Nonoperative Management of Tibial Stress Fractures Result in Higher Return to Sport Rates Despite Increased Failure Versus Operative Management: A Systematic Review

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Purpose: To compare return to sport (RTS) rates and complications after nonoperative versus operative management of tibial stress fractures. **Methods:** A literature search was conducted per the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines using EMBASE, PubMed, and Scopus computerized data from database inception to February 2023. Studies evaluating RTS sport rates and complications after nonoperative or operative management of tibial stress fractures were included. Failure was defined as defined by persistent stress fracture line seen on radiographic imaging. Study quality was assessed using the Modified Coleman Methodology Score. **Results:** Twenty-two studies consisting of 341 patients were identified. The overall RTS rate ranged from 91.2% to 100% in the nonoperative group and 75.5% to 100% in the operative group. Failures rates ranged from 0% to 25% in the nonoperative groups and 0% to 6% in the operative group. Reoperations were reported in 0% to 6.1% of patients in the operative group, whereas 0% to 12.5% of patients initially managed nonoperatively eventually required operative treatment. **Conclusion:** Patients can expect high RTS rates after appropriate nonoperative and operative management of tibial stress fractures. Treatment failure rates were greater in patients undergoing nonoperative management, with up to 12.5% initially treated nonoperatively later undergoing operative treatment. **Level of Evidence:** IV; Systematic Review of level I-IV studies.

Stress fractures occur as a result of repetitive mechanical loading surpassing the critical limit of mechanical tolerance, accounting for up to 10% of all sport-related injuries.[1-4] The frequent mechanical strain placed across the bone is often associated with the development of microdamage that is initially inconsequential because of the bone's ability to repair and remodel itself.[4,5] However, in cases in which repetitive loading prevents interval healing, the imbalance between damage and repair may result in a stress fracture.[4]

Currently, treatment for stress fractures of the tibia without radiographic evidence of injury consists of rest, protected weightbearing, and anti-inflammatory medication to allow for bony repair and healing.[6,7] However, in the setting of higher-grade or complete stress fractures of the tibia in which periosteal reaction or even a fracture line may be imaged, treatment options include nonoperative measures, including immobilization, bracing, pulsing electromagnetic field therapy, and ultrasound therapy, or operative intervention, consisting of drilling, excision and grafting, open reduction and internal fixation, or intramedullary nailing.[8-13] The implications associated with time lost, especially in younger active patients or athletes with tibial stress

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The authors report that they have no conflicts of interest in the authorship and publication of this article. Full ICMJE author disclosure forms are available for this article online, as supplementary material.

Received February 17, 2023; accepted April 21, 2023.

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2666-061X/23247

https://doi.org/10.1016/j.asmr.2023.04.015

fractures undergoing nonoperative versus operative management, remain largely unknown.

The purpose of this study was to compare return-to-sport (RTS) rates and complications after nonoperative versus operative management of tibial stress fractures. The authors hypothesized that patients undergoing nonoperative management would report quicker RTS with higher rates of clinical failure requiring further treatment compared to patient undergoing operative management.

Methods

Search Strategy and Eligibility Criteria

A systematic review was conducted according to the 2020 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.[14] An independent and comprehensive database search was conducted by 2 independent authors (S.S., T.T.) using EMBASE, PubMed and Scopus computerized databases from database inception through February 2, 2023. The following search terms with Boolean operators were used: "Tibia," "Tibial," "Shin," "Overuse," "Stress," and "Fracture." The inclusion criteria consisted of level I to IV studies written in English or with English translation reporting RTS rates and complications after operative or nonoperative management for radiographically and clinically diagnosed tibial stress fractures. Exclusion criteria consisted of cadaveric or biomechanical studies, non-full text articles, surveys, review articles, studies failing to report RTS rates and studies reporting on stress fractures not involving the tibia.

Data Extraction

Data extraction was conducted by 2 independent authors (S.S., T.T.) from the included studies and entered into a Microsoft Excel version 16.63 (Microsoft Corp, Redmond, WA) spreadsheet for further analysis. The collected data was comprised of the first author's name, year of publication, level of evidence (as reported by Wright et al.[15]), patient demographics, number of patients with stress fractures, location of stress fractures (distal, midshaft or proximal tibia, anterior diaphysis, posterior diaphysis), treatment

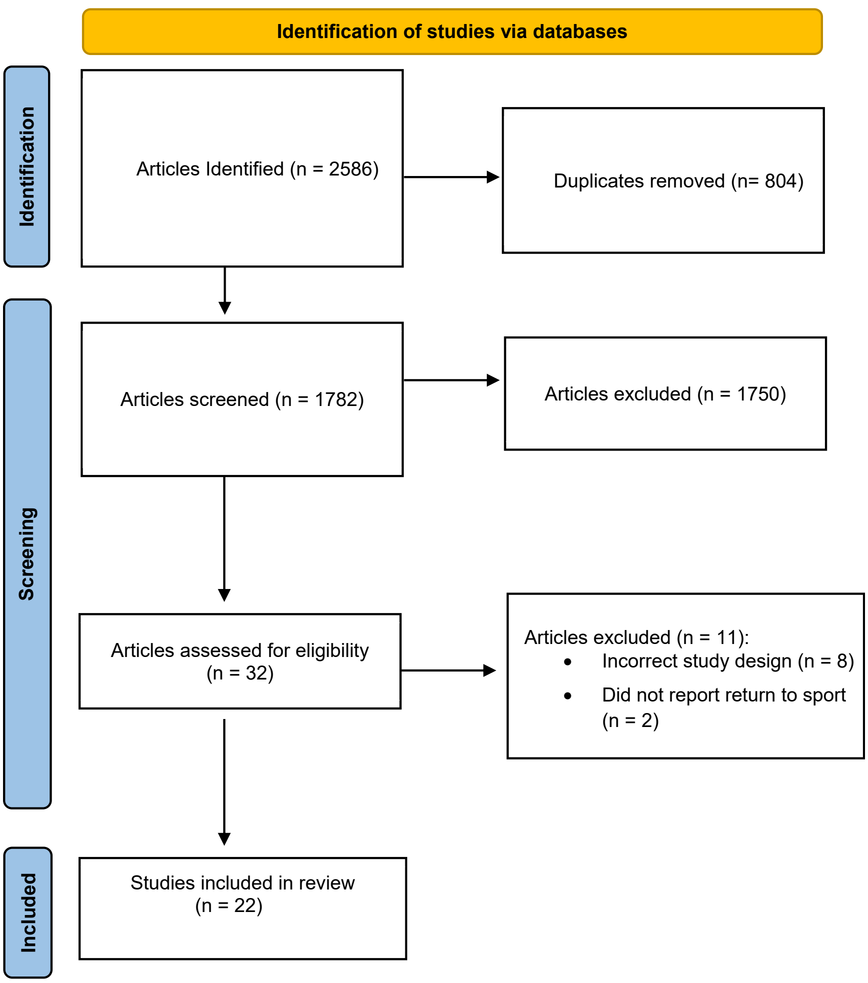

Fig 1. Flow diagram according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines.

Table 1. Patient Demographics

Study (Year)	LOE	No. of Patients	No. of Stress Fractures	Location of Stress Fracture	Sex (M/F)	Age (Yr), Mean (Range)	Follow-up (Mo), Mean (range)	Sport/Activity	Surgical Intervention	Nonoperative Management	Modified CS
Nonoperative management											
Milgrom (2021)	III	31	31	Anterior Tibial diaphysis	31/0	19.4 ± 0.9	NR	Military Personnel	—	Modified rest	85
Van der Velde (1999)	IV	3	3	Posterior proximal diaphysis (n = 2); Posterior distal diaphysis (n = 1)	2/1	25 (15-35)	8.5 (1.5-1.6)	Marathon runner (n = 1); Jogger (n = 1); Hill-walking (n = 1)	—	Modified rest	68
Batt (2001)	III	3	4	Anterior Tibial diaphysis	1/2	28 (24-32)	NR	Ballet (n = 1); Runner (n = 1); Netball (n = 1)	—	Pneumatic leg brace while performing ADLs	68
Brand (1999)	II	8	8	Anterior Tibial diaphysis (n = 1); Posterior medial Tibia (n = 7)	2/6	NR	1	Soccer; Basketball	—	Pulsed low intensity ultrasound therapy	83
Chauhan (2006)	I	34	NR	Tibia	34/0	22.5 (19-24)	0.5	NR	—	Modified rest with low level laser therapy	92
Dickson (1987)	III	10	13	Proximal 1/3 of Tibia (n = 1); Mid-diaphyseal Tibia (n = 4); Junction of middle and distal 1/3 of Tibia (n = 7)	0/10	NR	NR	Track (n = 5); Basketball (n = 3); Field Hockey (n = 1); Gymnastics (n = 1)	—	Pneumatic leg brace with ADLs	68
Johansson (1992)	III	41	46	Posterior medial Tibia (n = 32); Anterior Tibial diaphysis (n = 14)	15/26	26 (11-50)	24-60	Running/Orienteering (n = 19); Soccer (n = 4)	—	Restricted of sports activities	73
Moretti (2009)	II	4	4	Anterior middle third (n = 3); Anterior proximal third (n = 1)	4/0	22.8 (19-26)	NR	Soccer (n = 4)	—	Extracorporeal shock wave therapy	83
Rettig (1988)	II	8	8	NR	7/1	(14-23)	NR	Basketball (n = 8)	—	Pulsing electromagnetic field system	83
Rue (2004)	I	26	43	NR	13/13	18.6 ± 0.8 (17-20)	NR	Navy Midshipmen (n = 26)	—	Pulsed ultrasound therapy	92
Swenson (1997)	I	18	18	Distal 2/3 Tibia	NR	20 (15-44)	NR	NR	—	Pneumatic leg brace and non-weightbearing	88
Uchiyama (2007)	II	5	5	Anterior Tibial diaphysis	4/1	22 (17-33)	7.4	Soccer (n = 1); Judo (n = 1); Tennis (n = 1); Basketball (n = 2)	—	Low intensity pulsed ultrasound therapy	78

(continued)

Table 1. Continued

Study (Year)	LOE	No. of Patients	No. of Stress Fractures	Location of Stress Fracture	Sex (M/F)	Age (Yr), Mean (Range)	Follow-up (Mo), Mean (range)	Sport/Activity	Surgical Intervention	Nonoperative Management	Modified CS
Whitelaw (1991)	II	17	20	Tibia	8/9	20.2 (17-25)	NR	Aerobics (n = 2), Track (n = 9), Football (n = 1), Lacrosse (n = 2), Volleyball (n = 1), Soccer (n = 1), Basketball (n = 1)	—	Pneumatic leg brace for ambulation	78
Yadav (2008)	I	39	39	Tibia	NR	NR	1	Military Personnel	—	Pulsed ultrasound therapy	92
Operative management											73
Zbeda (2015)	IV	12	13	Anterior Tibial diaphysis	3/9	23.6 (20-32)	28.9 (6-127.3)	Track and Field (n = 5); Basketball (n = 4); Volleyball (n = 2); Ballet (n = 1)	Tension-band plating	—	73
Varner (2005)	IV	7	11	Anterior Tibial diaphysis	4/3	(17-23)	17 (4-42)	Basketball (n = 8); Running (n = 3)	Intramedullary nail	—	73
Miyamoto (2009)	IV	7	8	Anterior Tibial diaphysis	4/3	22.6 (18-26)	(4.5-47)	Dancer (n = 7)	Curettage with bone graft substitute (n = 5); Intramedullary nail (n = 3)	—	73
Cruz (2013)	IV	3	4	Anterior Tibial diaphysis	3/0	21.3 (18-24)	11.7 (6-20)	Ballet (n = 1); Soccer (n = 1); Pole vaulter (n = 1)	Tension-band plating	—	70
Borens (2006)	IV	4	4	Anterior Tibial diaphysis	0/4	21.5 (19-27)	15 (12-24)	Track and Field (n = 3); Volleyball (n = 1)	Tension-band plating	—	70
Beals (1991)	III	7	8	Anterior Tibial diaphysis	7/0	(16-24)	21 (4-48)	Football (n = 1); Basketball (n = 3); Basketball/ Running (n = 1); Football/Basketball (n = 1); Ballet (n = 1)	Excision (n = 2); bone grafting (n = 1); excision with bone grafting (n = 1); ORIF with plate (n = 1); ORIF with plate and bone grafting (n = 1); excision, drilling, and bone grafting (n = 1); Intramedullary nail (n = 1)	—	73

(continued)

Table 1. Continued

Study (Year)	LOE	No. of Patients	No. of Stress Fractures	Location of Stress Fracture	Sex (M/F)	Age (Yr), Mean (Range)	Follow-up (Mo), Mean (range)	Sport/Activity	Surgical Intervention	Nonoperative Management	Modified CS
Chang (1996)	III	5	5	Anterior Tibial diaphysis	5/0	24.3 (20.9-30.4)	21 (10-39)	Military personnel	Intramedullary nail	—	73
Limatainen (2009)	II	49	NR	NR	34/15	26 (16-37)	NR	Endurance running (n = 23); Soccer (n = 11); Jumping events (n = 5); Dance (n = 4); 400-m hurdles (n = 4); Cross country skiing (n = 1); Orienteering (n = 1)	Drilling (n = 20); Laminofixation (n = 29)	—	85

ADLs, activities of daily living; CS, Coleman score; F, female; LOE, level of evidence; M, male; No., number; NR, not reported; ORIF, open reduction internal fixation.

(nonoperative versus operative), RTS rate and timing, reoperation rates, conversion from nonoperative to operative management, and the incidence of complications. Complications were categorized into the following: failure (defined by persistent stress fracture line seen on radiographic imaging), delayed union/nonunion, symptomatic hardware, and persistent tibial pain.

Risk of Bias Assessment

Study quality was assessed by 2 independent authors (S.S., T.T.) using the Modified Coleman Methodology Score. This quality assessment tool uses 10 criteria to score each included study from 0 to 100. A maximum score of 100 indicates a study that avoids bias, confounding factors, and chance.

Statistical Analysis

Data pooling and formal meta-analysis were not performed because of the high risk of bias and high level of heterogeneity of the included studies.

Results

Study participants

The initial search yielded a total of 2586 articles. Upon initial screening, a total of 804 duplicate articles were identified and excluded. After title and abstract screening, a total of 32 full-text articles were assessed for full-text screening, after which 22 studies consisting of 341 patients (n = 378 stress fractures) were identified meeting inclusion/exclusion criteria (Fig 1). The included studies were published between 1987 and 2021. Fourteen studies[8-10,16-26] (n = 247 patients; mean age range, 18.6-28 years) reported on outcomes after nonoperative management whereas 8 studies[3,13,27-32] (n = 94 patients; mean age range, 21.3-26 years) reported on operative management (Table 1). Nonoperative treatment modalities consisted of a combination of bracing (n = 48 fractures), ultrasound therapy (n = 78 fractures), restricted mobility with laser therapy (n = 34 fractures), activity restriction (n = 41 fractures), extracorporeal shock wave therapy (n = 4 fractures), modified rest (n = 42 fractures), and pulsing electromagnetic field system (n = 8 fractures). In patients undergoing operative management, the following interventions were performed: excision (n = 2 fractures), bone grafting (n = 1 fractures), excision with bone grafting (n = 6 fractures), open reduction, internal fixation (ORIF) with plate (n = 1 fractures), ORIF with plate and bone grafting (n = 1 fractures), drilling plus bone grafting (n = 1 fractures), intramedullary nailing (n = 20 fractures), drilling (n = 29 fractures), laminofixation (n = 29 fractures), or tension-band plating (n = 21 fractures).

Table 2. Return to Sport Rate

Study (Year)	Overall RTS, (%)	Mean Time to RTS (range), mo
Nonoperative management		
Milgrom (2021)	100 (n = 31/31)	(0.23-1.5)
van der Velde (1999)	100 (n = 3/3)	1.3 (0.5-2)
Batt (2001)	100 (n = 4/4)	12 (11-14)
Brand (1999)	100 (n = 8/8)	1
Chauhan (2006)	91.2 (n = 31/34)	NR
Dickson (1987)	100 (n = 10/10)	(0.25 − 1)
Johansson (1992)	95.1 (n = 39/41)	(2-6)
Moretti (2009)	100 (n = 4/4)	4
Rettig (1988)	100 (n = 8/8)	8.7
Rue (2004)	100 (n = 26/26)	2.0 ± 0.7
Swenson (1997)	100 (n = 18/18)	(0.5-1.5)
Uchiyama (2007)	100 (n = 5/5)	3
Whitelaw (1991)	100 (n = 17/17)	1.3 (1-1.8)
Yadav (2008)	100 (n = 39/39)	0.9 ± 0.1 (0.7-1.2)
Operative management		
Zbeda (2015)	92.3 (n = 12/13)	2.8 (1.4-5)
Varner (2005)	100 (n = 7/7)	4 (3-5)
Miyamoto (2009)	100 (n = 7/7)	6.5 (4-12)
Cruz (2013)	100 (n = 3/3)	2.8 (2.5-3)
Borens (2006)	100 (n = 4/4)	2.5 (1.5-3)
Beals (1991)	85.7 (n = 6/7)	NR
Chang (1996)	100 (n = 5/5)	NR
Liimatainen (2009)	75.5 (n = 37/49)	(5-6)

NR, not reported; RTS, return to sport.

RTS

The overall RTS rate ranged from 75.5% to 100% among both treatment modalities. The overall RTS rate ranged from 91.2% to 100% with nonoperative treatment versus 75.5% to 100% in patients undergoing operative management (Table 2).

Complications

Recurrent fracture was the most frequently reported complication in patients undergoing nonoperative management, reported to occur in 0% to 33.3% of patients (Table 3). Persistent tibial pain was the most commonly reported complication in patients undergoing operative treatment, ranging from 0% to 100% of patients. The overall reported failure rate ranged from 0% to 25% with nonoperative treatment versus 0% to 6% after operative management. In patients initially managed nonoperatively, 0% to 12.5% of patients eventually underwent operative treatment with excision and bone grafting (n = 1 patient) and tibial intramedullary nailing (n = 1 patient). Among patients undergoing surgery, 0% to 6.1% of patients underwent reoperation using drilling after initial laminofixation (n = 1 patients) and repeat drilling after initial drilling (n = 2 patients).

Discussion

This study found that RTS rates ranged from 75.5% to 100% of patients undergoing nonoperative versus 91.2% to 100% of patients treated surgically. Recurrent fracture was the most commonly reported complication after nonoperative treatment, with persistent tibial pain being most frequent after operative management. Up to 12.5% of patients initially undergoing nonoperative management required subsequent operative treatment.

RTS rates were noted to be high in both patients treated using nonoperative and operative modalities. A prior investigation by Robertson et al.[33] observed no statistically significant difference between operative and nonoperative management of anterior tibial stress fractures and RTS. A recent study by Milgrom et al.[18] reported that 77.4% (n = 24/31) of elite infantry personnel diagnosed with medial tibial stress fractures were successfully treated after a mean of 1 to 4 weeks of rest based on the severity of the initial injury, including restrictions in running, marching, carrying >10% body weight, standing for >6 hours a day, and guarding >30 consecutive minutes standing. All 31 participants were reported to be treated successfully, with return to full activity with additional rest for up to a total of 6 weeks, if needed.[18] Similarly, Liimatainen et al.[3] reported 49 tibial stress fracture patients with symptoms refractory to conservative management that subsequently underwent surgery. Twenty patients underwent drilling at the fracture site before 1992, at which time laminofixation was introduced and used for the last 29 cases. This novel technique included ORIF with 4 or 6 screws, in addition to drilling of the cortex proximally and distally to reduce intramedullary pressure. Fifty percent of the drilling group was able to RTS without limitation, whereas 93% of the laminofixation group was able to RTS.[3] Although the current literature supports a high RTS rate for both nonoperatively and operatively treated patients, further investigations examining patient and fracture-specific factors are warranted to better understand variables that may be predictive of failed nonoperative management and delaying RTS.

Complications of tibial stress fracture commonly involved recurrent fracture (0%-33%) after nonoperative treatment and persistent tibial pain (0%-100%) in operatively treated patients. Chang et al.[28] observed that, in 5 patients undergoing intramedullary nailing for tibial stress fractures recalcitrant to nonoperative treatment, 100% of patients reported persistent tibial symptoms consisting of discomfort over proximal locking screws (n = 2/5 patients) or the incision sites (n = 1/5 patients). In their investigation, nonoperative management had failed in each patient for a minimum of 1 year before operative treatment.[28] This finding is in agreement with prior literature reporting a high rate of knee pain after intramedullary nailing, with recent reports estimating an incidence of approximately 23%.[33] As such, this complication is likely attributed to the treatment rather than the tibial stress fracture.

Table 3. Post-treatment Complications

Study (Year)	Failure	Refracture	Delayed Union/ Nonunion	Symptomatic Hardware	Underwent Hardware Removal	Tibial Pain	Reoperation
Nonoperative management							
Milgrom (2021)	0	0	0	—	—	0	0
van der Velde (1999)	0	33.3% (n = 1/3)	0	—	—	0	0
Batt (2001)	25% (n = 1/4)	0	0	—	—	0	0
Brand (1999)	12.5% (n = 1/8)	0	0	—	—	0	12.5%; Tibial intramedullary nailing (n = 1)
Chauhan (2006)	8.8% (n = 3/34)	0	0	—	—	16.1% (n = 5/31)	0
Dickson (1987)	0	7.7% (n = 1/13)	0	—	—	7.7% (n = 1/13)	0
Johansson (1992)	6.5% (n = 3/46)	0	0	—	—	0	0
Moretti (2009)	0	0	0	—	—	0	0
Rettig (1988)	12.5% (n = 1/8)	12.5% (n = 1/8)	0	—	—	0	12.5%; Excision and bone grafting (n = 1)
Rue (2004)	0	0	0	—	—	0	0
Swenson (1990)	0	0	0	—	—	0	0
Uchiyama (2007)	0	0	0	—	—	0	0
Whitelaw (1991)	0	0	0	—	—	0	0
Yadav (2008)	0	0	0	—	—	0	0
Operative management							
Zbeda (2015)	0	0	0	0	38.5% (n = 5/13)	0	0
Varner (2005)	0	9% (n = 1/11)	0	9% (n = 1/11)	0	0	0
Miyamoto (2009)	0	0	0	0	0	0	0
Cruz (2013)	0	0	0	0	0	0	0
Borens (2006)	0	0	0	25% (n = 1/4)	25% (n = 1/4)	25% (n = 1/4)	0
Beals (1991)	0	0	0	0	0	0	0
Chang (1996)	0	0	0	40% (n = 2/5)	0	100% (n = 5/5)	0
Liimatainen (2009)	6.1% (n = 3/49)	0	0	2% (n = 1/49)	2% (n = 1/49)	2% (n = 1/49)	6.1%; Drilling after laminofixation (n = 1), Drilling after primary drilling (n = 2)

Meanwhile, in the cohort investigation performed by Liimatainen et al.,[3] only 6.1% of patients complained of persistent tibial discomfort, whereas Beals et al.[13] denied any persistent tibial pain after surgery. After nonoperative management, Chauhan et al.[16] observed a 16.1% rate of persistent pain 2 weeks after the initiation of treatment with low-level laser therapy, compared to 47% in their control group. Meanwhile, Dickson et al.[17] reported that 7.7% of patients experienced persistent pain after treatment using a pneumatic leg brace. Overall, 3 of the surgically treated patients required a return to the operating room for revision, whereas two nonoperatively managed patients ultimately required surgical intervention. As such, patients undergoing both nonoperative and operative management for tibial stress fractures should be informed about the potential risk for complications and the risks associated with each treatment modality.

Limitations

This study is not without limitations. The primary limitations are related to the available literature, which was limited by our strict inclusion/exclusion criteria, resulting in a small sample size, limiting the ability of the authors to perform any meaningful statistical analyses between treatment types. Some of the interventions in the included studies have become defunct and are no longer performed in common practice, limiting the generalizability of these findings to contemporary patients sustaining tibial stress fractures. It is important to note that studies investigating operative intervention frequently report failure of conservative management before pursuing surgery; therefore the general treatment algorithm at this time appears consistent with trial of nonoperative management followed by operative intervention based on location of fracture and persistence of symptoms, similar to other authors' recommendations.[33-35] Moreover, there was substantial heterogeneity in the reporting of data and interventions used, further prohibiting any statistical or meta-analyses comparing outcomes between treatment groups based on athletic activity, patient age, sex, fracture location, and length of symptoms. The included studies are also primarily of low-level evidence, with the majority being level III or IV evidence, because there remains a paucity of prospective, randomized trials evaluating outcomes in patients with tibial stress fractures. Future directions should focus on increasing power, using modern-day treatment modalities, and improving level of evidence to determine the optimal treatment strategy for tibial stress fractures based on patient and fracture characteristics.

Conclusion

Patients can expect high RTS rates after appropriate nonoperative and operative management of tibial stress fractures. Treatment failure rates were greater in patients undergoing nonoperative management, with up to 12.5% initially treated nonoperatively later undergoing operative treatment.

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