adolescent elbow injury', 'elbow physeal injury', 'avulsion fracture medial epicondyle' and 'little league elbow'. Inclusion criteria were: English language, Level of Evidence I–IV, physeal elbow injury as a direct consequence of athletic activity, involvement of a distinct treatment modality and/or outcome, publication after 1989 and skeletal immaturity demonstrated through radiographic measurements.

Findings Twelve studies consisting of treatment of avulsion fractures of the medial epicondyle, medial epicondyle fragmentation, olecranon stress fractures and olecranon apophysitis met criteria and were included in this study. The most common injury was avulsion fracture of the medial epicondyle. Of these patients, 68.5% underwent operative fixation with average return to play at 3.3 months and 31.5% underwent non-operative treatment with an average return to play of 8.4 months. For medial epicondylar fragmentation, 90.2% of patients were treated non-operatively with average return to play at 3.8 months. Operative intervention was performed on 85.7% of patients with olecranon epiphysial stress fractures and average return to play was at 7 months. Operative intervention was performed on 87.5% of patients with persistence of the olecranon physis with average return to play of 4 months. All cases of olecranon apophysitis were treated non-operatively and return to play was not documented.

Conclusions and relevance This systematic review demonstrates the heterogeneity of the treatment options for physeal injury in the adolescent athlete. This analysis supports that operative management may expedite return to play for avulsion fracture of the medial epicondyle, though medial epicondylar stress fractures can be successfully managed non-operatively. Limited data suggest surgical intervention of olecranon epiphysial stress fractures and persistence of the olecranon physis may allow athletes faster return to play.

Level of evidence IV.

What is already known

- The incidence of elbow injuries is increasing in skeletally immature athletes.
- There are little established data on optimal treatment strategies of physeal elbow injuries in athletes.

What are the new findings

- The present review yielded 12 studies addressing physeal elbow injuries in athletes including avulsion fracture of the medial epicondyle, medial epicondylar fragmentation, olecranon stress fractures, olecranon apophysitis and persistence of the olecranon physis.
- While avulsion fractures of the medial epicondyle can be treated non-operatively, operative management may allow for faster return to play.
- Medial epicondylar fragmentation is primarily treated using non-operative strategies.
- Surgical management of olecranon stress fractures and persistence of the olecranon physis may expedite return to play, though evidence is limited.

INTRODUCTION

Youth participation in recreational and competitive athletics continues to rise in overhead throwing sports.[1 2] The elbow is a common site of orthopaedic injury in the skeletally immature athlete and elbow injury incidence has risen due to increased athletic demand.[3–7] The physis is particularly vulnerable to injury in adolescence because of rapid pubescent growth which leads to increased fragility.[8–10] Physeal elbow injuries represent a particularly challenging pathology to both prevent and treat in the context of greater pressure from parents, coaches and players to remain competitive in an era of specialised sports participation.[1] The incidence of physeal elbow injuries in the skeletally immature athlete may also be rising due to increased participation and intensity of recreational and competitive sports activities.[4]

Many youth initiate participation in sports at an early age and are often involved in year-round specialisation. This can include competing in club

sports, travel leagues, school sports teams or all of the above.[1 4] Increased playing time leads to a greater risk of injury in these young athletes.[1] Sports which involve repetitive overhead loading or throwing, most notably baseball, predispose the skeletally immature athlete to physeal elbow injury.[1 4] A growing body of literature supports that paediatric elbow injury is correlated to increased baseball pitch counts in a game.[4 11–13] Despite this awareness, a large percentage of coaches, players and parents continue to disregard pitch count and type of pitches as a risk factor for elbow injuries.[14] Furthermore, there is the perception that medial collateral ligament (MCL) reconstruction is a viable prophylactic option for elbow injuries in overhead throwing athletes.[14] These findings highlight confusion regarding orthopaedic treatment recommendations and a lack of consensus on the treatment options and outcomes of elbow injuries in young throwing athletes.

The physis is a cartilaginous structure that varies in thickness depending on age and location. It is known to be the 'weakest point' of bone and is therefore predisposed to injury.[7 8] From a cellular standpoint, the physis can be divided into four zones: reserve, proliferative, hypertrophic and endochondral ossification. Physeal fractures are most commonly seen through the hypertrophic zone of the growth plate, with the most common level being at the junction of calcified and uncalcified hypertrophic cells.[15] Longitudinal bone growth comprised the physis or growth plate and the epiphysis. While ligamentous injuries in adults are common, they are rare in children. This is secondary to ligaments in children being functionally stronger than the physis, resulting in a higher proportion of physeal injuries in children.[4 7 8]

The topic of physeal elbow injury in the current day is becoming increasingly important for the young athlete. Despite increased youth sports participation and patient demand for faster treatment, there are little established data on the superiority of treatment strategies across the spectrum of physeal elbow injuries. This systematic review sought to collect and analyse available data to aid physicians in their clinical decision regarding management of physeal elbow injuries based on the best available evidence. We specifically aimed to synthesise the current literature regarding treatment options and outcomes of common physeal elbow injuries that can occur in the skeletally immature athlete, including avulsion fractures of the medial epicondyle, medial epicondylar fragmentation, olecranon stress fracture, olecranon apophysitis and persistence of the olecranon physis.

METHODS

This study was conducted in accordance with the 2009 Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) statement. A literature review was completed using PubMed and ScienceDirect to identify all relevant articles related to physeal elbow injuries in skeletally immature athletes published from January 1990 to May 2016. Search terms included 'paediatric elbow injury', 'adolescent elbow injury', 'elbow physeal injury', 'avulsion fracture medial epicondyle' and 'little league elbow'. Each term was searched for articles relevant to physeal injuries of the paediatric athletic elbow. The reference list of each relevant article was scrutinised to identify any additional studies for inclusion.

Inclusion criteria were: English language, Level I–IV study as defined by the Journal of Bone and Joint Surgery, physeal elbow injury being a direct consequence of athletic activity, reports that included a distinct treatment modality and/or outcome, published in 1990 or after and the cohort of study patients demonstrated skeletal immaturity through radiographic assessment. Studies were excluded if they were case reports, expert opinion or patients were skeletally mature. Information was collected from each study on participant demographics (including age, gender, sport), injury type and treatment details and outcome measures (including return to play and complications). Return to play was defined as number of days from initial evaluation until the first date of return to full sports participation. Descriptive statistics were presented as means, ranges and percentages. When possible, data were pooled prior to reporting on descriptive statistics.

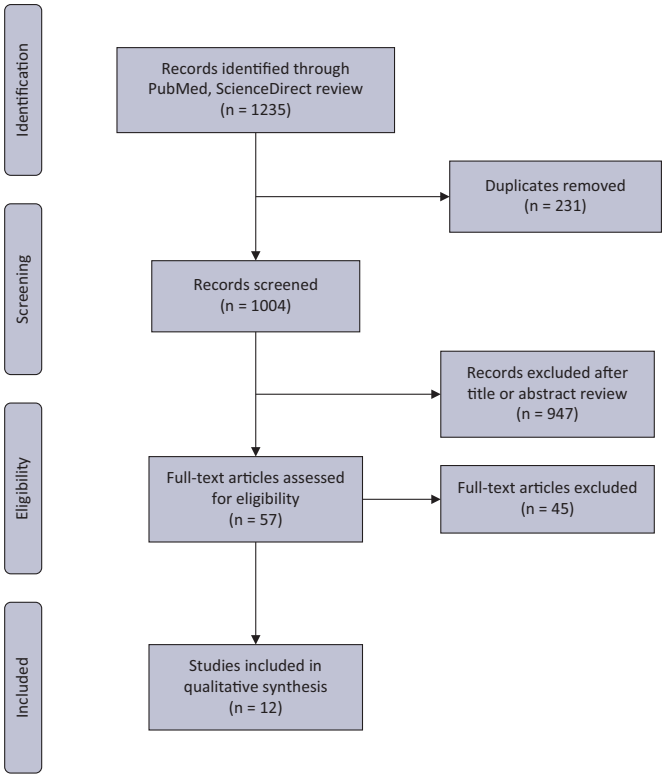

Figure 1 PRISMA diagram detailing systematic literature review process.

RESULTS

Literature search

A total of 18 articles detailing the treatment of physeal elbow injury in the skeletally immature athlete were identified. Six case reports were excluded. Twelve studies therefore met criteria and were included in this study (figure 1).[2 16–26] There were 157 total patients in this analysis and the average age was 13.5 years, with the majority being male (86.6%). Patient demographics for the included studies are presented in tables 1 and 2. The most common injury was an avulsion fracture of the medial epicondyle which occurred in 73 patients (46.5%). The remainder of patients sustained the following injuries: medial epicondylar fragmentation (61 patients, 38.9%), olecranon physeal stress fracture (seven patients, 4.5%), olecranon apophysitis (eight patients, 5.1%) and persistence of the olecranon physis (eight patients, 5.1%). As medial epicondyle and olecranon pathology exhibited significant variability in operative characteristics and outcomes, analysis of the literature was subdivided by injury type.

Table 1 Demographics by study

Authors	Year	Methodology, LOE	# of patients (male/female)	Average age, years (range)	Sport	Injury
Case *et al*[16]	1997	Case Series, IV	7/1	11 (9–15)	Multiple	Avulsion fracture of medial epicondyle
Charlton and Chandler [17]	2003	Case Series, IV	4/1	– (15–20)	Baseball	Persistence of the olecranon physis
Harada *et al*[19]	2014	Prospective Cohort, I	6/0	11.6 (11–13)	Tennis	Medial epicondylar fragmentation
Harada *et al*[18]	2012	Cohort Study, III	55/0	11.2 (10–13)	Baseball	Medial epicondylar fragmentation
Haxhija *et al*[20]	2006	Case Series, III	15/10	12 (7–15)	21 'sports injury'; four not sports related	Avulsion fracture of medial epicondyle
Lawrence *et al*[2]	2013	Case Series, IV	13/7	12.4 (7–17)	Multiple	Avulsion fracture of medial epicondyle
Lokiec *et al*[21]	1991	Case Reports, IV	4/0	14.5 (14–15)	Arm Wrestling	Avulsion fracture of medial epicondyle
Lowery *et al*[22]	1995	Case Reports, IV	3/0	16.3 (15–17)	Baseball	Persistence of the olecranon physis
Maffulli *et al*[23]	1992	Case Reports, IV	6/2 2/0	13. 5 (11–15) 18.5 (18–19)	Gymnastics	Eight olecranon apophysitis Two olecranon epiphysial stress fracture
Nyska *et al*[24]	1992	Case Reports, IV	8/0	13 (13–15)	Arm Wrestling	Avulsion fracture of medial epicondyle
Osbahr *et al*[25]	2010	Case Series, IV	8/0	13 (11–15)	Baseball	Avulsion fracture of medial epicondyle
Rettig *et al*[26]	2006	Case Series, IV	5/0	15 (13–17)	Baseball	Olecranon epiphysial stress fracture

LOE, level of evidence.

Treatment and outcomes of medial epicondylar injuries

Avulsion fracture of the medial epicondyle

A total of six studies discussed the treatment of avulsion fractures of the medial epicondyle in athletes. Of the 73 patients with an avulsion fracture of the medial epicondyle, 23 (31.5%) underwent non-operative treatment consisting of brief immobilisation (range 1.5–4 weeks) in a splint or long arm cast and gradual increase of activity.[2 21 24 25] The average time to return to play in this population was 8.4 months (range 6–10 months); however, these data were only available for five of the patients (21.7%). Among all non-operatively treated patients, the primary complication was a loss of range of motion: one patient lost 30° of elbow extension, three patients lost less than 10° of motion and two patients reported a subjective decrease in range of motion.[2 24] Other complications included intermittent numbness with prolonged elbow flexion (one patient) and continued pain (one patient).[2] However, all patients were able to continue playing sports at their previous level.

The other 50 patients with an avulsion fracture of the medial epicondyle (68.5%) underwent operative fixation due to fragment displacement severity and concomitant pathology.[2 16 20 25] Thirty-five patients (70%) who underwent open reduction and internal fixation (ORIF) had an associated elbow dislocation.[2 16 20] Typically, patients with at least 5 mm of fragment displacement were offered surgical treatment due to concern for incarcerated fragment or valgus instability. In those studies reporting fragment displacement, patients who underwent ORIF had larger displacement (avg 8.7 mm, range 3.8–15 mm) than those who had conservative treatment (4.6 mm, range 2.5–7.8 mm).[2 16 25] Fixation was performed using either Kirschner wires or a cannulated screw with or without a washer (figure 2). After surgery, patients were immobilised for 4 days to 3 weeks, followed by gradual activity progression. Data regarding return to play were available for 36 patients, 25 of which (69.4%) were from a single study.[20] The average time to return to play in these patients was 3.3 months (range 1–10 months). Complications for avulsion fracture of the medial epicondyle patients treated operatively included intermittent numbness with prolonged elbow flexion in six patients (12%), loss of less than 10° of elbow range of motion in five patients (10%) and subjective loss of range of motion in five patients (10%).[2 16 20] Additionally, one patient underwent subsequent surgery for prolonged elbow stiffness (tables 3 and 4).[2]

Medial epicondylar fragmentation

Only two studies were identified that reported on the treatment of medial epicondylar fragmentation. All of the 61 cases of medial epicondylar fragmentation were treated non-operatively.[18 19] Fifty-five (90.2%) of these patients were treated with activity limitations with gradual increase to full activity.[18] Return to play time averaged 3.8 months (range 1–8 months). Nine patients (16.4%) reported pain at 6 months. Forty-one patients were available for follow-up at 1 year and seven (17%) reported

Table 2 Demographics by injury

	Total participants	Avulsion fracture of medial epicondyle	Medial epicondylar fragmentation	Olecranon physeal stress fractures	Persistence of olecranon physis	Olecranon apophysitis
# of patients	157	73 (46.5%)	61 (38.9%)	7 (4.5%)	8 (5.1%)	8 (5.1%)
Male	136 (86.6 %)	55 (75.3%)	61 (100%)	7 (100%)	7 (87.5%)	6 (75%)
Female	21 (13.4%)	18 (24.7%)	0 (0%)	0 (0%)	1 (12.5%)	2 (25%)
Average age (range)	13.5 (7–20)	12.7 (7–17)	11.4 (10–13)	16 (13–18)	–, (15-20)	13.8 (11–15)
Sport	Varied Sports	Baseball (20) Arm Wrestling (12) Varied Sports	Baseball (55) Tennis (6)	Baseball (5) Gymnastics (2)	Baseball	Gymnastics
Operative	63 (40.1%)	50 (68.5%)	0 (0%)	6 (85.7%)	7 (87.5%)	0 (0%)
Non-operative	94 (59.9%)	23 (31.5%)	61 (100%)	1 (14.3%)	1 (12.5%)	8 (100%)

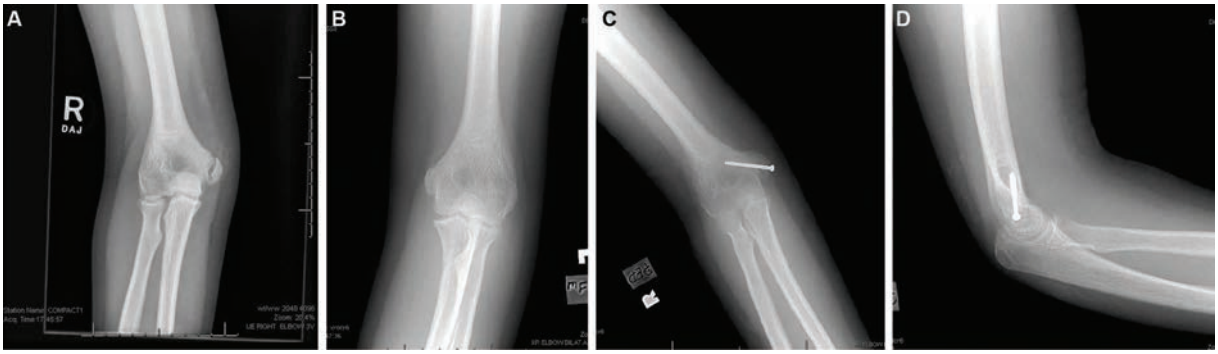

Figure 2 Anterioposterior radiographs of the throwing and non-throwing elbow (A, B) of an adolescent 14-year-old baseball pitcher demonstrating an avulsion fracture of the medial epicondyle. This patient underwent cannulated screw fixation and 6-week postoperative radiographs (C, D) show healing of the fracture site.

continued pain at that time. Three patients with documented union at 6 months were found to have recurrence at 1-year follow-up. The remaining six cases (9.8%) of medial epicondylar fragmentation did not undergo any intervention and continued with full sports participation after diagnosis.[19] Five of these patients (83.3%) had documented union at follow-up (average of 20.4 months, range 12–30) and three (60%) continued to report intermittent elbow pain that did not limit play. The remaining patients without spontaneous union continued to report elbow pain beyond 1 year (tables 3 and 5).

Treatment and outcomes of posterior compartment physeal elbow injuries

Olecranon stress fracture

A total of two studies reported on the treatment of olecranon stress fractures. Five of seven patients failed initial non-operative treatment of an olecranon stress fracture and one elected to undergo operation before an initial trial of conservative treatment. The average trial of non-operative treatment before operation lasted 8 weeks. Six of seven patients (85.7%) who sustained olecranon epiphysial stress fractures were treated operatively with a cannulated screw (figure 3). Average time to return to play was 7 months (range 4–10 months). One of these patients suffered an acute displacement through the site of his olecranon stress fracture prior to surgical treatment.[26] The patient also experienced redisplacement after initial K-wire and tension band wires 2 weeks after surgery. This required a second surgery with bone regrafting and placement of a K-wire and screw. This patient showed radiographic delayed union which resolved 33 weeks after the initial surgery. Two patients complained of postoperative hardware irritation and subsequently underwent hardware removal without complication (tables 3 and 6).[23 26] The one patient was successfully treated with non-operative treatment consisting of rest, cryotherapy and physical therapy though time to return to play was not reported.[23]

Table 3 Treatment by injury type

	Non-operative	Operative
Avulsion fracture of the medial epicondyle		
Total patients	23 (31.5%)	50 (68.5%)
Return to play, months (range)	8.4 (6–10) (n=5)	3.3 (1–10) (n=36)
Loss of ROM (any amount)	6 (26%)	10 (20%)
Continued pain	1 (4.3%)	0 (0%)
Intermittent numbness	1 (4.3%)	6 (12%)
Medial epicondylar fragmentation		
Total patients	61 (100%)	0 (0%)
Return to play, months (range)	3.8 (1–8)	–
Recurrence at 1 year	3 (5%)	–
Continued pain	11 (18%)	–
Olecranon epiphysial stress fracture		
Total patients	1 (14.3%)	6 (85.7%)
Return to play, months (range)	–	7 (4–10)
Hardware Irritation	–	2 (33%)
Persistence of the olecranon physis		
Total patients	1 (12.5%)	7 (87.5%)
Return to play, months (range)	6	4
Hardware irritation	–	4 (57%)

ROM, range of motion.

Persistence of the olecranon physis

Two studies were identified that discussed the management of persistence of the olecranon physis. Seven of eight patients (87.5%) who had persistence of the olecranon physis were treated operatively after failing initial non-operative treatment that ranged from 1 month to 60 months.[17 22] All players treated operatively returned to play at 4 months. Four patients complained of hardware irritation and had subsequent removal at 22 weeks (range 12–38 weeks) after the initial surgery without complication.[17] One patient was successfully managed with conservative treatment consisting of avoidance of throwing activities, physical therapy for range of motion, then gradual increase in throwing activities as tolerated.[22] He was able to return to play at 6 months (tables 3 and 7).

Olecranon apophysitis

Only one study reported on the treatment of olecranon apophysitis in adolescent athletes. All of the eight cases of olecranon apophysitis reported in the literature were treated non-operatively with cryotherapy, rest and physical therapy.[23] They were all reported to have healed without complication; however, time to return to play was not documented. Three of these athletes (33%) did not return to sport due to unrelated injuries (table 8).

DISCUSSION

The annual incidence of elbow pain in 9–12-year-old baseball players is 20%–40%.[27] Increased participation in youth sports has correlated with increase in physeal elbow injuries.[4] This systematic review sought to collect and analyse available data since 1990 to aid physicians in their evidence-based clinical decision making for management of physeal elbow injuries in

Table 4 Treatment of avulsion fracture of the medial epicondyle

Study	Treatment	Treatment details	Follow-up, years (range)	Return to play, months (range)	Complications
Case *et al*[16] (n=8)	Operative	Cannulated screw, 4 days immobilisation post-op	0.833 (0.5–1.08)	3	Loss of 5 degrees of ROM (1)
Haxhija *et al*[20] (n=25)	Operative	Kirschner wires or cannulated screw, 3 weeks immobilisation post-op	3 (1–8)	3 (1–8)	Loss of<10 degrees of ROM (4)
Lawrence *et al*[2] (n=20)	Non-operative (31.5%)	3–4 weeks immobilisation until non-tender, gradual activity progression	3.6 (2–6.9)	–	Subjective loss of ROM (2) Continued pain (1) Intermittent numbness (1)
	Operative (68.5%)	Cannulated screw with or without washer, 1.5–3 weeks immobilisation post op			Subjective loss of ROM (5) Intermittent numbness (6)
Lokiec *et al*[21] (n=4)	Non-operative	1.5 weeks immobilisation, gradual activity progression	1	–	–
Nyska *et al*[24] (n=8)	Non-operative	1.5–3 weeks immobilisation, gradual activity progression	1	–	Loss of 30 degrees of ROM (1) Loss of<10 degrees of ROM (3)
Osbahr *et al*[25] (n=8)	Non-operative (62.5%)	3 weeks immobilisation, gradual activity progression	–	8.4 (6–10)	–
	Operative (37.5%)	Cannulated screw		6.3 (4–10)	–

ROM, Range of motion.

the adolescent athletic population. We evaluated non-operative and operative treatment with regard to return to play time and potential complications with each treatment modality. We also sought to elucidate and synthesise data regarding less commonly reported physeal elbow injury to increase awareness of these potential pathologies in our youth athletes.

Most physeal elbow pathologies are chronic overuse injuries and thus prior pedagogy regarding the management of physeal elbow injury was non-operative management with rest, ice and non-steroidal anti-inflammatory drugs (NSAIDS). Non-operative measures commonly produce satisfactory results and return to play.[1–3 6 18 19 24 26–30] However, despite evidence of satisfactory results of non-operative treatment, there has been an increasing trend in operative treatment for physeal elbow injury.[31] Particularly for athletes, there remains a theoretical advantage of operative management in achieving bony union, given the heavy demand on the dominant elbow.[31] Operative fixation goals are to maximise the possibility of early return to full function and high level activity, minimise late deformity and decrease elbow stiffness. We theorise the increasing operative trends may be due to increasing emphasis of the importance of the ligamentous origin in athletic function, particularly for the medial epicondyle, increased participation and specialisation within sports at an early age and desire for faster return to play.

Medial epicondylar injuries

Avulsion fracture of the medial epicondyle

Prior studies have reported non-operative complications of avulsion fractures of the medial epicondyle including an unrecognised incarcerated fragment, ulnar nerve dysfunction, tardy ulnar neuritis, malunion, loss of terminal extension and patient and family dissatisfaction with ultimate functional result.[31] Indications for surgical treatment of these injuries have previously been reported to include fragment incarceration in the joint, open fracture, gross instability, ulnar nerve entrapment or involvement and fragment displacement greater than 5–15 mm with a lower threshold for valgus stress athletes such as pitchers or gymnasts.[32] In our review, these guidelines were followed and surgical treatment was typically offered to patients with 5 mm or more of fragment displacement. Overall, 68.5% of patients underwent operative treatment while 31.5% were treated non-operatively. Regardless of treatment, our review revealed similar rates of complications, such as mild loss of range of motion and intermittent numbness, none of which prevented these patients from participating in their activities. The review did show patients were able to return to play faster following operative treatment compared with non-operative treatment (3.3 months and 8.4 months, respectively). However, these results were based on a limited subset of studies that reported return to play. Furthermore, provider preferences may have contributed to differences in reported return to play times between studies. Only one study assessed return to play for both non-operative and operative management.[25] Within that population, non-operative and operative management led to return to play times of 8.4 and 6.3 months, respectively. These results suggest that operative management may shorten the time to return to play, though it is unclear as to what extent. While the decision of management of this injury is multifactorial, a lower threshold for surgical treatment of an avulsion fracture of the medial epicondyle should be considered in the young athlete as complication rates are minimal and the return to play time may be favourable.

Medial epicondylar fragmentation

Medial epicondylar fragmentation differs from avulsion fracture of the medial epicondyle in that it is caused by repetitive valgus stress leading to traction apophysitis and separation.[33] Our review showed that these injuries are uniformly treated

Table 5 Treatment of medial epicondylar fragmentation

Study	Treatment	Treatment details	Follow-up, years (range)	Return to play, months (range)	Complications	Comments
Harada *et al*[19] (n=6)	Non-operative	No intervention	1.83 (1–2.5)	–	Continued pain (1) Intermittent pain not prohibitive to play (3)	All returned to play immediately
Harada *et al*[18] (n=55)	Non-operative	Gradual activity progression	2.91 (0.5–7.6)	3.8 (1–8)	Continued pain at 1 year (7) Recurrence at 1 year (3)	Increased complication rate with treatment non-compliance

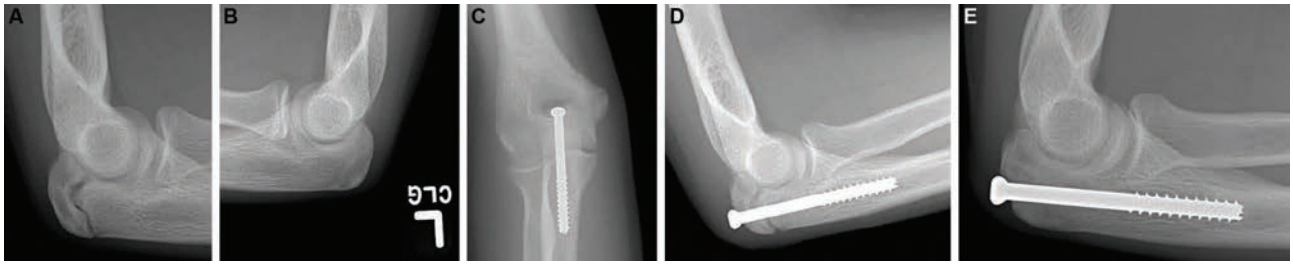

Figure 3 A 14-year-old right-hand-dominant baseball pitcher who failed non-operative treatment of an olecranon stress fracture. Lateral plain films comparing affected and non-affected elbow (A, B). Postoperative week 2 anterioposterior (C) and lateral (D) plain films following cannulated screw fixation. Final follow-up lateral plain film (E).

conservatively. Non-operative treatment in one study of baseball players consisted of prohibition of throwing until the elbow was pain-free and not tender, followed by limited throwing until bony union achieved.[18] This study found bone union in 72.7% of patients at 6-month follow-up and full return to play at 3.8 months on average. Furthermore, of patients who were compliant with treatment, only 7.3% experienced delayed union at 6 months. In comparison, among patients who were not compliant with recommended throwing restrictions, 85.7% had delayed union at 6 months. This suggests that adherence to non-operative treatment, particularly limitations on activity, is an important factor leading to quick recovery. However, another study documented outcomes in six tennis players with medial epicondylar fragmentation that did not abide by any prescribed activity limitations.[19] They found that 83.3% of patients had bone union at follow-up and while 60% of this group reported intermittent pain at follow-up, this was not prohibitive to play. While this suggests that patients will heal without any intervention, follow-up did not occur until 22 months on average, limiting our ability to determine when union occurred or how long these athletes continued to experience pain. Therefore, we recommend activity limitations for these athletes to facilitate faster return to play without complication.

Posterior compartment physeal elbow injuries

Persistence of the olecranon physis, olecranon stress fractures and olecranon apophysitis are a grouping of similar posterior compartment physeal injuries that remain an uncommon source of physeal elbow injury. Adams provided an early description of olecranon apophysitis or 'little league elbow' in paediatric elbow injuries.[34] This term was specific for apophyseal injury in paediatric throwing athletes; however, over time this term has progressed to include a range of paediatric elbow pathologies which includes physeal elbow injuries. Repetitive stress on the olecranon causes a traction apophysitis and continued injury to this area can lead to subsequent stress fracture through the epiphysial plate. Continued traction on the physis can lead to persistence of the olecranon physis, which is defined as an olecranon physis that exists in a person with demonstrated skeletal maturity of the contralateral elbow. Posterior compartment physeal injury comprised only 14.6% of the total injuries in our review of the literature. While olecranon apophysitis was treated non-operatively without any reported complications, no data were provided regarding time to return to play in these individuals.[23]

Olecranon stress fracture

Alternatively, 85.7% of olecranon epiphysial stress fractures were treated operatively without long-term complications. Our review showed a high rate of olecranon stress fractures that failed initial non-operative treatment (57%), suggesting a potential need for more aggressive initial management.[2 26] One patient with an olecranon stress fracture who was treated operatively without initial non-operative treatment had the most expeditious return to play following surgical intervention (19.6 weeks) compared with those treated initially with non-operative treatment (avg 44.6 weeks).[26] Similarly, studies of olecranon stress fractures in adult athletes have also found that these injuries often fail to respond to extended non-operative treatment. Therefore, early internal fixation has been recommended in the adult athlete population.[35] We suggest extending this recommendation to the paediatric athlete as patients may have greater benefit and more expeditious return to play with initial surgical fixation.

Persistence of the olecranon physis

Similar results were seen with treatment of persistence of the olecranon physis. The majority of these patients (87.5%) were treated operatively and ultimately returned to play faster (4 months) compared with the 12.5% successfully treated conservatively (6 months). However, hardware irritation was a notable postoperative problem requiring removal in some of those treated which led to resolution of symptoms.[17] The use of headless screws could be an option to mitigate this potential issue. Overall, it remains difficult to evaluate the best treatment for these uncommon injuries, given the limited literature that is based on isolated case reports. Prospective randomised trial, pooling data from multiple centres, would greatly benefit further clinical decision-making on posterior compartment physeal injuries.

Table 6 Treatment of olecranon epiphysial stress fracture

Study	Treatment	Treatment details	Follow-up, years (range)	Return to play, months (range)	Complications
	Non-operative (1)	Cryotherapy, rest, physical therapy		–	–
Maffulli *et al*[23] (n=2)	Operative (1)	Cannulated screw	6.2 (1–9)	–	–
Rettig *et al*[26] (n=5)	Operative	Cannulated screw and washer with or without figure of 8 tension banding and bone graft	–	7 (4–10)	Acute displacement prior to surgery and delayed union (1)

Table 7 Treatment of persistence of the olecranon physis

Study	Treatment	Treatment details	Follow-up, years (range)	Return to play, months (range)	Complications
Charlton and Chandler[17] (n=5)	Operative	Figure of 8 tension banding or screw, bone graft	2.66 (0.58–7.0)	4	Discomfort from prominent wires (3) Restricted pronation (1)
	Non-operative (1)	Gradual activity progression		6	–
Lowery *et al*[22] (n=3)	Operative (2)	Figure of 8 tension banding with Kirschner wires or cannulated screw, bone graft	(0.5–2.0)	4	–

Table 8 Treatment of olecranon apophysitis

Study	Treatment	Treatment details	Follow-up, years (range)	Return to play, months (range)	Comments
Maffulli *et al*[23] (n=8)	Non-operative	Cryotherapy, rest, physical therapy	6.2 (1–9)	–	Three did not return to sport due to other injuries Remaining returned to play without complication

Limitations

The majority of the studies meeting inclusion criteria were case series and retrospective reviews, with inherent heterogeneity of patient evaluation and outcome reporting of range of motion, follow-up and return to play. There appears a paucity of data existing on uncommon physeal elbow injuries in this patient population. Thus, it remains difficult to determine a unified systematic conclusion regarding these underreported injuries. However, we elected to discuss all relevant pathology in skeletally immature athletes in order to increase awareness of the limitations within the current literature. This review summarises and pools the available data to help guide the clinician in managing these injuries; however, more research and better powered studies are needed.

CONCLUSION

The current review of literature demonstrated an avulsion fracture of the medial epicondyle continues to be the most common physeal elbow injury, while posterior compartment physeal injuries remain uncommon. Both non-operative and operative treatment of physeal elbow injuries can result in successful outcomes for athletes who return to high-level play after treatment. However, our review highlights the heterogeneity of the treatment provided for adolescent athlete elbow injuries and the resultant variable return to play. While limited data suggest that surgery may favour a shorter return to play for patients with an avulsion fracture of the medial epicondyle, olecranon epiphysial stress fractures and persistence of the olecranon physis, the indications for surgery remain unclear. Further investigation is required to definitively determine the best treatment for the myriad of elbow pathologies affecting the skeletally immature athlete.

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REFERENCES

1 Gregory B, Nyland J. Medial elbow injury in young throwing athletes. *Muscles Ligaments Tendons J* 2013;3:91–100.
2 Lawrence JT, Patel NM, Macknin J, *et al*. Return to competitive sports after medial epicondyle fractures in adolescent athletes: results of operative and nonoperative treatment. *Am J Sports Med* 2013;41:1152–7.
3 Greiwe RM, Saifi C, Ahmad CS. Pediatric sports elbow injuries. *Clin Sports Med* 2010;29:677–703.
4 Magra M, Caine D, Maffulli N. A review of epidemiology of paediatric elbow injuries in sports. *Sports Med* 2007;37:717–35.
5 Adirim TA, Barouh A. Common orthopaedic injuries in young athletes. *Current Paediatrics* 2006;16:205–10.
6 Bernhardt DT, Landry GL. Sports injuries in young athletes. *Adv Pediatr* 1995;42:465–500.
7 Ireland ML, Hutchinson MR. Upper extremity injuries in young athletes. *Clin Sports Med* 1995;14:533–69.
8 Caine D, DiFiori J, Maffulli N. Physeal injuries in children's and youth sports: reasons for concern? *Br J Sports Med* 2006;40:749–60.
9 Brooks A, Hammer E. Acute upper extremity injuries in young athletes. *Clin Pediatr Emerg Med* 2013;14:289–303.
10 Davis KW. Imaging pediatric sports injuries: upper extremity. *Radiol Clin North Am* 2010;48:1199–211.
11 Fleisig GS, Weber A, Hassell N, *et al*. Prevention of elbow injuries in youth baseball pitchers. *Curr Sports Med Rep* 2009;8:250–4.
12 Leahy I, Schorpion M, Ganley T. Common medial elbow injuries in the adolescent athlete. *J Hand Ther* 2015;28:201–11.
13 Gerbino PG. Elbow disorders in throwing athletes. *Orthop Clin North Am* 2003;34:417–26.
14 Ahmad CS, Grantham WJ, Greiwe RM. Public perceptions of Tommy John surgery. *Phys Sportsmed* 2012;40:64–72.
15 Ogden J. *Skeletal Injury in the child*. New York: Springer-Verlag, 2000.
16 Case SL, Hennrikus WL. Surgical treatment of displaced medial epicondyle fractures in adolescent athletes. *Am J Sports Med* 1997;25:682–6.
17 Charlton WP, Chandler RW. Persistence of the olecranon physis in baseball players: results following operative management. *J Shoulder Elbow Surg* 2003;12:59–62.
18 Harada M, Takahara M, Hirayama T, *et al*. Outcome of nonoperative treatment for humeral medial epicondylar fragmentation before epiphyseal closure in young baseball players. *Am J Sports Med* 2012;40:1583–90.
19 Harada M, Takahara M, Maruyama M, *et al*. Characteristics and prognosis of medial epicondylar fragmentation of the humerus in male junior tennis players. *J Shoulder Elbow Surg* 2014;23:1514–20.
20 Haxhija EQ, Mayr JM, Grechenig W, *et al*. [Treatment of medial epicondylar apophyseal avulsion injury in children]. *Oper Orthop Traumatol* 2006;18:120–34.

21 Lokiec F, Velkes S, Engel J. Avulsion of the medial epicondyle of the humerus in arm wrestlers: a report of five cases and a review of the literature. *Injury* 1991;22:69–70.
22 Lowery WD, Kurzweil PR, Forman SK, *et al*. Persistence of the olecranon physis: a cause of "little league elbow". *J Shoulder Elbow Surg* 1995;4:143–7.
23 Maffulli N, Chan D, Aldridge MJ. Overuse injuries of the olecranon in young gymnasts. *J Bone Joint Surg Br* 1992;74:305–8.
24 Nyska M, Peiser J, Lukiec F, *et al*. Avulsion fracture of the medial epicondyle caused by arm wrestling. *Am J Sports Med* 1992;20:347–50.
25 Osbahr DC, Chalmers PN, Frank JS, *et al*. Acute, avulsion fractures of the medial epicondyle while throwing in youth baseball players: a variant of Little League elbow. *J Shoulder Elbow Surg* 2010;19:951–7.
26 Rettig AC, Wurth TR, Mieling P. Nonunion of olecranon stress fractures in adolescent baseball pitchers: a case series of 5 athletes. *Am J Sports Med* 2006;34:653–6.
27 Benjamin HJ, Briner WW. Little league elbow. *Clin J Sport Med* 2005;15:37–40.
28 Brucker J, Sahu N, Sandella B. Olecranon stress injury in an adolescent overhand pitcher: a case report and analysis of the literature. *Sports Health* 2015;7:308–11.
29 Blohm D, Kaalund S, Jakobsen BW. "Little league elbow"-acute traction apophysitis in an adolescent badminton player. *Scand J Med Sci Sports* 1999;9:245–7.
30 Maffulli N, Longo UG, Gougoulias N, *et al*. Long-term health outcomes of youth sports injuries. *Br J Sports Med* 2010;44:21–5.
31 Kamath AF, Baldwin K, Horneff J, *et al*. Operative versus non-operative management of pediatric medial epicondyle fractures: a systematic review. *J Child Orthop* 2009;3:345–57.
32 Redler LH, Dines JS. Elbow trauma in the athlete. *Hand Clin* 2015;31:663–81.
33 Wei AS, Khana S, Limpisvasti O, *et al*. Clinical and magnetic resonance imaging findings associated with Little League elbow. *J Pediatr Orthop* 2010;30:715–9.
34 Adams JE. Little league elbow. *Calif Med* 1973;118:34–5.
35 Cain EL, Dugas JR, Wolf RS, *et al*. Elbow injuries in throwing athletes: a current concepts review. *Am J Sports Med* 2003;31:621–35.