Os supranaviculare and navicular osteochondral lesion contributing to the development of a navicular stress fracture in an adolescent male athlete: case report

Authors: Katherine Drexelius MD,\textsuperscript{a}
Jonathan Bartolomei MD,\textsuperscript{b}
Alexander Shu MD,\textsuperscript{a}
Kenneth J. Hunt MD\textsuperscript{b}

Institution: \textsuperscript{a}University of Colorado School of Medicine, 13001 E. 17\textsuperscript{th} Pl, Box C290, Aurora, CO 80045, USA. \textsuperscript{b}Department of Orthopedic Surgery, University of Colorado, 12631 E. 17\textsuperscript{th} Ave, Room 4508, Aurora, CO 80045, USA

*Corresponding Author: Dr. Kenneth J. Hunt; Kenneth.j.hunt@cuanschutz.edu
ABSTRACT

Stress fractures of the tarsal navicular bone can be problematic in the athlete. This case details the injury and outcome of an adolescent male athlete who experienced one year of intermittent foot pain without acute trauma. Radiographs and computed tomography demonstrated a triad of a navicular stress fracture, an os supranaviculare, and an osteochondral defect of the navicular bone. The patient underwent successful operative fixation and returned to painless full function with imaging demonstrating healing at six months. Diagnosis of a navicular stress fracture in the setting of both an os supranaviculare and osteochondral lesion of the navicular bone have not been reported elsewhere in the literature. While repetitive loading on the navicular bone can independently produce a stress fracture, the patient had an increased risk for this injury; the presumably preexisting navicular osteochondral lesion and os supranaviculare may have resulted in decreased effective articular surface area, thereby increasing force on the navicular bone and producing a stress fracture. Understanding navicular stress fractures and concomitant bony pathology contributing to injury is crucial to successful diagnosis, management, and prevention of recurrence.

Key Words:
“Os supranaviculare,” “osteocondral lesion,” “osteocondral defect,” “stress fracture,” “case report”
The case

- An adolescent male athlete presented with one year of midfoot pain and tenderness to the dorsal aspect of the midfoot, without any clear inciting event or direct trauma to the foot.
- Upon imaging, he was found to have a navicular stress fracture, an osteochondral lesion of the navicular bone, and an os supranaviculare.
- He underwent open reduction and internal fixation with autograft bone harvest, debridement and allograft cartilage of a navicular osteochondral lesion, addition of a bone stimulator, and dorsal talar exostectomy.
- Six months postoperatively, imaging showed complete healing of the navicular fracture with stable hardware, and the patient resumed full physical activity and returned to sport. Three years postoperatively, he had no residual foot pain or dysfunction.

Lessons learnt

- The presence of either an osteochondral lesion of the navicular bone or an os supranaviculare may independently increase the risk of developing a navicular stress fracture. Taken in combination, the risk of stress fracture may be further increased, possibly due to decreased effective surface area between the navicular bone and the talus. A Type III navicular stress fracture in this context can be treated successfully with open reduction and internal fixation and surgical treatment of the osteochondral defect.
- Reaching the correct diagnosis and achieving optimal outcomes in patients with complex navicular pathology requires both independent review of imaging and collaboration with colleagues in radiology.
INTRODUCTION

Although navicular stress fractures (NSF) are considered rare in the general population, they are not uncommon in athletes. NSFs are overuse injuries seen in repetitive impact athletes, particularly those who participate in sports that involve explosive sprinting, cutting, and jumping.[1] Heightened awareness of the injury and increased participation in sports have led to more frequent diagnosis of the injury, with literature citing that NSFs comprise approximately one-third of all stress fractures of the lower extremity.[2-5] Repetitive foot strike during intense physical activity without adequate rest leads to the formation of microfractures in the navicular bone, while poor blood supply to the navicular bone contributes to diminished healing potential. Under continued load, these microfractures can propagate to form a true cortical break[1]. Diagnosis of an NSF is often delayed due to an initial presentation of fluctuating, vague foot pain and false-negative results on plain radiographs[3,6]. A high index of suspicion must be maintained for this injury as delayed diagnosis and treatment can result in chronic pain, high rates of nonunion, and prolonged time out of sport.[7]

An os supranaviculare is an accessory ossicle of the foot located on the dorsal aspect of the talonavicular joint. While it can be misdiagnosed as a fracture of the navicular bone or talar head, an os supranaviculare appears as a well-corticated bony density on the dorsal aspect of the navicular bone.[8] This is demonstrated radiographically on the lateral view of the right foot in Figure 1. An osteochondral lesion – also called osteochondritis dissecans (OCD) – of the navicular bone must also be differentiated from a navicular fracture. OCDs of the navicular bone are rare and have not been well described.[9]

This case report details a teenage male athlete who experienced one year of intermittent foot pain without acute trauma. He was found to have pain related to a combination of 1) a
navicular stress fracture, 2) an adjacent navicular osteochondral defect, and 3) an os supranaviculare. He underwent successful operative treatment followed by six weeks of non-weightbearing status, and he successfully returned to his functional baseline without complication. A search was performed of the peer review literature to identify available case reports and series of similar navicular injuries. The search strategy utilized a free text PubMed search including both MeSH and tiab terms, as well as a query of the EMBASE database (see Appendix for full search description). Very few previous reports detail tarsal navicular OCD with concomitant NSF.[10,11] These were case reports discussing the rarity of OCD of the navicular bone and presenting techniques for operative fixation of NSF in a total of two athletes. Additionally, there are few previous publications examining the role of os supranaviculare in NSF, and all of these are case reports that discuss the presence of an os supranaviculare as a predisposing factor for NSF. [12-14]. No published reports describe the triad of an os supranaviculare, OCD of the navicular bone, and navicular stress fracture. This case report discusses the presentation, management, and relationships among these pathologies.

**BODY/CASE:**

A healthy adolescent male experienced an insidious onset of right foot pain during sports with no inciting event or direct trauma to the foot. He participated in two field sports for his high school team: football and lacrosse. In addition to high school lacrosse, he played lacrosse on a competitive traveling club team with intense training and high competition year-round. His competitive lacrosse involvement averaged ten hours of training per week at baseline. Training hours increased to approximately sixteen hours per week when high school sport seasons overlapped with competitive lacrosse, which was the case for ten months per year. Walking and running exacerbated his symptoms, and the pain was relieved with rest. He had not tried any
therapeutic interventions. After one year of intermittent pain with physical activity, the patient presented to an outside podiatry clinic for evaluation. Initial x-rays indicated the presence of an os supranaviculare, loss of the sharp cortical line of the navicular bone where it articulates with the talus, and sclerosis of the navicular bone (Figure 1). The podiatrist ordered a computed tomography (CT) scan, and he referred the patient to an orthopedic foot and ankle surgeon.

The patient presented to the orthopedic foot and ankle clinic, where he again denied any past acute trauma to the foot. His physical exam was only significant for tenderness to palpation on the dorsal aspect of the midfoot over the navicular bone. The CT scan was reviewed and demonstrated a cortical depression with a rim of sclerosis on the central lateral aspect of the navicular bone, consistent with a navicular OCD. A complete fracture line extending from the base of the OCD to the inferior cortex of the navicular bone was also identified (Figure 2). These findings were consistent with the concomitant diagnoses of an os supranaviculare, navicular osteochondral defect, and linear navicular stress fracture.

This patient had no significant past medical history, no chronic disease that could alter bone mineral density, and no history of steroids or anti-epileptic medication intake. Given the patient’s age, overall health status, and rigorous training schedule, the presence of a stress fracture was attributed to supraphysiologic forces on his existing anatomy. In this context and with his known os supranaviculare and navicular OCD, no metabolic workup was performed. Metabolic evaluation – including vitamin D, calcium, alkaline phosphatase, and parathyroid hormone levels – would likely be performed in a different clinical scenario, namely for patients who develop a stress fracture from exerting relatively normal amounts of force on bone.

In regard to imaging, magnetic resonance imaging (MRI) is the gold standard diagnostic test for navicular stress reactions due to its high sensitivity. However, in this case, the patient
presented to clinic with completed plain radiographs and CT scan that was sufficient to confirm the diagnosis and formulate a treatment plan. In the context of a complete navicular stress fracture demonstrated on the CT scan ordered by the outside provider, an MRI was not deemed necessary nor cost-effective in this case. However, MRI should be considered during routine work-up of most navicular bone stress injuries.

Given the patient’s strong desire to return to sport safely, he and his parents chose to proceed with surgical management. Pre-operatively, the athlete was diagnosed with a linear NSF, navicular OCD, and os supranaviculare. The patient underwent open reduction internal fixation (ORIF) with autograft bone harvest from the ipsilateral calcaneus, debridement and curettage of the OCD with application of minced allograft cartilage (BioCartilage; Arthrex, Naples, FL), and addition of a bone stimulator. Surgical fixation involved insertion of 2.0-mm and 3.5-mm screws fixating the major fragments. Intra-operatively, a small osteophyte on the dorsal aspect of the talus was identified. This was possibly contributing to talonavicular impingement with increased forces on the dorsal aspect of the navicular bone, so a dorsal talus exostectomy was included. After screw placement, the patient exhibited full passive dorsiflexion with clearance of the talus by the navicular bone and fixation was deemed satisfactory (Figure 3, 4). A timeline of the patient’s course is available in Table 1.

Following surgical fixation, the patient remained non-weightbearing for six weeks. Postoperative radiography at six weeks indicated interval healing of a well-fixed, well-aligned navicular stress fracture without complications. The patient then transitioned into a controlled ankle motion (CAM) walker boot with physical therapy. Three months postoperatively, he had no interval complaints of pain, tenderness to palpation, or pain with midfoot manipulation. A CT scan at this time demonstrated complete healing of the fracture without acute hardware
complication (Figure 5). After three months, he transitioned into an accommodative shoe with supportive insoles and was cleared for light jogging. He was permitted to advance activities as tolerated and continue physical therapy as needed.

At six-month follow-up, he was unrestricted in physical activity and returned to sport. Three views of the right foot showed complete healing of the NSF with stable hardware (Figure 6). An MRI would also have been a reasonable choice to evaluate postoperative healing, but the patient was asymptomatic with activity and had no pain on physical exam. Additionally, metal artifact may have limited the utility of this exam. Three years postoperatively, he did not have any complaints of residual foot pain or disability and continued to participate fully in sport.

**DISCUSSION:**

While navicular stress fractures are rare in the general population, they are relatively common in athletes, accounting for up to 35% of all stress fractures in some series.[4,15,16] This injury can have a major effect on an athlete’s career, with one study finding that only 36% of athletes with this injury returned to previous level of play and did not experience recurrence of an NSF; this was described as an “alarmingly poor” overall outcome.[17] Given the incidence and career implications of this injury, determining patient risk factors and best course of management are crucial for optimizing patient care.

One contributor to the development of an NSF is poor blood supply to the navicular bone, as the central third of the bone is relatively hypovascular.[12] Other contributing factors for NSF include intense physical activity and repetitive foot strike, placing athletes who run on hard surfaces at increased risk.[6] Predisposition for this injury is furthered by anatomical variations that increase biomechanical load on a plantar-flexed foot, including reduced ankle dorsiflexion with a tight gastrocsoleus complex, limited subtalar joint motion, pes cavus, metatarsus adductus,
and a foot with a relatively long second ray. Relevant to this case, the presence of an os supranaviculare has been suggested as another predisposing factor for NSF, with a previous case series of 23 navicular stress fractures revealing that 22% of these patients had an ipsilateral os supranaviculare. One proposed explanation for this association comes from Ingalls et al, who hypothesized that the dorsal cortical notch in the navicular bone that often accompanies an os supranaviculare may increase the likelihood of developing an NSF. The authors describe that this depression in the bone may act as a stress riser, increasing stress over the dorsal aspect of the navicular bone, which is already a site of maximal shear stress. Following an insult to the dorsal cortex – such as that which occurs with repetitive loading and push-off during sprinting sports – the force may be more likely to propagate through the bone to produce a stress fracture.

While the overall incidence of os supranaviculare is estimated at 1-3.5% of the general population, the incidence of navicular OCD has not been reported. It is described as an extremely rare diagnosis and is thought to be due to repetitive trauma to the hypovascular portion of the navicular bone. The finding of an OCD with a concurrent NSF has been reported twice in the literature. Kanazawa et al describes successful operative treatment with complete resection of the osteochondral lesion followed by insertion of block-shaped iliac bone grafts, along with a single screw across the NSF. Their patient returned to sport fifteen weeks after surgery. Nunag et al describes the treatment of a professional athlete with NSF and a navicular OCD with curettage, bone grafting and plate stabilization. The athlete in their report resumed full activity six months postoperatively.

This patient’s diagnosis of an NSF in the setting of both an os supranaviculare and navicular OCD is a combination that has not been reported elsewhere in the literature. While we suspect that both the os supranaviculare and the OCD were preexisting and likely non-
symptomatic, they may have decreased the effective surface area between the talus and the navicular bone. In the setting of these two conditions and repetitive loading with sports, the increased force produced a stress fracture. However, we cannot rule out the possibility that the patient sustained an NSF in the setting of only an os supranaviculare, then subsequently developed an OCD in the presence of a chronic NSF. Type III NSF in particular can predispose to the development of OCD because these fractures involve two cortices and are more likely to involve the talonavicular joint.[23] Without imaging prior to the onset of symptoms, it is difficult to determine whether the NSF predated the OCD or if the OCD contributed to the formation of an NSF.

The treatment of navicular stress fractures remains somewhat controversial. Many use the type of NSF as described by Saxena et al to guide management. Type I injuries are dorsal cortex fractures, while Type II fractures extend into the navicular body. Type III fractures propagate into another cortex to create a complete fracture.[24] Most often, an uncomplicated Type I NSF should undergo a trial of conservative management with six to eight weeks of non-weightbearing cast immobilization. A more recent expert opinion and discussion of the literature by Gross and Nunley describes their guiding principles for treatment, which include consideration of CT findings, athletic participation level, and the patient’s functional status.[5] After reviewing available literature, they recommend ORIF for Type II and III NSFs and in fractures with sclerotic or cystic borders. In the context of a need for further high-quality studies to determine the optimal treatment of NSF, treatment should be individualized to the patient’s functional demands, fracture pattern, and concomitant musculoskeletal pathology.

The patient reported here was diagnosed with a Type III NSF. With this fracture and the patient’s desire to return to sport safely and quickly, he and his family elected to pursue surgical
The most common method of operative fixation for a navicular fracture consists of independent lag screw fixation, often with bone graft, as performed in this patient’s case.[25] The os supranaviculare was included in fixation, ideally improving talonavicular joint mechanics and increasing joint stability. This resulted in a successful radiographic and clinical outcome. When the patient was asked for his perspective six months postoperatively, 18 months postoperatively, and three years postoperatively, he was consistently very satisfied with his treatment, speed of recovery, and functional outcome.

This case highlights a potential diagnostic challenge in orthopedic sports medicine. It can be difficult to distinguish an os supranaviculare from a fracture fragment of the talus or navicular bone. An os supranaviculare will be found in its typical position on the proximal dorsal cortex of the navicular bone with well-corticated edges, while a fracture fragment will have more irregular edges and possible history of trauma. Another potential challenge is that of misidentifying the combination of a stress fracture, accessory ossicle, and osteochondral lesion as a comminuted fracture. In the presented case, the patient’s CT was interpreted by two musculoskeletal radiologists as a comminuted navicular fracture with areas of central impaction; the os supranaviculare and navicular OCD were not recognized. More broadly, this case exemplifies the value of independently reviewing patient imaging while still working cohesively with colleagues in radiology. Evaluating imaging independently of the report – followed by reading the radiologist interpretation – can lead to fewer incongruencies among provider conclusions. When the conclusions of orthopedists and radiologists do not align, there is opportunity for collaboration and bidirectional education in order to reach the most accurate diagnosis.

In summary, this case is representative of the complexity of navicular stress fractures. The tarsal navicular is a unique bone that can experience high magnitude forces in certain sports
and foot postures. The blood supply to the navicular bone places it at risk for stress fractures with poor healing, osteochondral pathologies, sclerosis, and osteophyte formation. Further, accessory ossicles and their potential contribution to pathology must be understood. As this case demonstrates, more than one of these elements can complicate a given situation. Careful diagnostic work-up in collaboration with musculoskeletal radiologists can help identify the correct treatment path and optimize patient outcomes.

**TABLE 1: Timeline of Events**

<table>
<thead>
<tr>
<th>Timeframe</th>
<th>Event Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early July</td>
<td>Patient presents to outside clinician after approximately one year of right foot pain; Radiographs and CT ordered by outside clinician</td>
</tr>
<tr>
<td>Early August</td>
<td>Patient undergoes surgery</td>
</tr>
<tr>
<td>Late July</td>
<td>Patient presents to clinic with prior imaging results; Imaging results and management options discussed with patient and family; Patient/family opt to proceed with surgery</td>
</tr>
<tr>
<td>Late September</td>
<td>Patient follow up visit #2 (Six weeks post-operation); Placed in CAM boot; Weightbearing as tolerated; Physical therapy begun</td>
</tr>
<tr>
<td>Late August</td>
<td>Patient follow up visit #1 (Two weeks post-operation); Placed in non-weightbearing cast</td>
</tr>
<tr>
<td>November</td>
<td>Patient follow up visit #3 (Approximately three months post-operation); Transitioned to accommodative shoes; Cleared to begin jogging and progress to activities as tolerated</td>
</tr>
<tr>
<td>Late January</td>
<td>Patient follow up visit #4 (Approximately six months post-operation); Unrestricted in activity; Cleared to follow up only as needed</td>
</tr>
</tbody>
</table>
Figure 1. Initial plain radiographs of right foot demonstrating os supranaviculare and suggestive of navicular osteochondral lesion. Anteroposterior view demonstrates sclerosis of the navicular bone articulating with the talus, while lateral view best demonstrates loss of the sharp cortical line of the navicular bone articulating with the talus.
Figure 2A: Pre-operative computed tomography scan of right foot demonstrating navicular osteochondral defect and navicular stress fracture in the coronal plane. Lateral (L) and medial (M) sides of foot denoted.

Figure 2B: Pre-operative computed tomography scan of right foot demonstrating os supranaviculare and navicular osteochondral defect in the sagittal plane. Dorsal (D) and plantar (P) aspects of foot denoted.
Figure 3: Intraoperative fluoroscopy of right foot at case completion.

Figure 4: Intraoperative photograph of surgical site, with dorsal-to-plantar screw head in sight.
Figure 5: Three-month postoperative computed tomography scan with axial and sagittal views of right foot demonstrating intact hardware, fracture healing, and filling of osteochondral lesion. Lateral (L) and medial (M) sides of foot denoted on axial view.

Figure 6: Plain radiographs at six-month postoperative time point, anteroposterior and lateral views.
APPENDIX: Search Strategy

PubMed: 
Combinations of free text search terms, with Boolean operator “AND”:
“[tiab]” was used in all queries to limit the search to title or abstract.
MeSH index term search included with PubMed search:
“navicular fracture*” (no results), for which the closest relevant term for the presented case was “fracture, stress”
“osteochondritis dissecans”
“accessory ossicle*” (no results), for which the closest term was “accessory bone, navicular”
“os supranaviculare” (no results)
A combination of these index terms yielded no literature results on PubMed.

EMBASE: 
Combinations of free text search terms, with Boolean operator “AND”:
“.tw.” was used in all queries to limit the search to title or abstract.
A combination of these index terms yielded no literature results on PubMed.

Search completed in August 2022

ACKNOWLEDGEMENTS

The authors would like to acknowledge the patient whose injury is presented here, as well as that of his legal guardian, for allowing us to present his case. We would also like to acknowledge all of the clinical care staff who contributed to the care of the patient.

REFERENCES:


**COMPETING INTERESTS**

None declared.
FUNDING
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

ETHICS APPROVAL STATEMENT - EXEMPT
A completed version of this manuscript was submitted for review to the Institutional Review Board and found to be Non Human Subject Research, meeting ethics standards and requiring no continuing review. Patient/legal guardian consent was obtained prior to the presentation of this case.
Late July:
Patient presents to clinic with prior imaging results; Imaging results and management options discussed with patient and family; Patient/family opt to proceed with surgery

Early July
Patient presents to outside clinician after approximately one year of right foot pain; Radiographs and CT ordered by outside clinician

Early August:
Patient undergoes surgery

Late August:
Patient follow up visit #1 (Two weeks post-operation);
Placed in non-weightbearing cast

Late September:
Patient follow up visit #2 (Six weeks post-operation);
Placed in CAM boot;
Weightbearing as tolerated;
Physical therapy begun

Late January:
Patient follow up visit #4 (Approximately six months post-operation);
Unrestricted in activity;
Cleared to follow up only as needed

November:
Patient follow up visit #3 (Approximately three months post-operation);
Transitioned to accommodative shoes;
Cleared to begin jogging and progress to activities as tolerated
Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: