

Stress Fractures of the Elbow in the Throwing Athlete

A Systematic Review

Shelby R. Smith,* BS, Nirav K. Patel,[†] MD, MS, FRCS, Alex E. White,* BA, Christopher J. Hadley,[†] BS, and Christopher C. Dodson,^{†‡} MD

Investigation performed at the Rothman Institute, Thomas Jefferson University, Philadelphia, Pennsylvania, USA

Background: Stress fractures of the elbow are rare in throwing athletes and present a challenge from both a management and rehabilitation perspective. Although the incidence of stress fractures of the elbow is increasing, there is a lack of data in the literature focused on throwers.

Purpose: To evaluate studies regarding the management and outcomes of stress fractures of the elbow in throwing athletes.

Study Design: Systematic review; Level of evidence, 4.

Methods: A systematic review was conducted by searching the Scopus, PubMed, and Cochrane Library electronic databases to identify studies reporting on the management and outcomes of stress fractures in overhead-throwing athletes. Management data included nonoperative and operative modalities, and outcome data included return to play, encompassing the timing and level of activity. Studies were excluded if the stress fracture of the elbow was not a result of a sport injury attributed to throwing or if the study failed to report whether an athlete returned to play.

Results: Fourteen studies met the inclusion criteria and were included in this analysis. There were 52 patients in total (50 male, 2 female) with a mean age of 19.7 years (range, 13-29.1 years). The olecranon was the most common location of the stress fracture (51 patients; 98.1%), followed by the distal humerus (1 patient; 1.9%). The majority of patients ($n = 40$; 76.9%) were treated operatively. Of the 40 patients who were treated surgically, 14 (35.0%) underwent a period of conservative treatment preoperatively that ultimately failed because of persistent nonunion or continued elbow pain. A total of 50 patients (96.2%) returned to sport either at or above their preinjury level. Of the 2 patients (3.8%) who did not return to sport, 1 did not return because of continued elbow pain postoperatively, and the other was lost to follow-up. Complications occurred in 9 patients (17.3%), all of whom were treated surgically.

Conclusion: On the basis of this systematic review, the majority of elbow stress fractures were treated operatively and approximately one-third after a period of failed nonoperative management. The return-to-sport rate was high. Further, higher level studies are needed to optimize management and return-to-sport rates in this population.

Keywords: stress fracture; elbow; throwing athlete; management; return to sport

[‡]Address correspondence to Christopher C. Dodson, MD, Rothman Institute, Thomas Jefferson University, 925 Chestnut Street, Philadelphia, PA 19107, USA (email: ccdodson7@gmail.com).

*Sidney Kimmel Medical College, Thomas Jefferson University, Philadelphia, Pennsylvania, USA.

[†]Rothman Institute, Thomas Jefferson University, Philadelphia, Pennsylvania, USA.

One or more of the authors has declared the following potential conflict of interest or source of funding: C.C.D. is a consultant for Arthrex and receives royalties from DePuy. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

The Orthopaedic Journal of Sports Medicine, 6(10), 2325967118799262

DOI: 10.1177/2325967118799262

© The Author(s) 2018

Stress fractures of the elbow are rare in throwing athletes. More commonly, injuries involve soft tissue structures of the elbow, including the ulnar collateral ligament or flexor-pronator muscles and their attachment sites.⁴ In a review of stress fractures in athletes, Iwamoto and Takeda⁹ cited the olecranon as the most frequent site of problems in baseball players, comprising 58% of stress fractures. In throwing athletes, the mechanism of injury of olecranon stress fractures has been attributed to forces similar to valgus extension overload. Such forces include the olecranon repetitively abutting the olecranon fossa, triceps traction on the olecranon during the deceleration phase of throwing, and medial olecranon impaction onto the olecranon fossa due to valgus stress.¹ Despite our understanding of elbow mechanics in throwing, these

injuries present a challenge in management and rehabilitation.

Traditionally, the treatment for olecranon stress fractures has comprised an initial period of nonoperative treatment, which includes rest, immobilization, and cessation of throwing.¹⁷ Immobilizing splints have also been reported to aid in pain relief.¹ Operative treatment is usually only considered when there is a true fracture, apophyseal nonunion, or failure of nonoperative management.²² Operative techniques often require open reduction internal fixation (ORIF) with the use of plate osteosynthesis or compression screw fixation.^{1,17,23} The decision to operate without an initial nonoperative course of management has been suggested for time-restricted, elite-level, competitive athletes. Return to sport is typically allowed when the patient is asymptomatic and radiographs demonstrate complete fracture healing. Stress fractures heal more slowly than complete fractures and, in some cases, can take up to 6 months for complete resolution when managed nonoperatively.¹

There is a lack of data in the literature focused on stress fractures in throwers. Additionally, no study, to our knowledge, has reviewed the incidence, management, and return to play in this patient population. The purpose of this study was to evaluate the management and outcomes, including return-to-play rates, of stress fractures of the elbow in throwing athletes by a systematic review.

METHODS

Search Strategy

The literature search was completed using the PubMed, Scopus, and Cochrane Library databases from inception to September 15, 2017. Search terms included several combinations of “elbow,” “stress fracture,” “stress injury,” and “throwing.” The search was restricted to the English language and human participants and excluded keywords such as “tennis elbow,” “collateral ligaments,” “gymnastics,” and “wrist injury.” Two reviewers (S.R.S., A.E.W.) independently screened titles and abstracts to determine the inclusion of the results. Full-text articles were then obtained and reviewed for inclusion. The references of all selected articles were reviewed as well to find potential articles that were missed. The search resulted in 14 articles after duplicates were removed (Figure 1).

The inclusion criteria for this study were all of the following: (1) the injury included a stress fracture located at the elbow (but not limited to the same anatomic location), (2) the injury was the result of participating in a sport that involved repetitive throwing, (3) a distinct treatment modality was reported, (4) the study indicated whether an athlete returned to sport, and (5) the study’s level of evidence was stated as 1 to 4. The systematic review was not limited by age, specific treatment, or anatomic location of the stress fracture within the elbow.

Data Extraction

The following data points were recorded, when available: number of patients, demographics (sex, age), sport, location

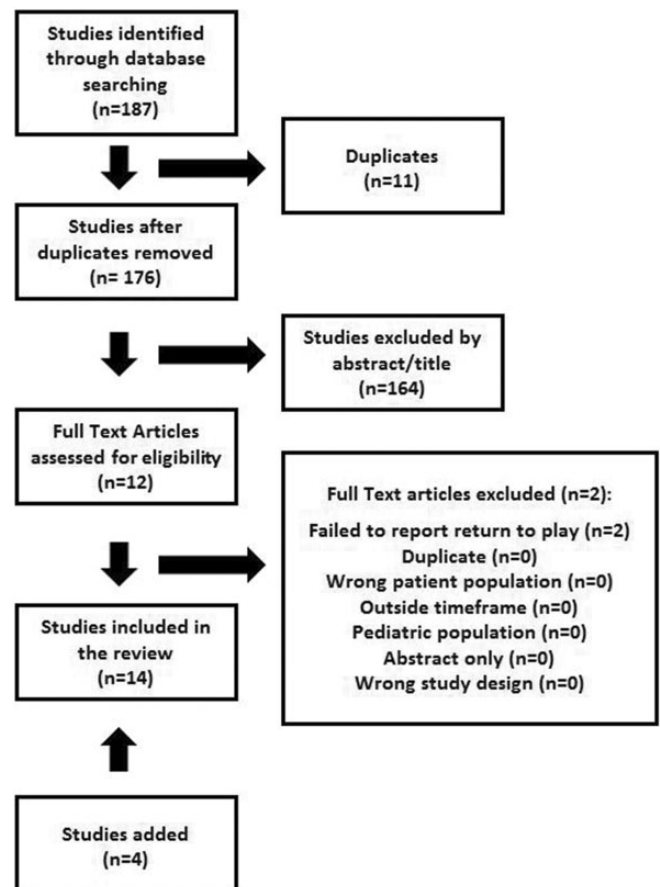


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) chart outlining the review of articles from the search.

of the stress fracture, duration of symptoms, unsuccessful treatment, follow-up time period, primary treatment modality, time to radiographic union, time to symptom resolution, time to return to sport, level of competition to which the athlete returned, complications, and revision surgery. The available data were used to evaluate the effectiveness of nonoperative and operative therapeutic options as treatment for stress fractures of the elbow in the throwing athlete.

RESULTS

Study Characteristics and Patient Demographics

Of the 14 articles included in this review, 4 articles were retrospective case series (level 4), and the remaining articles were case reports (level 4). The study characteristics are summarized in Table 1. There were 52 patients in total: 50 male (96.2%) and 2 female (3.8%). The primary sport played was baseball (88.5%), followed by javelin throw (7.7%), football (1.9%), and softball (1.9%). Stress fractures of the olecranon were reported in the majority of patients (98.1%), 7 of which were epiphyseal nonunion (13.5%). The

TABLE 1
Study Demographics^a

Author (Year)	Study Design	Total Patients (Male/Female), n	Age, Mean (Range), y	Sport	Location of Stress Fracture	Primary Treatment	Follow-up, Mean (Range), y
Alpert et al ² (2014)	CR	1 (1/0)	NR ^b	Football	Distal humerus	Nonoperative	NR
Fujioka et al ⁵ (2012)	CS	6 (5/1)	18 (16-21)	Baseball, softball	Olecranon	Operative	2.3 (2-3)
Hulkko et al ⁷ (1986)	CR	4 (3/1)	23 (21-28)	Javelin throw	Olecranon	Nonoperative (1/4), operative (3/4)	1.3 (0.75-1.8)
Imade et al ⁸ (2011)	CR	1 (1/0)	23	Baseball	Olecranon	Operative	NR
Kvidera and Pedegana ¹⁰ (1983)	CR	2 (2/0)	24 (23-25)	Baseball	Olecranon	Operative	NR
Mamaneet al ¹¹ (2000)	CR	1 (1/0)	14	Baseball	Proximal ulna	Nonoperative	1.0
Nakaji et al ¹² (2006)	CR	1 (1/0)	25	Baseball	Olecranon	Operative	2.0
Nuber and Diment ¹³ (1992)	CR	2 (2/0)	22 (21-23)	Baseball	Olecranon	Nonoperative	NR
Paci et al ¹⁵ (2013)	CS	18 (18/0)	20 (16-24)	Baseball	Olecranon	Operative	6.2 (2-10)
Pavlov et al ¹⁸ (1981)	CR	1 (1/0) ^c	16	Baseball	Olecranon	Operative	0.25
Rettig et al ¹⁹ (2006)	CS	5 (5/0)	15 (13-17)	Baseball	Olecranon	Operative	NR
Schickendantz et al ²⁰ (2002)	CS	7 (7/0)	22 (18.8-29.1)	Baseball	Proximal ulna	Nonoperative	4.0 (2-7)
Suzuki et al ²¹ (1997)	CR	2 (2/0)	19 (17-21)	Baseball	Olecranon	Operative	1.0
Torg and Moyer ²² (1977)	CR	1 (1/0)	16	Baseball	Olecranon	Operative	2.3

^aCR, case report; CS, case series; NR, not reported.

^bAuthors reported that the patient was a collegiate athlete.

^cOne patient was excluded for failing to report return-to-sport data.

remaining stress injuries were located at the distal humerus (1.9%). The mean age of the patients was 19.7 years (range, 13.0-29.1 years). A total of 40 patients (76.9%) underwent operative treatment, while the remaining 12 patients (23.1%) were managed nonoperatively. The mean follow-up for these studies was 4.8 years (range, 3 months to 10 years); however, follow-up was not specified for 15 patients (28.8%).

Nonoperative Treatment

The mean duration of symptoms before nonoperative management was 2.8 months (range, 2 weeks to 36 months).^{11,13} Most authors recommended an initial 4 to 6 weeks of rest, during which any form of valgus stress was to be avoided.^{11,13,20} In the case series by Schickendantz et al,²⁰ a custom-fabricated hinged elbow orthosis was set from full flexion to 20° short of full extension. At 2 weeks, light forearm and progressive resistance exercises were allowed. The orthosis was discontinued, and full range of motion was generally allowed at 4 weeks with the addition of light weight lifting and continuation of resistance exercises.²⁰ For most authors, a progressive throwing program was initiated at 2 to 3 months after the injury, and upon successful completion, patients were allowed to return to sport.^{11,13,20}

The National Collegiate Athletic Association Division I quarterback in the case report by Alpert et al² was held from practice for 1 day, modified his repetitions in practice and weight training to reduce triceps and brachialis exercises, and underwent a posterior shoulder stretching program. Treatment details and outcomes of the nonoperatively managed patients are presented in Table 2.

Operative Treatment

The mean duration of symptoms reported by patients before the beginning of any treatment was 6.7 months (range, 1 week to 24 months).^{5,8,10,12,18,19,21,22} Of the 40 patients who underwent surgery, 14 (35.0%) reported a trial of nonoperative treatment that failed because of fracture displacement,¹² persistent nonunion,^{10,21} and continued elbow pain.⁵ The overall mean duration of nonoperative treatment before moving on to surgery was 8.9 weeks (range, 1-20 weeks).^{10,12,19,21} Fujioka et al⁵ reported that their 6 patients failed nonoperative treatment after "several weeks." The remaining 65.0% of patients were managed operatively without implementing a period of nonoperative treatment. Various techniques were used to manage these patients operatively: ORIF using cannulated screws (31/40; 77.5%),^{5,15,19,21} tension band wiring using

TABLE 2
Summary of Nonoperative Outcomes^a

Author (Year)	Duration of Symptoms, Mean (Range), mo	Duration of Nonoperative Treatment, Mean (Range), wk	Time to Radiographic Union, Mean (Range), wk	Time to Symptom Resolution, Mean (Range), wk	Returned to Play	Time to Return to Play, Mean (Range), wk	Complications
Alpert et al ² (2014)	Inconsistent over 36 mo	3	NR	2	Yes	Immediate	No
Hulkko et al ⁷ (1986)	“Several months”	“Several months”	72	NR	Yes	NR	No
Mamane et al ¹¹ (2000)	3	4-6	NR	5	Yes	12	No
Nuber and Diment ¹³ (1992)	2.5 (2-3)	9-13	8.5 (5-12)	NR	Yes	24 (1/2)	No
Schickendantz et al ²⁰ (2002)	0.5-3	12-14	NR	8	Yes (6/7)	NR	No

^aNR, not reported.

Kirschner wires (4/40; 10.0%),^{7,8,12} bone grafting (2/40; 5.0%),^{18,22} fracture site drilling (2/40; 2.5%),¹⁰ and excising of the olecranon tip (1/40; 2.5%)⁷ (Table 3).

Symptom Resolution and Radiographic Union

Symptom resolution was achieved in all nonoperatively treated patients (n = 12) and 97.5% (n = 39) of the operatively treated patients. The operatively treated patient who failed to return to sport attributed it to continued elbow pain.¹⁵ The time to symptom resolution was reported in 9 of the 14 (64.3%) studies; the mean was 20 weeks and 16 weeks for nonoperative and operative treatment, respectively. The time to radiographic union, defined as evidence of fracture healing on radiographs, was reported in 3 patients (25.0%) treated nonoperatively and 28 patients (70.0%) treated operatively. For patients managed nonoperatively, the mean time to radiographic union was achieved at 29.6 weeks (range, 5-72 weeks). For patients treated operatively, the mean time to radiographic union was 14.3 weeks (range, 3.9-56 weeks). In the case series by Paci et al,¹⁵ 2 patients did not have postoperative radiographs, and 2 other patients had postoperative radiographs available only after 6 months postoperatively and therefore were excluded.

Return to Sport

Of the 52 patients included in this review, 50 were able to return to play; 1 patient treated nonoperatively was lost to follow-up and was unable to confirm returning to play, and the other patient was unable to return because of unresolved pain after operative treatment.^{15,20} For the 11 patients managed nonoperatively, only 2 patients (18.2%) reported a time to return to sport at a mean of 16.0 weeks (range, 12-24 weeks).^{11,13} The patient in the case report by Alpert et al² was held out of practice for 1 day and modified his weight training for 3 weeks; however, he became asymptomatic within 2 weeks. He finished training camp and played 10 games that season without further

symptoms.² All nonoperatively managed patients returned to the same preinjury competition level.

In the operative group of 40 patients, 31 (77.5%) reported their return to sport at a mean of 25.7 weeks (range, 8-50 weeks). Imade et al⁸ reported that their patient was allowed to return to full strength pitching 3 months after surgery; however, they failed to specify when the patient was able to return to competitive sport. One patient in the case report by Kvidera and Pedegana¹⁰ sustained 2 separate traumatic falls on the postoperative elbow after removal of the cast. The authors stated that this may have led to a prolonged recovery period and a 20% deficit in elbow extension 3 months later. Six weeks after discovery of the deficit, extension was fully resolved, and the patient was able to return to sport.¹⁰ Overall, 29 (72.5%) of the 40 patients returned to the same preinjury competition level; of the remaining patients, 9 (22.5%) returned to a competition level above their preinjury level. For 1 patient who returned to sport, the level of competition was not reported.²²

Complications

There were 9 reported complications, resulting in an overall complication rate of 17.3%. Two patients in the case series by Rettig et al¹⁹ had symptoms related to hardware leading to hardware removal at 3 (screws) and 35 (tension band wires) months postoperatively. The nature of the symptoms was not reported; however, both patients achieved symptom resolution after the removal of hardware. Six patients in the case series by Paci et al¹⁵ required hardware removal; in 2 of these patients, the hardware was removed because of an infection. Both patients who developed an infection were treated with irrigation and debridement, 6 weeks of intravenous vancomycin, and delayed hardware removal after fracture union. Both infections resolved completely, and the patients returned to play at a mean of 27 weeks. It was not reported why the remaining 4 patients in this case series required hardware removal. In the case report by Hulkko et al,⁷ 1 patient experienced

TABLE 3
Summary of Operative Outcomes^a

Author (Year)	Treatment Details	Unsuccessful Nonoperative Treatment	Duration of Unsuccessful Treatment, Mean (Range), wk	Duration of Symptoms, Mean (Range), mo	Time to Radiographic Union, Mean (Range), wk	Time to Symptom Resolution, Mean (Range), mo	Returned to Play	Mean Time to Return to Play, Mean (Range), wk	Complications
Fujioka et al ⁵ (2012)	Double-threaded cannulated screw (double-threaded Japan screw) ^b	Yes	“Several weeks”	6.8 (0.5-16)	NR	NR	Yes	21.3 (16-24)	No
Hulkko et al ⁷ (1986)	Tension band and 2 Kirschner wires (2/3), removal of olecranon tip (1/3)	No	—	2.25 (0.75-4)	16 (1/3)	3 (1/3)	Yes	NR	Ulnar nerve impingement (1/3)
Imade et al ⁸ (2011)	Cable pin system ^c	No	—	2	52	3	Yes	NR ^d	No
Kvidera and Pedegana ¹⁰ (1983)	Drilling	Yes (1/2)	4	12.1 (0.25-24)	7 (1/2)	NR	Yes	NR	No
Nakaji et al ¹² (2006)	Tension band and 2 Kirschner wires	Yes	1	1.25	11	4	Yes	16	No
Paci et al ¹⁵ (2013)	Single cannulated titanium screw	NR	—	NR	10.9 (3.9-17.9)	NR	Yes (17/18)	29 (8-50)	Symptomatic hardware removal (6/18), infection (2/6) No
Pavlov et al ¹⁸ (1981)	Bone grafting	NR	—	24	12	NR	Yes	NR	No
Rettig et al ¹⁹ (2006)	Cannulated compression screw, ^e 13-mm stainless steel washer and figure-of-8 tension band with 18-gauge wire	Yes (4/5)	13 (8-20)	4.5 (0.25-18)	15.4 (6.1-33)	2.75 (7.7-13.6)	Yes	29.4 (18.9-40.4)	Symptomatic hardware removal (2/5)
Suzuki et al ²¹ (1997)	Titanium screw and 2 iliac bone pegs	Yes	7 (6-8)	1.5 (1-2)	10 (8-12)	4 (1/2)	Yes	20 (16-24)	No
Torg and Moyer ²² (1977)	Bone grafting	No	—	24	56	13	Yes	NR	No

^aNR, not reported.

^bMeira.

^cZimmer.

^dAllowed full pitching at 3 months.

^eSynthes.

increasing pain in the medial aspect of the elbow. As such, the patient underwent a second surgical procedure to release a constricted ulnar nerve 10 months postoperatively. His symptoms resolved, and he subsequently participated in the Olympic Games the same year.

Revision Surgery

A total of 3 patients (5.8%) required additional surgery related to fracture displacement or refracture of the stress

injury after the initial operative treatment. One patient (1.9%) had initial acute displacement of his stress fracture after diving for a ball during a game and required emergent surgery with ORIF using Kirschner and tension band wires. Two weeks later, the fracture displaced, and the patient required revision surgery, during which the Kirschner wires were replaced by a 7-mm screw.¹⁹ The patient had delayed union of the fracture, with complete union at 33 weeks.

The patient in the case report by Nakaji et al¹² was initially treated with Kirschner and tension band wires that

were removed after the confirmation of bone union at 11 weeks postoperatively. However, the patient complained of re-emerging pain in the posterior and lateral aspects of the elbow 1 year after the initial surgery. A small, undisplaced fracture line was detected on imaging, thought to be recurrence of the stress fracture. The patient underwent revision surgery using Acutrak (Acumed) 4.5-mm screw fixation. The patient was not immobilized with a cast and started rehabilitation for active range of motion 1 day after surgery. The patient returned to competitive baseball without further symptoms 8 weeks after surgery, and radiographic union was confirmed 4 months postoperatively.¹²

One patient in the case report by Hulkko et al⁷ was initially treated with a tension band and Kirschner wire fixation that was removed 12 weeks postoperatively. She began feeling slight pain in the elbow and was diagnosed with a refracture of the stress injury. The second surgical procedure was 13 months after the index procedure and involved a compression screw and 2 bone pegs placed across the fracture line. The screw was removed 4 months later, and the patient achieved radiographic union and returned to sport 8 months postoperatively.⁷

DISCUSSION

Stress fractures of the elbow are rare injuries that can pose challenges for management and rehabilitation in throwing athletes. This systematic review of 14 studies and 52 patients found that the olecranon was the most common site of stress fractures and that the majority of these were treated operatively, with over one-third of patients failing nonoperative treatment beforehand. The return-to-sport rate was high with both operative and nonoperative management, with the latter having the advantage of no complications. Overall, these patients did well regardless of which management option was employed, although a good proportion may have required surgery after failed nonoperative treatment. However, much of this evidence needs to be interpreted with caution, as the number of studies reviewed was relatively few.

There are limitations to this study. First, the number of studies and patients was small. This obviously limits the strength and generalizability of our results, but to describe such a rare problem, a systematic review is the best way to assimilate the limited data and give meaningful conclusions. Second, all the studies examined were retrospective case reviews and case reports, which have inherent limitations regarding quality of the data. Again, this simply reflects the limited reports of this rare injury. The studies were heterogeneous, namely with differing sports and locations of the stress fractures reported. As such, this introduces confounders and limits the generalizability of the results. Last, subjectivity may have resulted in the exclusion of some studies, but this was minimized by grading the studies on the level of evidence using a systematic approach and 2 reviewers.

Furushima et al⁶ classified stress fractures of the olecranon into 5 categories based on the origin and direction of the fracture plane: physeal (mean age of onset [MAOO],

14.1 years), classic (MAOO, 18.6 years), transitional (MAOO, 16.9 years), sclerotic (MAOO, 18 years), and distal (MAOO, 19.6 years). The likelihood of falling into 1 of the 5 classifications of olecranon stress fractures is heavily dependent on the age of the patient at symptom onset, primarily whether the stress fracture occurs before or after maturation of the epiphyseal plate. Surgical treatment is indicated in physeal (stages 3 and 4), classic, transitional, and distal types after approximately 3 months of nonoperative treatment. Surgery is not recommended in sclerotic types of olecranon stress fractures. Unfortunately, the applicability of the classification system to this systematic review was not possible; however, future use of this classification system could be beneficial for an approach to treatment of the different types of olecranon stress fractures.

Nonoperative treatment was initiated after a mean duration of symptoms of 2.8 months, much shorter than the 6.7 months reported for operative management. Once again, this may relate to less severe symptoms managed by the athletic trainers, ultimately leading to radiographs and presentation. These patients may simply be the group that presented earlier and were thus directed down the formal nonoperative route and given more time for healing.

The current study has shown that the majority of elbow stress fractures are managed operatively, although there can be a lengthy duration of symptoms beforehand. Presumably, these adolescents are managed with rest and routine treatment upon symptom onset, which are not too severe, and once persistent, radiographs are taken. Even at this stage, these may be negative and thus further delay the time to diagnosis and surgery. Related to this, a trial of nonoperative treatment was documented in over one-third of patients, and one would presume this proportion was higher, particularly given the high complication rate observed (17.3%) in the operatively treated patients. A possible explanation is that many of the remaining two-thirds of patients already had chronic symptoms upon presentation and had exhausted nonoperative measures. In addition to continued pain, nonunion and fracture displacement were cited as indications for surgery despite a mean of 8.9 weeks of nonoperative treatment.

Nakaji et al¹² reported initial nonoperative treatment in their case report; however, 1 week after presentation, the patient returned for an examination, and follow-up radiographs demonstrated that fracture displacement occurred. Therefore, operative treatment occurred at this time. Suzuki et al²¹ also reported initial nonoperative management in their 2 patients, but after no evidence of fracture healing at 6 and 8 weeks, respectively, operative management was performed. Mamanee et al¹¹ noted that stress lesions of the medial elbow physis can commonly be treated successfully with just rest, with healing typically around the 6- to 8-week time point depending on the degree of fracture. While the results of these studies demonstrate some guidance, establishing a definitive time frame for when nonoperative treatment has failed and surgery becomes necessary requires further examinations in this patient population. Surgical techniques varied but predominantly utilized ORIF with cannulated screws in over three-fourths of the patients. Overall, surgical management of

these patients is common but is usually initiated after a prolonged period of symptoms and/or a trial of nonoperative management.

The rate of symptom resolution was very high, comprising all patients treated nonoperatively and all but 1 patient treated operatively. This 1 patient complained of persistent elbow pain and consequently did not return to sport. Overall, the time to symptom resolution (a key marker for clinical union) was relatively similar between both treatment modalities, with nonoperative being slightly longer at 20 weeks versus 16 weeks for operative. The time to radiographic union was less well reported, especially in the nonoperatively treated patients; when reported, the time was nearly twice as long compared with the operatively treated patients (29.6 vs 14.3 weeks, respectively). Similar to symptom resolution, this is often the case for fractures in general.¹⁶ As per the results, radiographic union often lags behind clinical union, and the former tends to be more subjective, despite various definitions based on the presence of cortical bridging and a lack of a radiolucent line.¹⁶ Practically speaking, time to healing is a combination of both parameters, which in turn influence rehabilitation and return to sport.

The return-to-sport rate after elbow stress fractures was high, irrespective of the treatment modality. In fact, all those treated nonoperatively returned except for 1 patient lost to follow-up. Interestingly, the time to return to sport was much longer in the operatively treated patients, at a mean of 25.7 weeks, compared with the nonoperatively treated patients, at 16.0 weeks. Once again, few studies reported a time to return to sport, especially in the nonoperatively treated patients, thus limiting any interpretations that can be made. This is contrary to the findings of symptom resolution and particularly radiographic union, both being longer in the nonoperatively treated patients. Possible explanations include very few nonoperatively treated patients with reported return-to-sport details, return to sport in operatively treated patients potentially delayed by complications, operatively treated patients needing further surgery, and added caution from athletes, parents, and surgeons to participate in sporting activity. Moreover, 50 patients (96.2%) returned to at least their preinjury level of sport, with almost one-fourth of those treated operatively returning to a higher level, which indicates the resolution of chronic symptoms in this group that may have been limiting their performance.

The complication rate was high at 17.3%, and all occurred after surgery. Issues with hardware requiring removal was most common (15.4%); where reported, these issues included painful irritation and infections. The former resolved completely on removal, and the latter were also eradicated after removal, debridement, and antibiotic therapy. Other studies have shown even higher (7/12 patients; 58.3%) hardware removal rates for prominence and irritation after screw and washer fixation for medial epicondyle fractures but none for removal of a screw alone, highlighting the importance of the type of hardware used.¹⁴ Boulos et al³ examined pediatric hardware removal after fracture fixation in 2536 patients and found that infections

(32%), mechanical failure (25.4%), and pain (13%) were the most common indications.

Two patients had persistent elbow pain, which in 1 case had no obvious cause and precluded a return to sport as mentioned earlier and in the other warranted ulnar nerve release, which resulted in symptom resolution and return to sport. Three patients required revision fixation: 1 for fracture displacement from noncompliance during rehabilitation and the other 2 for refractures about a year after the primary surgery. Compliance with rehabilitation must be reiterated to patients, athletic trainers, and parents alike. A refracture can occur after nonoperative and operative treatment, and there is a variable risk period after the removal of hardware of approximately 6 to 12 weeks.³ It is unusual for these to occur a year later, and the ones reported^{7,12} may have been caused by an occult lack of union or simply recurrence from overuse.

CONCLUSION

Stress fractures of the elbow in adolescent throwers are rare injuries, most commonly affecting the olecranon and distal humerus. They are challenging to manage, and treatment can be nonoperative or operative, both of which can lead to return to sport at preinjury levels or better. Nonoperative management requires a longer time for symptom resolution and radiographic union but avoids the risk of complications of surgery. A subset of these patients fails nonoperative treatment and requires subsequent surgery. Surgery is performed in most patients, but there is a high risk of complications, notably requiring the removal of hardware, thus further delaying rehabilitation and return to sport. There are few studies in the literature on this topic, with limited patient numbers, and as such, larger prospective studies are required.

REFERENCES

1. Ahmad C, ElAttrache N. Valgus extension overload syndrome and stress injury of the olecranon. *Clin Sports Med*. 2004;23(4):665-676.
2. Alpert J, Flannery R, Epstein R, Monaco R, Prendergast N. Humeral stress edema: an injury in overhead athletes quarterback with humeral "shin" splints. A case report. *Clin J Sport Med*. 2014;24(5):e59-e61.
3. Boulos A, DeFroda S, Kleiner J, Thomas N, Gil J, Cruz A. Inpatient orthopaedic hardware removal in children: a cross-sectional study. *J Clin Orthop Trauma*. 2017;8(3):270-275.
4. Cain EL, Dugas JR, Wolf RS, Andrews JR. Elbow injuries in throwing athletes: a current concepts review. *Am J Sports Med*. 2003;31(4):621-635.
5. Fujioka H, Tsunemi K, Takagi Y, Tanaka J. Treatment of stress fracture of the olecranon in throwing athletes with internal fixation through a small incision. *Sports Med Arthrosc Rehabil Ther Technol*. 2012;4:49.
6. Furushima K, Itoh Y, Iwabu S, Yamamoto Y, Koga R, Shimizu M. Classification of olecranon stress fractures in baseball players. *Am J Sports Med*. 2014;42(6):1343-1351.
7. Hulkko A, Orava S, Nikula P. Stress fractures of the olecranon in javelin throwers. *Int J Sports Med*. 1986;7(4):210-213.
8. Imade S, Matsuura Y, Nishi H, Uchio Y. Olecranon stress fracture in an adult baseball pitcher: a case report. *Curr Orthop Pract*. 2011;22(4):379-381.

9. Iwamoto J, Takeda T. Stress fractures in athletes: review of 196 cases. *J Orthop Sci.* 2003;8(3):273-278.
10. Kvidera DJ, Pedegana LR. Stress fracture of the olecranon: report of two cases and review of the literature. *Orthop Rev.* 1983;12:113-116.
11. Mamanee P, Neira C, Martire JR, McFarland EG. Stress lesion of the proximal medial ulna in a throwing athlete: a case report. *Am J Sports Med.* 2000;28(2):261-263.
12. Nakaji N, Fujioka H, Tanaka J, et al. Stress fracture of the olecranon in an adult baseball player. *Knee Surg Sports Traumatol Arthrosc.* 2006;14(4):390-393.
13. Nuber GW, Diment MT. Olecranon stress fractures in throwers: a report of two cases and a review of the literature. *Clin Orthop Relat Res.* 1992;(278):58-61.
14. Pace GI, Hennrikus WL. Fixation of displaced medial epicondyle fractures in adolescents. *J Pediatr Orthop.* 2017;37(2):e80-e82.
15. Paci JM, Dugas JR, Guy JA, et al. Cannulated screw fixation of refractory olecranon stress fractures with and without associated injuries allows a return to baseball. *Am J Sports Med.* 2013;41(2):306-312.
16. Patel N, Beckles V, Calder P. Complications of fracture healing. In: Dawson-Bowling S, Achan P, Briggs T, Ramachandran M, eds. *Orthopaedic Trauma: The Stanmore and Royal London Guide.* Boca Raton, Florida: CRC Press; 2014; 44-59.
17. Patel RM, Lynch TS, Amin NH, Calabrese G, Gryzlo SM, Schickendantz MS. The thrower's elbow. *Orthop Clin North Am.* 2014;45(3):355-376.
18. Pavlov H, Torg JS, Jacobs B, Vigorita V. Nonunion of olecranon epiphysis: two cases in adolescent baseball pitchers. *AJR Am J Roentgenol.* 1981;136:819-820.
19. 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(4):653-656.
20. Schickendantz MS, Ho CP, Koh J. Stress injury of the proximal ulna in professional baseball players. *Am J Sports Med.* 2002;30(5):737-741.
21. Suzuki K, Minami A, Suenaga N, Kondoh M. Oblique stress fracture of the olecranon in baseball pitchers. *J Shoulder Elbow Surg.* 1997;6(5):491-494.
22. Torg JS, Moyer RA. Non-union of a stress fracture through the olecranon epiphyseal plate observed in an adolescent baseball pitcher: a case report. *J Bone Joint Surg Am.* 1977;59(2):264-265.
23. Wong TT, Lin DJ, Ayyala RS, Kazam JK. Elbow injuries in pediatric overhead athletes. *AJR Am J Roentgenol.* 2017;209(4):849-859.