Clinical Research

Intramedullary screw fixation for proximal fifth metatarsal zone II and III fractures on athlete population: a systematic review

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ABSTRACT

Introduction: Metatarsal fractures are the most common fractures in foot with an incidence of 6.7 per 10.000 persons. Fifth metatarsal fractures account for 70% of metatarsal fractures. Proximal 5th metatarsal zone II and III fractures have minimal vascularization, known as a 'watershed area', with delayed to non-union rate up to 50%. This study will review clinical and functional effectiveness from intramedullary screw fixation for proximal 5th metatarsal zone II and III fractures.

Methods: Publications from 2010-2020 in PubMed and Scopus databases were systematically reviewed using PRISMA guideline within the searching period from the 1st of June to the 10th of July 2020. Inclusion criteria for this study were published journal from the last 10 years, athlete population, undergone intramedullary screw fixation, assessed for time to bone union or return to sport duration, acute fractures, clearly stated followed-up period, and reported complications. All data were statistically analyzed using SPSS version 23.

Results: Data from 2010 to 2020 were systematically searched, there were 146 cases of proximal 5th metatarsal zone II and III fractures which undergone intramedullary screw fixation with a mean follow up of 5.6 $\pm$ 3.1 years. Time to bone union was 8.5 weeks on average. Return to sport was 8.7 weeks, the average reported midfoot AOFAS functional score was 98.4. Complications in the form of diaphyseal stress fracture, thermal necrosis of the skin, irritation of soft tissue, non-union, and refracture were reported.

Conclusion: The current study demonstrates the effectiveness of intramedullary screw fixation as the management of proximal 5th metatarsal zone II and III (Lawrence and Botte classification) fractures. We recommend this treatment modality as one of the techniques that provide optimal outcomes.

ABSTRAK

Pendahuluan : *Fraktur metatarsal merupakan fraktur tersering pada kaki dengan insidensi 6.7 per 10.000 orang. Fraktur metatarsal 5 terjadi pada 70% fraktur metatarsal. Fraktur proksimal metatarsal 5 zona II dan III memiliki vaskularisasi yang minimal dan dikenal sebagai* 'watershed area'. *Keadaan ini mengakibatkan tingkat dari waktu tertunda hingga* non-union *sekitar 50%. Studi ini meninjau efektivitas klinis dan fungsional dari fiksasi intrameduler dengan sekrup pada fraktur proksimal metatarsal zona II dan III.*

Metode: *Publikasi sejak tahun 2010-2020 pada basis data PubMed dan Scopus ditinjau secara sistematis menggunakan pedoman PRISMA dalam periode pencarian 1 Juni-10 Juli 2020. Kriteria inklusi pada penelitian ini adalah jurnal yang diterbitkan 10 tahun terakhir, atlet yang dilakukan fiksasi intrameduler dengan sekrup, waktu penyembuhan tulang atau durasi kembali berolahraga diukur, fraktur akut, periode tindak lanjut yang jelas, dan melaporkan komplikasi. Analisis statistik dilakukan menggunakan SPSS versi 23.*

Hasil: *Dari hasil pencarian sistematik dalam periode 2010-2020, sebanyak 146 kasus fraktur proksimal metatarsal 5 zona II dan III yang dilakukan fiksasi intrameduler dengan sekrup ditinjau secara sistematis dengan rata-rata tindak lanjut 5.6$\pm$3.1 tahun. Rata-rata waktu yang diperlukan hingga tulang menyatu secara radiologis adalah 8.5 minggu. Durasi kembali berolahraga rata-rata didapatkan 8.7 minggu, nilai rerata skor fungsional AOFAS untuk* midfoot *adalah 98.4. Adapun komplikasi yang dilaporkan adalah fraktur stres diafisis, nekrosis termal pada kulit, iritasi jaringan lunak,* non-union*, dan refraktur.*

Kesimpulan: *Studi terkini menunjukan efektivitas dari fikasi intrameduler dengan sekrup untuk tatalaksana fraktur proksimal metatarsal 5 zona II dan III (Klasifikasi Lawrence dan Botte). Kami merekomendasikan metode ini sebagai salah satu modalitas tatalaksana yang memberikan hasil terbaik.*

Keywords: Intramedullary screw fixation, Jones fracture, proximal fifth metatarsal fracture
https://doi.org/10.31282/joti.v3n2.55

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INTRODUCTION

Fractures of the metatarsal bones are the most common fracture area in the foot with a reported incidence of 6.7 fractures per 10,000 people. Fifth metatarsal fractures account for 70% of metatarsal fractures.[1,2] Dr. Robert Jones in 1902 described 5th metatarsal proximal fracture, and Lawrence and Botte classified it into 3 zones, namely zone I (tuberosity avulsion fracture due to excessive pedis inversion), zone II (metaphyseal fracture-diaphyseal junction, "True Jones Fracture"), and zone III (fracture in the diaphysis, distal to the tuberosity). Although only 20% of 5th metatarsal fractures occur, zones II and III are at risk for delayed union or malunion in up to 50% of all cases.[3,4]

Zone II and III have minimal vascularization and often disrupted when a fracture occurred, so as called "watershed areas". This condition results in a longer fracture healing time and even non-union. Zones II and III are often discussed together because of the similarities in management principles and outcomes.[5]

Unlike the management in zone I, which has reached a consensus, the management in zones II and III is still a matter of controversy; however, conservative management in these 2 zones is often associated with slower union times, as well as a high prevalence of non-union and refracture.

Although intramedullary screw fixation is often the chosen treatment for the proximal 5th metatarsal zone II and III fractures because of its simplicity and less invasive technique, some studies reported 4-12% of cases to occur with non-union, refracture, and screw breakage.[6] This study aims to evaluate the clinical and functional effectiveness of intramedullary screw fixation on proximal 5th metatarsal zone II and III fractures.[7]

METHODS

To test the hypothesis, a systematic approach was carried out according to the PRISMA Guidelines (Optional Reporting Items for Systematic Review and Meta-Analysis). In the early stage of the search, Pubmed and Scopus databases were systematically searched in a period of time from June 1st -July 10th, 2020. The keywords applied for searching strategy were shown in Table 1.

Three independent reviewers (BR. Hartanto, A. Priambodo, Rofi'i) separately conducted a systematic literature search. All journals were considered and relevant studies were analyzed. All articles reviewed must be published in a peer-reviewed journal for qualification. All articles were initially screened for relevance by title and abstract. The 3 reviewers separately read the abstracts from each publication. Full texts of the selected studies were reviewed to assess their suitability for inclusion and exclusion criteria then extract the relevant data to minimize selection bias and error. Disagreements between reviewers were resolved by means of discussion until consensus was reached (Figure 1).

Inclusion Criteria

The inclusion criteria used were as follows: (1) article that was written in English and published in the last 10 years, (2) study design was randomized controlled trial, cohort, or case-series study of intramedullary screw fixation on proximal 5th metatarsal zone II and III fractures in athlete population, (3) measure the duration of time to bone union or return to sport or using a standardized outcome measurement score, (4) acute proximal 5th metatarsal fractures, (5) clear follow-up duration, (6) reported complications.

Exclusion criteria

The exclusion criteria were (1) review articles, (2) cadaveric studies or animal studies, (3) other fracture or disease on the ipsilateral pedis, (4) other injury to the soft tissue interfering the patient's weight-bearing.

Data extraction

Each selected journal was evaluated for its methodological quality by 3 independent authors. Data were extracted according to the following: level of evidence, number of samples, duration of follow-up, mean of age, time to bone union, time of returning to sport, functional score after surgery, post-operative protocol, and complications. Data that had been extracted were cross-checked to improve accuracy. The studies characteristics are shown in Table 2.

Statistical analysis

Descriptive statistics were used to describe demographic and parameter characteristics, including the number of samples, mean of age, mean of follow up duration, time to bone union, time of returning to sport using mean, SD, and as appropriate. The analysis was performed using SPSS software version 23.

Table 1. Search strategy applied to database

No.	Search Terms
1	Proximal Fifth Metatarsal Fracture
2	Jones Fracture
3	1 OR 2
4	Intramedullary Screw Fixation
5.	3 AND 4
6.	3 AND 4 AND Athlete

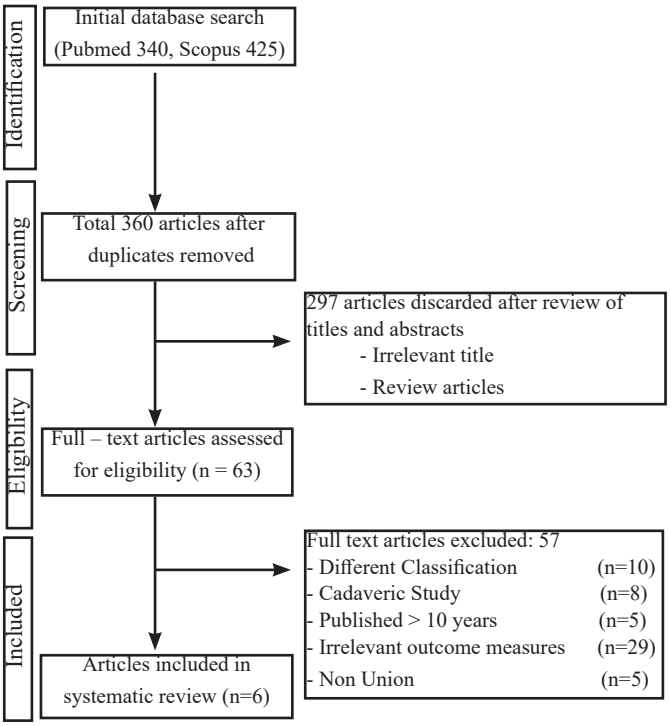

Figure 1. PRISMA flow chart

Surgical procedures

All studies reported their similar surgical procedures. Patients in all studies were operated under general anaesthesia using lateral or supine position, tilted 45 degrees towards the unaffected side to expose the lateral side of the foot fracture; 5 studies reported surgeries without using any tourniquet and 1 study used a tourniquet. The metatarsal base was approached through a small dorsolateral incision followed by a rhomboid dissection taking care not to injure the sural nerve. After that, the intervals between the tendons of the fibularis longus and brevis muscles were separated to reach the metatarsal bones. With the aid of fluoroscopy, Kirschner wire was inserted through the proximal tuberosity passing through the fracture site. After obtaining the optimal position, confirmed with AP, lateral, and oblique views, a screw with a diameter of 4-5 mm was inserted. The screw passed through the fracture site and the screw head was directed into the cortex to prevent interference from the midfoot movement.

RESULTS

Six case series articles met the inclusion criteria (level of evidence IV). From all studies, proximal 5th metatarsal zone II and III (Laurence and Botte classification) fractures were subjected to internal fixation using intramedullary screw fixation with fluoroscopy. After the procedure, time to bone union, time of returning to sport, and functional score using the AOFAS midfoot score (American Orthopaedic Foot and Ankle Society) were measured.

Outcomes of the treatment are shown in Table 3. There are total 146 cases of proximal 5th metatarsal zone II and III fractures which were underwent intramedullary screw fixation with a mean patient age of 23.5 years (SD $\pm$ 6.9) and a mean follow-up of 5.6 (SD $\pm$ 3.1) years. Four of the 5 studies measured the duration of bone union occurrence as measured radiologically from post-surgery with a mean of 8.5 weeks (SD $\pm$ 2.9). The time taken from postoperative to return to normal sport activities was measured in 5 of the 6 studies and a mean of 8.7 weeks (SD $\pm$ 2.9) was obtained, while the AOFAS midfoot functional score reported in 2 studies with a mean of 98.4. AOFAS midfoot score assessed pain (40 points), function (45 points), and alignment (15 points).

The complications reported on this operative method include 2 cases of a diaphyseal stress fracture on the tip of the screw, 1 case of thermal necrosis of the skin, 3 cases of irritation of soft tissue, and 2 cases of re-fracture, 1 case of non-union after 6 months, 2 cases experienced hardware pain required removal and 1 case of sural neuritis**.**

DISCUSSION

Proximal 5th metatarsal fractures often occur as a result of sport injuries and were first described by Sir Robert Jones in 1902 after he himself experienced it while dancing.[5,8] Understanding the anatomy of the proximal 5th metatarsal is very important and helps in making the appropriate treatment of choice. The proximal 5th metatarsal is vascularized by the collection of arterioles that enter through the non-articular surfaces of the tuberosity, while the diaphysis area is vascularized by nutrition arteries that enter mid-diaphysis and give longitudinal

Table 2. Studies Characteristics

Authors	Study design (level of evidence)	No. of Patients	Mean age (range) (years)	Years published	Journal	Mean follow up duration (years)
Tsukada et al.[7]	Case series (Level IV)	15	20	2012	Sports Medicine, Arthroscopy, Rehabilitation, Therapy & Technology Journal	4.1 (1.1-9.8)
Massada et al.[7]	Case series (Level IV)	17	19.9	2012	Acta Orto Bras Journal	4.5 (3.1-5.8)
Watson et al.[13]	Case series (Level IV)	26	20 (18-23)	2012	The Orthopaedic Journal of Sports Medicine	8.6 (1.5-20)
Pecina et al.14	Case series (Level IV)	20	21 (16-26)	2011	Journal of the American Podiatric Medical Association	10.3 (3.5-19)
Miller et al.	Case series (Level IV)	37	23	2018	European Society of Sports Traumatology, Knee Surgery, and Arthroscopy (ESSKA)	5.05 (SD±23.7)
Waverly et al.	Case series (Level IV)	31	37.45 ± 12.59	2017	Journal of Foot and Ankle Surgery	1.5 (SD±0.5)

branch proximally and distally. This anatomical condition of blood vessels causes watershed areas in the metaphysis-diaphysis junction, so the risk of delayed or non-union in fractures in this region tends to be higher.[9,10]

Lawrence and Botte in 1993 differentiated the 3 fracture zones at proximal to the 5th metatarsal. Zone I is an avulsion fracture of the tuberosity with or without the involvement of the tarsal-metatarsal joint caused by tension from the peroneus brevis tendon or lateral band of the plantar fascia during foot inversion.[11] Zone II fracture is a fracture at the metaphyseal-diaphysis junction involving the 4th and 5th metatarsal joint often caused by forced adduction of the forefoot while the hindfoot in the plantar flexion position. Zone III fracture is a fracture of the proximal diaphysis, distal to the fourth-fifth metatarsal articulation caused by an excessive load or chronic overload such as stress fracture. [10,12]

The choice of treatment for the 5th proximal metatarsal fracture depends on the classification of the fracture, other accompanying injuries, and the demographics of the patient.[15,12] Treatment of choice for zone II and III fractures are still frequently debated. Several studies have demonstrated that acute Jones fractures which are treated operatively manage to provide a faster clinical healing time and return to sport, especially in the athlete population.[16]

A study by Raikin *et al*. described that 90% of patients with Jones fracture have a varus deformity of the hindfoot, whereas the incidence of hindfoot varus in the normal population is approximately 24%.[17,18] Some of the operative management modalities that can be done in the proximal 5th metatarsal fractures include percutaneous fixation with an intramedullary screw, cortico-cancellous bone graft,[18] closed reductions with pinning using Kirschner wire fixation, tension band wiring, or open reduction and internal fixation with locking compression plate and screw.[19,20]

The operative technique that is most frequently chosen is the intramedullary screw fixation because according to previous studies it gives the most optimal results and reduces the re-fracture rate (Figure 2).[21] However, this screw insertion has several challenges, which requires high technique, especially when inserting a straight screw straight into an anatomically curved 5th metatarsal, the screw may break or penetrate the cortex excessively, metatarsalgia, causing rupture of the peroneus brevis tendon, irritation of the sural nerve, and inaccurate reduction may also be obtained.[22,23]

A compression locking plate is frequently used recently because it can achieve a fixation that is believed to be more stable despite the bad quality of the bone as a result of bone loss and the lower risk of loss of reduction.

Table 3. Outcome from Intramedullary Screw Fixation

Authors	Treatment	Time To Bone Union (weeks)	Time of Return to Sport (weeks)	AOFAS Functional Score	Post-Operative Protocol	Complications
Tsukada et al.[7]	Intramedullary Screw Fixation	8.4 (6-12)	12.1 (9-17)		Non-Weight bearing in a splint or cast for 2 weeks. Non-weight bearing without external stabilization for an additional two weeks. Full weight-bearing was allowed six weeks post-operatively.	Diaphyseal stress fractures at the distal tip of the screw, thermal necrosis of skin
Massada et al.[7]	Intramedullary Screw Fixation	7.3	7.5 (2-12)	95	Immediate progressive total weight-bearing with the functional orthosis and external support. Sports was partially limited for six-week post-surgery	No Complication
Watson et al.[13]	Intramedullary Screw Fixation		4.6 (3-6)		Phase 1: Toe-touch Weight-bearing in crutches; Phase 2: Full weight-bearing in a walking boot, bone stimulator and ankle exercise; Phase 3: Walking boot replaced with training shoes with rigid inserts; Phase 4: Full weight-bearing running at full intensity; Phase 5: Full Sport Participation. Time inter-phase: 4-7 days	Soft tissue irritation, Refracture
Pecina et al.[14]	Intramedullary Screw Fixation		9 (5-14)	93.8	Non-weight-bearing with short-leg cast for 3 weeks; weight-bearing in a hard-soled shoe. Sports are restricted for the first 6 weeks	Refracture
Miller et al.	Intramedullary Screw Fixation	12.7±6.5	10.5 (SD ± 3.4)		Non-weight bearing 0-2nd week Partial weight bearing with short boot 2nd-4th week Full weight-bearing in a short boot from 4th-6th week	Non-union after 6 months
Waverly et al.	Intramedullary Screw Fixation	5.7±1.47			Immediate weight-bearing in a CAM boot for the first 2 weeks, transitioned to athletic shoes with low impact exercise for the next 4 weeks	Painful hardware required removal including sural neuritis

However, the high cost of the locking compression plate makes this method not applicable everywhere.[24]Extra-portal, Rigid, Innovative[25] The use of Kirschner wire with tension band wiring fixation has also been reported to provide good results, the problem with this method is hardware intolerance, especially for athletes who do strenuous activities.[19,26]

This study has several limitations; thus, it is still necessary to conduct further studies differentiating acute fracture, refracture, and non-union cases. This study also lacks data on the duration from fracture to surgery and the mechanism of injury that causes the fracture. In addition, the type of screws used in the intramedullary screw fixations, such as cannulated and non-cannulated, are also not discussed yet in this study. From this systematic review, no high level of evidence research has been found for the past ten years, so randomized controlled trial research needs to be carried out in the future so that it can provide stronger conclusions.

CONCLUSION

The current study yields an optimal outcome of intramedullary screw fixation as the management of proximal 5th metatarsal zone II and III (Lawrence and Botte classification) fractures. We recommend this treatment modality as one of the techniques that provide an optimal outcome.

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