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## CASE REPORTS

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## CASE REPORT

### Unique Applications of Carbon Fiber–Reinforced Polyetheretherketone Nails in Tibia and Ankle Injuries

*Gil R. Ortega, MD, MPH and Cody Pehrson, MD*

**Summary:** Tibial shaft and distal tibial pilon fractures can be a clinical and surgical challenge for the orthopedic surgeon and the recovering patient. Despite advances in nonsurgical and surgical techniques, fracture fixation alternatives, and adjuncts to healing, tibial shaft, and distal tibia nonunions continue to occur. Another challenge in our athletic population is the treatment of tibial stress fractures. With the introduction of carbon fiber–reinforced polyetheretherketone (CFR-PEEK) nails, we present the unique applications in 2 cases that challenge orthopedic surgeons and patients. The CFR-PEEK implants' lower modulus of elasticity more closely matches that of bone when compared with metal implants, and their fatigue strength is greater than metal implants. CFR-PEEK nails are the same cost when compared with titanium or stainless steel nails. This article reviews the unique use of these implants in a collegiate athlete with bilateral, symptomatic tibial shaft stress fractures that failed conservative management, and a patient who suffered an initial, open tibial shaft, and pilon

fracture who was surgically treated initially, which then became a nonunion.

**Key Words:** tibia fracture, pilon, stress fracture, CFR-PEEK, nonunion

#### INTRODUCTION

In 1939, Dr Küntscher introduced intramedullary nails (IMNs) and helped revolutionize the treatment of long bone fractures.<sup>1</sup> In many circumstances, IMNs can be used in proximal, tibial shaft, and distal tibia fractures including pilon fractures.<sup>2–8</sup> A systematic approach to the evaluation and treatment of tibial nonunions and stress fractures is required for a successful outcome because of the multifactorial nature of these problems. A tibial nonunion often results in a significant economic burden to the patient and the health care system,<sup>9,10</sup> and a tibial stress fracture can hamper and even end the career of a competitive athlete.<sup>11–13</sup> The origin of the nonunion and/or stress fracture process requires the meticulous investigation of the cause. For instance, what is the cause of the nonunion or stress fracture (ie, mechanical or biological reason), was a fixation strategy previously used, and if a surgically treated nonunion, are there signs of infection? In overview, a critical evaluation of the characteristics of the nonunion, including both mechanical and biological causes, is required.

Tibial stress fractures are relatively common in athletes, with a reported incidence as high up to 20% in runners.<sup>11</sup> Although most tibial stress fractures can be treated to healing with conservative management, some require operative intervention. In competitive athletes, the time to return to sport is critical. Most commonly, tibial stress fractures are caused by repetitive micro-trauma that causes increased osteoclastic activity and an inappropriate imbalance between resorption and bone regeneration. When required, IMNs of tibial stress fractures in addition to biologic optimization can offer athletes a healed advantage allowing for return to sport.

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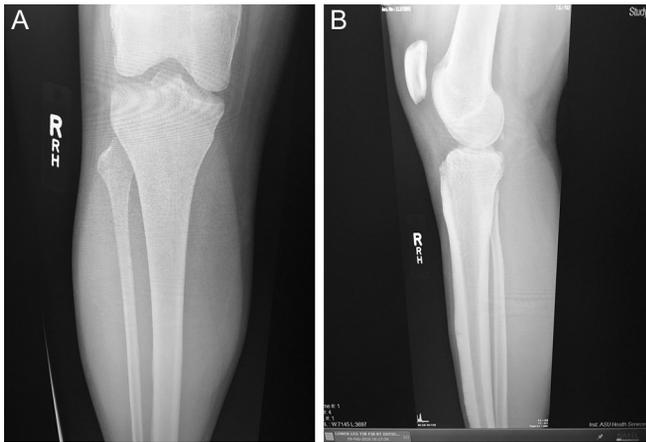


FIGURE 1. A and B, Preoperative right tibial x-rays.



FIGURE 2. A and B, Preoperative left tibial x-rays.

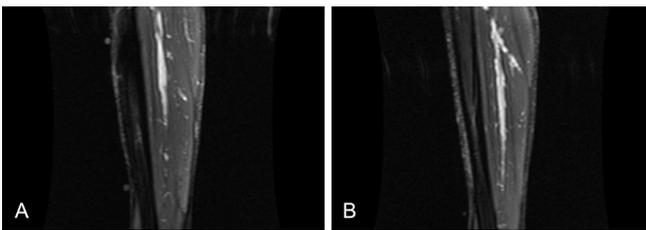


FIGURE 3. Bilateral preoperative MRIs showing focal thickening of the anterior cortex at the level of distal tibial diaphysis with cortically based stress fracture with mild surrounding intracortical and periosteal edema consistent with grade 4B injury. Right (A), left (B).

### CASE REPORT

#### Case 1: 21 Year-Old Man With Bilateral, Tibial Shaft Stress Fractures Treated With Bilateral Tibial Carbon Fiber–Reinforced Polyetheretherketone Intra-medullary Nails

A 21-year-old male collegiate, Division 1, football player presents with 1-year history of bilateral tibial midshaft pain with activities and walking (Figs. 1–7). He was treated conservatively with optimization of his vitamin D and calcium levels, bone stimulator utilization, and low-impact activity restrictions for more than 6

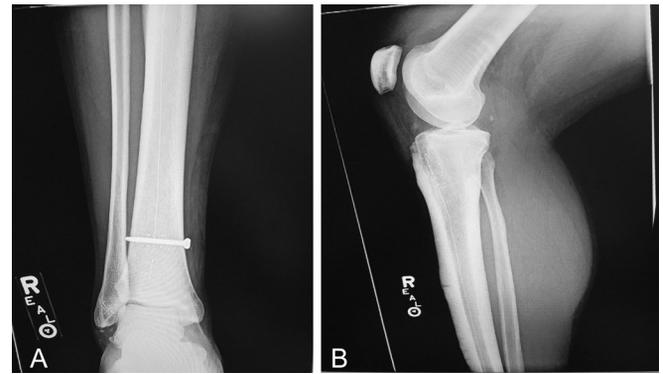


FIGURE 4. A and B, Immediate postoperative right tibial x-rays.

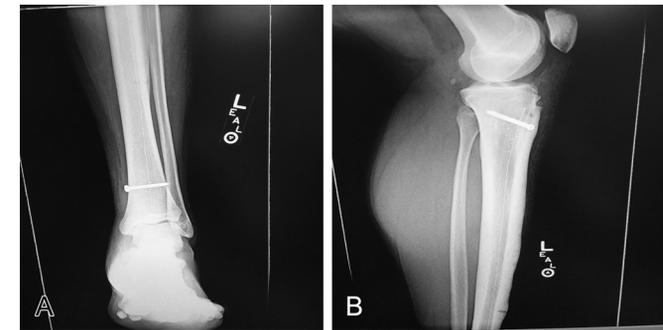


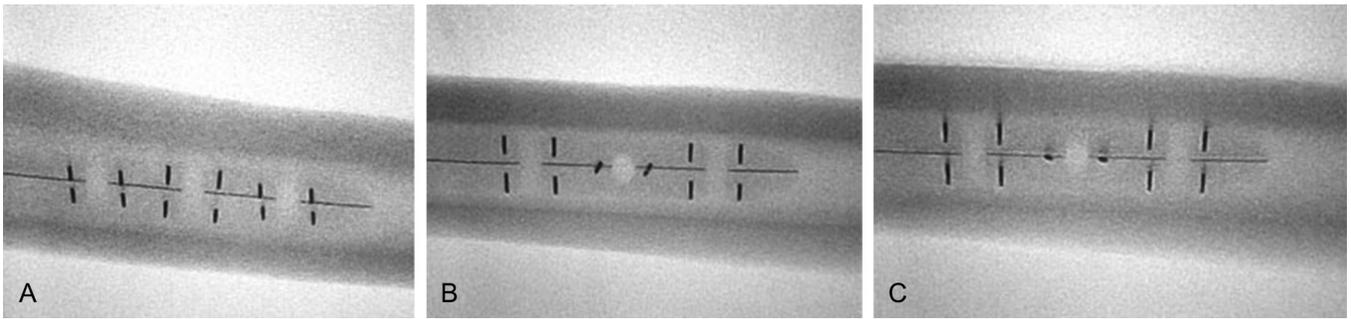
FIGURE 5. A and B, Immediate postoperative left tibial x-rays.

months. His bilateral tibial pain worsened, and his x-rays (Figs. 1, 2) and magnetic resonance imagings (MRIs) (Fig. 3) showed focal thickening of the anterior cortex at the level of distal tibial diaphysis with cortically based stress fractures with surrounding intra-cortical and periosteal edema consistent with grade 4B injuries.

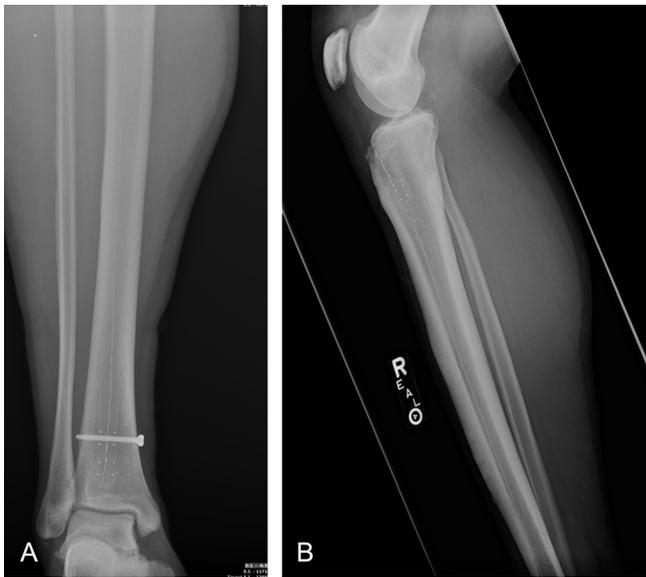
### Surgical Technique

He underwent operative treatment with bilateral IMNs of his bilateral tibias with carbon fiber–reinforced polyetheretherketone (CFR-PEEK) IMNs (Figs. 4, 5) in an outpatient setting. He received preoperative intravenous (IV) antibiotics and one additional dose of postoperative antibiotics. The surgical approach used for IMN insertion was a semiextended approach. Progressive reaming was performed from 9 to 11.5 mm. Both nails used were the same lengths and 10-mm diameter. The right tibial nail was not statically locked proximally, as it was the lesser stress fracture of both sides. The left tibial nail was statically locked proximally and distally. Similar to most nails, the proximal interlock screws in CFR-PEEK nails are placed through a guide that is attached to the nail. The distal interlock screws are localized under fluoroscopy using the alignment of 4 calendric markers made of tantalum that are within the nail. These 4 markers are aligned by the surgeon to make 2 dots that identify the interlock screw hole under fluoroscopy (Figs. 6A–C). Using standard free-hand, fluoroscopically guided technique, the surgeon can drill for the distal interlock screws then follow with screw measurement and screw placement.

The patient was made weight-bearing as tolerated with limitation of strenuous activities for 6 weeks. At 4 months, his tibial shaft stress fractures were healed clinically and radiographically by x-rays and MRIs (Figs. 7, 8), and he returned to sport.



**FIGURE 6.** A–C, Intraoperative imaging demonstrating alignment of 4 calendric, tantalum nail markers that align to 2 dots to demonstrate interlock hole (Courtesy of CarboFix Orthopedics, Inc).



**FIGURE 7.** A and B, Healed x-rays of the right tibia at 4 months.

### Case 2: 42 Year-Old Woman With Tibial Shaft and Distal Tibia Pilon Nonunion Treated With Tibial CFR-PEEK Intramedullary Nail

A 42-year-old woman presents after a fall from height (Figs. 9 and 10). She suffered a right type IIIA open tibial shaft and distal tibial pilon fracture. She was treated initially by another surgeon with debridement and irrigation, wound closure, and limited open reduction and internal fixation of her pilon fracture including distal tibia and distal fibula combined with spanning external fixation of her tibial shaft fracture. She suffered an early open fracture wound infection, which was treated with a repeat debridement and irrigation and IV antibiotics. Secondary to her infection, the surgeon treated her with maintenance of her external fixator for her definitive treatment. At 5 months, she presented for evaluation and treatment of her tibial shaft nonunion (Figs. 9A, B), as her tibial pilon joint component appeared healed.

#### Surgical Technique

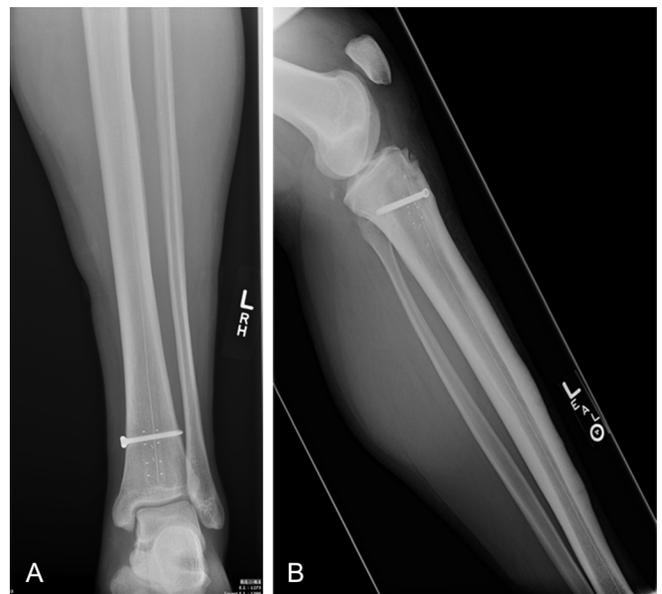
She was treated with a removal of her external fixator, debridement and irrigation of her pin sites, and open biopsy and deep cultures of her nonunion tibial shaft site. Infection workup including complete blood count, erythrocyte sedimentation rate, and C-reactive protein was all normal, and her biopsy pathology and deep cultures were negative for osteomyelitis and infection.

After final pathology and microbiology results were known, she underwent IMN of her right tibia with a CFR-PEEK IMN in an outpatient setting. She received preoperative IV antibiotics and one additional dose of postoperative antibiotics. The nonunion site was debrided and refreshed using a 2.5-mm drill bit and quarter inch osteotomes. The nonunion was reduced and aligned appropriately. The surgical approach used for IMN insertion was a semiextended approach. Progressive reaming was performed from 9 to 11.5 mm. The right tibial nail was statically locked proximally and distally and was 10-mm diameter.

The patient was made weight-bearing as tolerated. At 6 weeks, her tibial shaft fracture demonstrated early callus formation and healing (Figs. 10A, B). At 3 months, she was clinically and radiographically healed, complaining of deep hardware impingement from her fibular hardware (Figs. 11A, B).

### DISCUSSION

Although there are many techniques to stabilize tibial shaft and distal tibia pilon fractures, tibial shaft fractures are best treated with an IMN. Tibial shaft and distal tibia nonunions and tibial stress fractures are an encumbering clinical problem for patients. A systematic



**FIGURE 8.** A and B, Healed x-rays of the left tibia at 4 months.

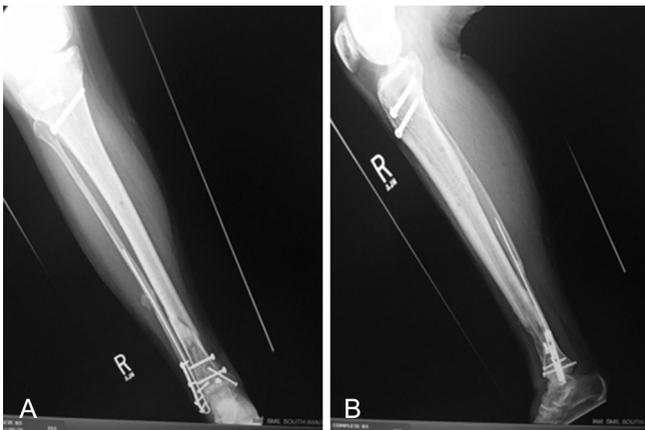


**FIGURE 9.** A and B, Initial presentation of the right tibial x-rays 5 months from the time of injury.

approach to the evaluation and treatment of tibial nonunions and tibial stress fractures are required for a positive outcome.

In athletic stress fractures, early emphasis on conservative management with optimization of nutrition and vitamin D/calcium levels and other important laboratory values, minimization of stress events such as running, jumping, tackling, utilization of a bone stimulator, and maintenance of muscular strength and flexibility are vital in treating most tibial stress fractures. When conservative management has failed such as in case 1, then IMN fixation of tibial stress fractures shows a high overall union rate with one study showing 100% healing rate in athletes with a chronic tibial stress fracture.<sup>13</sup>

In both cases, the real benefit came with CFR-PEEK IMN of these injuries, as both patients were allowed for immediate weight-bearing as tolerated, which helped promote union while avoiding fixation failures. We chose to use CFR-PEEK IMN as compared to metal nails in both patients, as one patient is a collegiate football lineman that had already missed significant playing time, whereas the other patient had a known initial tibial infection that was concerning for possible infection of a metal-type nail. CFR-PEEK nails are the same cost when compared with titanium or stainless steel nails. With the modulus of elasticity that more closely matches that of bone when compared with metal implants, and their fatigue strength being greater than metal implants, we chose (CFR-PEEK) implants to offer the best opportunity for our patients to heal. One patient returned to sport after he healed, and the other patient returned to some of her preinjury activities.



**FIGURE 10.** A and B, Six-week postoperative x-rays of the right tibia.



**FIGURE 11.** A and B, Healed final x-rays of the right tibia at 3 months.

## ACKNOWLEDGMENTS

*CarboFix Orthopedics, Inc. (Ocean Isle Beach, NC) manufactures the CFR-PEEK nails, and InVivo Biomaterials Solutions (Lancashire, United Kingdom) supplies the CFR-PEEK materials.*

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