

Outcome of surgical management of stress fractures in high demand individuals

ABSTRACT

Stress fractures represent one-fifth of overuse injuries in sport. Successful healing of stress fractures in high demand individuals is important to prevent complications upon early return to activity. This article reviews the literature on outcomes of surgical management of stress fractures in high demand individuals.

An online literature search was carried out for articles published up to and including January 2017. Twenty five papers were reviewed. In the majority of studies, no complications were reported, clinical and radiographic healing was achieved, and patients returned to their premorbid level of activity.

Current literature suggests good outcomes after surgical management of stress fractures in high demand individuals, particularly those in whom conservative treatment has failed. Further studies comparing surgical techniques are necessary to demonstrate the most efficacious.

Stress fractures are repetitive use injuries common in military populations and athletes of all levels (Jacobs et al, 2014). Recurrent strains cause material fatigue and microarchitectural discontinuities that end in fractures, which may be partial or complete (McInnis and Ramey, 2016). Stress fractures represent approximately 20% of overuse injuries in sports, more commonly reported in women, dancers, runners or field athletes (Moreira and Bilezikian, 2017).

A dynamic balance exists between the accumulation of stress forces, which create micro-damages, and the bone's repair process that is based on a balance of osteoclastic resorption and osteoblastic synthesis (Shindle et al, 2012). This balance is altered by intrinsic (individual characteristics) and extrinsic factors that can lead to stress fractures without adequate rest. Intrinsic factors include metabolic state, menstrual patterns, bone structure, conformation and vascularity, and level of fitness, while extrinsic factors include diet, training regimen, shoes and

type of athletic surface (Shindle et al, 2012). This repeated submaximal stress is less than the maximum tolerated, but repetitive application generates a disruption in bone homogeneity (Fredericson et al, 2006).

A true stress fracture is defined by cortical disruption, and it is often detected as a stress reaction on a magnetic resonance imaging or radionuclide bone scan (Kaeding and Najarian, 2010). The most common sites involved are the carpal scaphoid, femoral neck, anterior tibia, patella, medial malleolus, proximal fifth metatarsal and great toe sesamoids (McInnis and Ramey, 2016).

Stress fractures represent a real challenge to athletes, with time off training ranging from weeks to months (Varner et al, 2005) depending on the location of the fracture and its treatment. In the athletic population the major risks are delayed union or non-union which may occur if the athlete goes back to training or the field before a complete union of the stress fracture is achieved (Boden and Osbahr, 2000). In these high-demand patients, when initial conservative treatment has failed, surgical intervention may be necessary for early return to sport.

This review evaluates the current evidence regarding surgical outcomes of stress fracture of the femoral neck, anterior tibia, patella, medial malleolus, proximal fifth metatarsal and great toe sesamoids in elite athletes.

Materials and methods

Search strategy

A literature search was carried out using a computer-based search within Medline (OvidSP), PubMed Database (US National Library of Medicine, National Institutes of Health), Embase, Web of Science, Cochrane and Google Scholar for articles published up to and including January 2017. The search terms used were 'stress fracture', 'surgical outcomes', 'athlete', 'sport', 'femoral neck', 'anterior tibia', 'patella', 'medial malleolus', 'proximal fifth metatarsal', 'great toe sesamoids', and 'carpal scaphoid'.

Eligibility criteria

All publications reporting on the outcomes of surgically treated stress fractures in athletes were included. The following exclusion criteria were applied: articles not in English, publication types other than full-length journal articles, case series involving fewer than five patients, cadaveric and in vitro studies.

Identification of eligible studies

One author (AV) assessed each abstract to identify relevant studies; articles were excluded if the abstract was unavailable.

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The search resulted in 2571 articles with abstracts available. Titles and abstracts were reviewed and after the removal of 869 duplicates, 1702 articles were extracted for review in further detail. At the end of the process, 25 relevant papers were identified; *Figure 1* summarizes this process.

Quality assessment

Two authors (AR and CM) calculated a Coleman methodology score, a quality scoring system validated in the orthopaedic literature, for each paper (Coleman et al, 2000). A perfect score of 100 signifies a study that minimizes the influence of bias and confounding factors.

Data extraction

Data were compiled in an Excel document and consisted of the pathology, study design, number of patients, indication for surgical management, surgical technique, male:female ratio, and outcomes. Outcome measures included time to return to sports and daily activities, delayed and non-union rates, functional scores, complications, and patient satisfaction.

Statistics

When comparing pooled data on different outcomes from different surgical techniques 2x2 contingency tables were produced and Fisher's exact test was performed using GraphPad.

Results

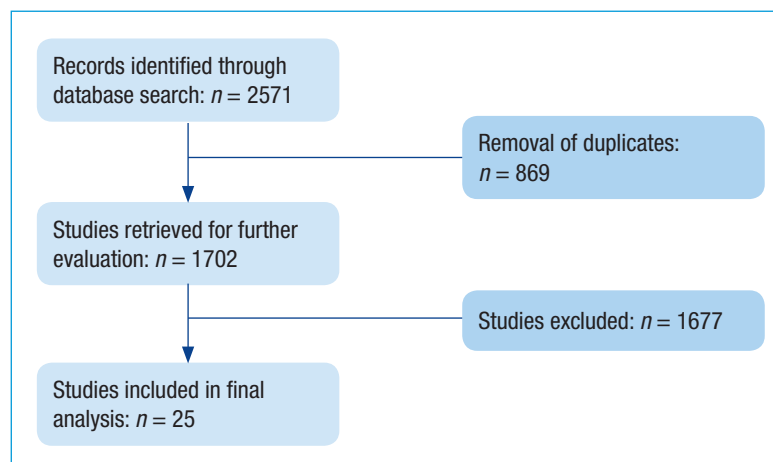
A total of 25 studies reported on the surgical outcomes of stress fractures in high demand individuals. The number of patients in individual papers ranged from five to 53; the total included in this review is 476. All relevant papers reporting on carpal scaphoid stress fractures were case studies and so were excluded. The average Coleman score was 54.5, indicating generally poor methodological quality; the highest scores were in the categories 'description of rehabilitation' and 'description of subject selection', while the lowest scores were in the categories 'mean follow up' and 'study size'. The features of each study are included in *Table 1* which is available as an appendix at www.bjhm.co.uk.

Femoral

Seven papers included data on the outcome of surgical management of femoral stress fractures in young active patients. The average Coleman score was 49. Several methods of fixation were reported including dynamic hip screw (Visuri et al, 1988; Johansson et al, 1990; Lee et al, 2003; Talbot et al, 2006; Evans et al, 2012), and cancellous screws (Lee et al, 2003; Chalupa et al, 2016). Dynamic hip screws were used successfully with patients returning to sport in 12 months in one example (Evans et al, 2012), and fracture healing occurring in an average of 7 weeks in another study (Bhatnagar et al, 2015).

Lee et al (2003) examined the outcomes from 17 cases of dynamic hip screw fixation *vs* 25 cases fixed with multiple

Figure 1. Flow chart showing identification of relevant studies.



cannulated screws. Seven of the 25 patients (28%) treated with cannulated screws developed avascular necrosis of the femoral head compared to three of the 17 patients (17.6%) with dynamic hip screw fixations. Of both groups 30 (71.4%) had good functional outcomes, four (9.5%) had acceptable and eight (19%) had poor results. Of the 42 fractures 36 united successfully with six showing delayed union.

Cannulated screw use was reported by Chalupa et al (2016). A higher percentage (66%) of patients returned to active duty, compared to conservatively managed patients (48%). However, surgical patients had significantly worse fracture appearances on magnetic resonance imaging and worse pain scores.

Effect of time to diagnosis

Lee et al (2003) noted that the incidence of avascular necrosis of the femoral head increased with increasing time between fracture displacement and fixation. The mean duration between fracture and surgery was significantly longer in patients with avascular necrosis of the femoral head (5.9 days) than in patients without avascular necrosis (1.9 days) ($P < 0.05$). Visuri et al (1988) also noted that only one case had same day surgical fixation and this case had a good outcome following this.

Comparing dynamic hip screws with cannulated screws

Several studies included multiple patients and sufficient detail on operative procedure and outcomes to compare different methods of fixation. However, these studies remain small with significant heterogeneity in patient demographics. Comparing the four studies with sufficient data, 34 patients were treated with dynamic hip screws. Of these, 24 (70.6%) had good outcomes defined as successful union and return to pre-injury activity, while 10 had poor outcomes, the most common reason for this being progressive avascular necrosis of the femoral head, occurring in eight cases (Visuri et al, 1988; Lee et al, 2003; Evans et al, 2012). In comparison, cannulated

screws when used in 29 hips had a good outcome in 22 cases (75.8%). Using Fisher's exact test, there was no significant difference between the method of fixation used and outcome ($P=0.778$).

Anterior tibial

Three papers reported results of the surgical treatment of anterior tibial fractures. The average Coleman score was 52.7 and either intramedullary nailing (Chang and Harris, 1996; Varner et al, 2005) or tension band plating (Zbeda et al, 2015) was used.

While intramedullary nailing is the traditional treatment, tension banding is a newer alternative. Tension plates fitted to the tibia are further from the central axis of the bone giving them a mechanical advantage opposing the forces involved in stress fractures. Of note, tension banding has been successful in revision cases following intramedullary nailing (Zbeda et al, 2015).

Chang and Harris (1996) demonstrated the use of closed, reamed intramedullary nailing of the tibia with the Russell-Taylor system (Smith and Nephew Richards, Memphis, Tennessee). Five military recruits presented with anterior tibial stress fractures recalcitrant to conservative management; there were no perioperative complications and patients all subjectively reported good or excellent functional results. Varner et al (2005) reported on 11 anterior tibial stress fractures that failed conservative management and underwent intramedullary nailing. Clinical union was achieved in a mean of 2.7 months, and radiological union at 3 months. All patients returned to sports within 4 months on average.

Tension band plating was described by Zbeda et al (2015), who reported the results of treatment of 12 athletes. All had failed conservative management and two had previously failed intra-medullary nailing. A locking compression plate was applied to the anterolateral aspect of the tibia and tension was applied across the fracture. BioHorizons Grafton demineralized bone matrix Flex was also packed into the fracture site both before and after. Bone union occurred an average of 9.6 weeks postoperatively (range 5.3–16.9 weeks), patients returned to training after 11.1 weeks on average (range 5.7–20 weeks), and 11 of the 12 patients returned to pre-injury levels of competition. One patient remained symptomatic despite complete union; later testing revealed that this patient had a nickel allergy. After removal of metalwork and revision with intramedullary nailing, this patient has yet to return to competition.

Comparison of surgical techniques

Of the papers that included sufficient detail and patient numbers, the 16 patients who underwent intramedullary nailing reported good outcomes, complete union, symptom resolution and return to pre-injury function. Good outcomes were reported in 12 of the 13 patients treated with anterior compression plates. There was no significant difference between the outcomes and the method of fixation

used ($P=0.448$). It should be noted that in several cases anterior compression plating was used following a failure of fracture healing after intramedullary nailing.

Patella

One paper reported on the outcome of surgical management of transverse and longitudinal (Orava et al, 1996) patella stress fractures in athletes; the Coleman score was 50. The indications for surgical management were non-union after conservative treatment, and delayed diagnosis after symptom onset.

Orava et al (1996) reported good results in all patients in a case series of five, following drilling of the fracture line with metal wire cerclage fixation, excision of the lateral fragment, and bone grafting with K wires and cerclage compression. The group who underwent drilling with wire fixation returned to activity the most quickly, with training 2–3 months after surgery. All patients returned to normal activity symptom free within 33 months of the fracture, and no complications were reported. Operative treatment seems a viable option in athletes for whom conservative treatment has failed or is not viable; however, despite the rarity of this type of stress fracture, larger studies are needed.

Medial malleolus

Four papers reported on medial malleolus stress fractures. The average Coleman score was 53.8. Indications for surgery included failure of conservative treatment (Shelbourne et al, 1988), delayed healing (Orava et al, 1995), delayed diagnosis (Lempainen et al, 2012), displacement (Orava et al, 1995), and desire to return quickly to sport (Shelbourne et al, 1988).

One case series reported outcomes of percutaneous fixation with cannulated screws (Jowett et al, 2008). Fracture union took on average 10.2 weeks (range 6–16 weeks), and on final follow up Ogilvie–Harris scores were rated 'good' or 'excellent' for all. Postoperative stiffness was seen in three out of five patients and managed successfully with hydrodilatation or physiotherapy. Two studies that examined the outcomes of osteosynthesis with AO screws reported a return to activity in all patients (Orava et al, 1995; Lempainen et al, 2012). Radiographic healing took on average 5 months (range 3–7 months) from diagnosis (Orava et al, 1995). One patient was unable to return to full sports activity (Lempainen et al, 2012).

Three patients treated with open reduction internal fixation using two 4 mm cancellous screws returned to sports without complications between 4 and 8 weeks after surgery (Shelbourne et al, 1988). It seems that while conservative treatment is suitable for uncomplicated stress fractures diagnosed early, operative treatment allows faster return to sports.

Proximal fifth metatarsal

Six papers reported on the outcomes of proximal fifth metatarsal stress fractures after surgery. The average Coleman score was 60. Indications for surgery included

unsatisfactory healing after conservative (Porter et al, 2005; Sarimo et al, 2006) or surgical management (Sarimo et al, 2006), symptomatic delayed union or non-union (Torg et al, 1984), and patients' choice (Porter et al, 2009).

Surgical methods included intramedullary fixation with a 4.5 mm AO malleolar screw (Pecina et al, 2011), fixation with cannulated stainless steel screws (Porter et al, 2005, 2009), tension band wiring techniques (Sarimo et al, 2006; Lee et al, 2011), and bone grafting and medullary cuttillage (Torg et al, 1984). Return to sports was reported from 14.7 weeks after tension band wiring (Sarimo et al, 2006) to 9 months after intramedullary fixation (Pecina et al, 2011). Despite the longer break from sports, Pecina et al reported that 60% of patients completed a higher level of training than before their injury. At 10.3 years, the mean American Orthopaedic Foot and Ankle Score was 93.8.

Porter et al (2009) compared 4.5 mm and 5.5 mm cannulated stainless steel screw fixation. No differences in functional outcomes were reported although three patients in the 5.5 mm group sustained a refracture. Despite this the 5.5 mm screw was recommended by the authors as it is less prone to bending.

Fractures healed radiographically between 4 weeks following intramedullary fixation (Pecina et al, 2011) and 12.8 weeks following tension band wiring (Sarimo et al, 2006). Lee et al (2011) noted that all fractures with delayed or non-union at 12 weeks after tension band wiring were Torg's type II. All methods produced complications, including vague foot discomfort (Torg et al, 1984), a minor episode of neuralgic pain (Sarimo et al, 2006), and refracture following both intramedullary fixation (Pecina et al, 2011) and modified tension band wiring (Lee et al, 2011).

There does not appear to be a notable difference in outcomes between screw fixation and tension band wiring.

Great toe sesamoid

Four studies reported on the outcomes of great toe sesamoid stress fractures after surgical management. The average Coleman score was 58.5. The indication for surgery was failed conservative treatment for between 3 months (Biedert and Hintermann, 2003) and 7 months (Anderson and McBryde Jr, 1997).

Saxena et al (2003) compared the outcomes of tibial and fibular sesamoidectomies. Fibular sesamoidectomy through a plantolateral incision resulted in the fastest return to activity at 7.3 weeks. The group found that patients defined as 'athletic' returned to sport at 7.5 weeks compared to 12 weeks for those described as 'active'; the difference was significant. Other studies reported a return to sport at 6 months after surgical excision, with mild restriction to full activity in one patient (Biedert and Hintermann, 2003). Anderson and McBryde Jr (1997) reported radiographic union in 90% patients 12 weeks after autogenous bone grafting, with a restriction to full activity in four patients. The average postoperative American Orthopaedic Foot

“ Fibular sesamoidectomy through a plantolateral incision resulted in the fastest return to activity. ”

and Ankle Score hallux score after percutaneous fixation with a Barouk screw and excision of the proximal fragment was 80.7 (Blundell et al, 2002) and 95.3 (Biedert and Hintermann, 2003) respectively. The heterogeneity of outcomes makes direct comparison challenging; however, sesamoidectomy appears most favourable for return to full activity.

Reported complications included hallux varus deformity and neuromas (Saxena and Krisdakumtorn, 2003), plantar fasciitis (Biedert and Hintermann, 2003), mild stiffness (Blundell et al, 2002) and digital neuritis (Anderson and McBryde Jr, 1997).

Discussion

The current literature on the surgical treatments for stress fractures in athletic population is scant.

This article shows that in selected patients with high demand, good results and earlier return to sport activities can be achieved following surgical treatment of stress fractures which has failed conservative management.

Surgical fixation will undoubtedly become increasingly relevant because of the increasing demand by athletes, sport teams and rehabilitators to return to play.

There is still no consensus on how to manage these challenging injuries, but this review suggests best outcomes are achieved when surgical management is considered for failure of at least 6 weeks of conservative management, delayed or non-union, and chronic pain that restricts activity. Additionally, the earlier detection of these injuries via high clinical suspicion is associated with better outcomes after surgery.

This article has several limitations. Many papers included were case reports or small case series with heterogeneity of surgical technique, length of follow up and outcomes scores. There was also often little detail about the fractures themselves and degree of displacement which will clearly affect outcome. The authors found an overall low methodological quality in the articles included based on the results of the Coleman scores. More research in this area is required to establish the best surgical techniques.

Conclusions

For femoral stress fractures dynamic hip screw fixation does not seem significantly different in outcome to cannulated screw fixation but patient selection is important as some will be unsuitable for cannulated screw fixation. For anterior tibial stress fractures, tension banding with plating shows good results with the most important application being revision cases which have failed intramedullary nail fixation. Screw fixation is the best treatment option in the case of medial malleolus stress fractures, while no superiority has been shown between screw and

KEY POINTS

- Stress fractures are a common injury in athletes, but the current literature on surgical management is scarce.
- Good outcomes are necessary to allow a timely return to activity in athletic individuals.
- In the majority of stress fractures, surgical intervention after failure of conservative treatment or other methods results in good outcomes and return to sport with few complications.
- Evidence remains scarce on the rarer types of stress fractures such as carpal scaphoid.

tension band wiring for proximal fifth metatarsal stress fracture. The most efficacious operative technique in the management of patella fractures is yet to be determined because of a lack of data and comparison of treatment outcomes. Sesamoidectomy is the treatment of choice for stress fracture of the great toe sesamoid. **BJHM**

Conflict of interest: none.

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Table 1. Key features extracted from each study

Reference	Bone	No of patients	Surgical technique	Outcomes	Complications	Coleman score
Chalupa et al (2016)	Femoral	53	Percutaneous screw fixation	Two-thirds of surgical patients did not return to full duty, compared to 48% of non-surgical patients ($P=0.266$); not returning was associated with high mean pain scores compared to those who did return	None reported	40
Bhatnagar et al (2015)	Femoral	5	Technique not specified	All patients returned to active training with a mean recovery time of 9 weeks	None reported	35
Evans et al (2012)	Femoral	6	Fixation with 2-holed dynamic hip screw device supplemented in three cases with an anti-rotation screw	All patients returned to rehabilitation within the Royal Marines with some of them going on to complete their training. Two are actively training while two have completed training and a further two have since been medically discharged. There was a mean time until union of 11 months	None reported	47
Lee et al (2003)	Femoral	42	17 treated with compression hip screw and 25 with multiple cancellous screws	Of all patients, 30 had good functional results, four had acceptable and eight had poor results at the end of evaluation. Of the 42 fractures, 36 united successfully and six showed delayed union	Seven of the patients treated with multiple cancellous screws and three of the patients treated with compression hip screw developed avascular necrosis of the femoral head	61
Talbot et al (2008)	Femoral	20	Surgical fixation	The medical discharge rate remained high at 40%, despite rehabilitation	One out of three patients with a displaced fracture develop avascular necrosis of the femoral head	47
Johansson et al (1990)	Femoral	23	Internal fixation	One patient reported excellent results, 13 reported good, and nine reported bad or fair. All elite level athletes were forced to stop competing	Seven patients developed complications that required major surgery: pseudarthrosis in one, avascular necrosis in three and re-fracture in three	67
Visuri et al (1988)	Femoral	12	Sliding hip compression screw used in 10 patients, Jewett nail in one, and 130° angled A0 plate in one	Acceptable results were achieved in six cases	Avascular necrosis of the femoral head occurred in five patients; in one case this was associated with permanent handicap. Delayed union in one case was treated with bone graft and siding compression screw	51
Varner et al (2005)	Anterior tibial	7	Reamed intramedullary nail	Clinical union achieved at a mean of 2.7 months and radiological union was achieved at a mean of 3 months. All patients were satisfied and returned to sporting activities within a mean of 4 months	Bursitis in one patient	56
Chang and Harris (1996)	Anterior tibial	5	Closed, reamed intramedullary nailing of the tibia using the Russell-Taylor system.	Each patient reported a good result except two who had excellent results. Patients were able to participate in recreational sports, to function at an activity level higher than that preoperatively, and described no limitations in daily activity	Mild peripatellar or patellar tendon pain was the most common symptom within the first 6 months postoperatively. Two patients reported significant discomfort over the screws that limits significant athletic activity	57
Zbeda et al (2015)	Anterior tibial	12	Tension band plating	Fracture union occurred on average at 9.6 weeks (5.3–16.9 weeks) postoperatively, and patients commenced training on average at 11.1 weeks (5.7–20 weeks)	Five patients underwent removal of the hardware as a result of plate prominence A nickel allergy caused persistent symptoms in one patient	51

Table 1. Key features extracted from each study (continued)

Reference	Bone	No of patients	Surgical technique	Outcomes	Complications	Coleman score
Orava et al (1996)	Patella	5	Drilling through fracture line with metal cerclage fixation	All patients were able to continue their sports without any symptoms	None reported	50
Shelbourne et al (1988)	Medial malleolus	6	Open reduction internal fixation with two 4.0 mm cancellous screws	Patients returned to full activity between 4 and 8 weeks	None reported	57
Jowett et al (2008)	Medial malleolus	5	Percutaneous cannulated screw fixation and ankle arthroscopy	All fractures united, at an average of 10.2 weeks (6–16 weeks), and all patients returned to their pre-injury level of activity	Postoperative stiffness in three patients; treated in one with physiotherapy and two with hydrodilatation	59
Lempainen et al (2012)	Medial malleolus	10	Compression osteosynthesis with two 4.0 mm cancellous compression screws	Nine patients returned to pre-injury level of activity between 3 and 5 months. The remaining patient was asymptomatic in day-to-day life	None reported	47
Orava et al (1995)	Medial malleolus	8	Osteosynthesis with A0 screws; oblique drilling of the medial malleolus	All patients returned to pre-injury level of activity with no recurrences. Average time to radiographic healing was 5 months (3–7 months) from time of diagnosis	None reported	52
Pecina et al (2011)	Proximal fifth metatarsal	20	Intramedullary fixation	60% of patients returned to a higher level of training, 35% to the same level, and 5% to a lower level. Return to sports took an average of 9 weeks (5–14 weeks). The average American Orthopaedic Foot and Ankle score at 10.3 years' follow up was 93.8 (85–100) and clinical healing was 95%	One re-fracture occurred as a result of full return to activity despite medical advice	60
Lee et al (2011)	Proximal fifth metatarsal	42	Modified tension band wiring technique	Average time to radiographic union was 75 days (40–150 days). Four patients had delayed union at 12 weeks and one patient had non-union at 3 months; all were Torg's type II fractures	Refracture in four patients; three with a Torg's type I and one with a Torg's type III fracture	56
Porter et al (2009)	Proximal fifth metatarsal	43	5.5 mm cannulated screw vs 4.5 mm partially threaded, cancellous cannulated stainless steel screw fixation	No differences in clinical outcomes between 4.5 mm and 5.5 mm screw groups. At final follow up, all fractures were clinically healed	Three patients in the 5.5 mm group suffered a re-fracture shortly after surgery. Minor nerve sensitivities that lasted under 1 month and did not affect rehabilitation	57
Sarimo et al (2006)	Proximal fifth metatarsal	27	Tension-band wiring technique	Return to full activity took on average 14.7 weeks (8–20 weeks), and all patients achieved this	One patient suffered minor neuralgia pain in lateral foot which resolved within the 2-year follow up	53
Porter et al (2005)	Proximal fifth metatarsal	23	Fixation with 4.5 mm cannulated screw	All athletes returned to sport at an average of 7.5 weeks (10 days–12 weeks) and all fractures healed clinically	None reported	69

Table 1. Key features extracted from each study (continued)

Study	Bone	No of patients	Surgical technique	Outcomes	Complications	Coleman score
Torg et al (1984)	Proximal fifth metatarsal	43	Medullary curettage and bone grafting	19 of 20 surgically treated fractures healed, clinically and roentgenographically, at a mean of 12.3 weeks (12–16 weeks)	One persistent non-union that was asymptomatic at follow up	66
Saxena and Kridakumtorn (2003)	Great toe sesamoid	24	Tibial sesamoidectomy through a midline medial or dorsomedial incision, or fibular sesamoidectomy through a dorsolateral or planterolateral linear incision	Fibular sesamoidectomies excised planterolaterally had the shortest return to activity of 7.3 weeks, followed by medial tibial sesamoidectomy in 10 weeks and dorsomedial tibial sesamoidectomy in 12.5 weeks	Two patients developed postoperative scarring and neuromas, one patient developed hallux varus, one patient had a postoperative increase in hallux valgus	46
Biedert and Hintermann (2003)	Great toe sesamoid	5	Surgical excision of the proximal fragment	All patients returned to sports within 6 months (range 2.5–6 months). There was an average American Orthopaedic Foot and Ankle hallux scale score of 95.3 (72–100)	Plantar fasciitis and partial tear suspected in one patient	65
Blundell et al (2002)	Great toe sesamoid	9	Percutaneous screw fixation with Barouk screw	At 6 months, all patients returned to their pre-injury level of activity with no symptoms. American Orthopaedic Foot and Ankle score improved from 46.9 before to 80.7 after the surgery ($P=0.0003$)	None reported	57
Anderson and McBryde Jr (1997)	Great toe sesamoid	21	Autogenous bone grafting	18 patients achieved bony union; 17 returned to their pre-injury level of athletic activity. The average time to radiographic union was 12 weeks	One patient had continued tenderness over the tibial hallux sesamoid, and another had generalized discomfort over the hallux metatarsophalangeal joint, One patient experienced tenderness over the course of the medial plantar digital nerve, one patient remained disabled with symptoms of digital neuritis	66