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Minimally invasive reduction and percutaneous fixation *versus* open reduction and internal fixation for displaced intra-articular calcaneal fractures: a systematic review of the literature

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- The aim of this article is to systematically identify and analyse research evidence available to compare the outcomes of minimally invasive reduction and percutaneous fixation (MIRPF) *versus* open reduction and internal fixation (ORIF) for displaced intra-articular calcaneal fractures.
- Articles from 2000 to 2016 were searched through MEDLINE (PubMed), Cochrane Library, Embase, ScienceDirect, Scopus and ISI Web of Knowledge using Boolean logic and text words. Of the 570 articles identified initially, nine were selected including three randomized controlled trials and six retrospective comparative studies.
- All nine studies had a total of 1031 patients with 1102 displaced intra-articular calcaneal fractures. Mean follow-up was 33 months. Of these, 602 (54.6%) were treated with MIRPF and 500 (45.4%) were treated with ORIF.
- Overall incidence of wound-related complications in patients treated with MIRPF was 4.3% (0% to 13%) compared with 21.2% (11.7% to 35%) in the ORIF group
- Functional outcomes were reported to be better in the minimally invasive group in all studies; however, the results did not reach statistical significance in some studies. All the studies had methodological flaws that put them at either 'unclear' or 'high' risk of bias for multiple domains.
- Overall quality of the available evidence is poor in support of either surgical technique due to small sample size, flaws in study designs and high risk of bias for various elements. Individual studies have reported minimally invasive techniques to be an effective alternative with lower risk of wound complications and better functional outcomes.

Keywords: intra-articular fractures; percutaneous fixation; minimally invasive technique

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Introduction

Calcaneal fractures comprise 2% of all fractures in the human body.^{1,2} They are the most common fractures in the tarsal bones, accounting for 60% of all tarsal fractures.³ Most calcaneal fractures (60%) occur in patients who are still at a wage-earning age (i.e. 30 to 50 years).⁴ Approximately 75% of these are displaced and intra-articular fractures (DIACFs).⁵ These fractures typically result from high-energy trauma; however, they can also result after low-energy injuries, especially in females aged > 60 years.² Patients usually present with a painful, swollen and bruised heel and arch of the foot. Significant swelling may lead to blistering of the skin. Approximately 15% of all calcaneal fractures have an associated open wound and 5% to 10% involve both heels.⁶

Surgical treatment

The optimal management of displaced intra-articular calcaneal fractures remains controversial.^{7,8} Surgical options include open reduction and internal fixation (ORIF), minimally invasive reduction with percutaneous fixation (MIRPF) or primary arthrodesis. Controversies and variable opinion exist among foot and ankle surgeons regarding the choice of operative or non-operative treatment. The results of a prospective randomized controlled trial (RCT) from Canada comparing operative and non-operative treatment of DIACFs suggested that without stratification of the groups, the functional results were equivalent in both groups. However, after unmasking the data by

removing patients who were receiving workers' compensation, the outcomes were significantly better in some groups of surgically treated patients.⁹ The results of another RCT from the UK comparing the operative and non-operative treatments for these fractures reported that the outcomes after ORIF were no better than after non-operative treatment at two years, with higher complications in the operative groups.¹⁰ However, the UK heel trial was heavily criticized by Pearce et al in view of high selection bias, recruiting only 30% of the total eligible patients (as the others did not wish to be included) and only two years of follow-up.¹¹ Another recently published multi-centre RCT from Sweden showed that patient-reported clinical, functional and quality-of-life outcomes were better after operative treatment at 8 to 12 years of follow-up.¹² Despite the advancements in surgical techniques, surgical fixation is still technically challenging and carries the risks of complications, such as wound infection, sural nerve injury and failure of the implants.^{3,13-15}

Open reduction and internal fixation

ORIF with plate and screws (locking or non-locking plates) via an extensile lateral L-shaped approach has been regarded as a standard surgical method for DIACFs because it provides an excellent exposure and allows direct reduction.¹⁶ However, it has been fraught with high incidence of wound-related complications (5.8% to 35.3% reported in various studies), including wound edge necrosis, dehiscence, deep infection, haematoma, damage to sural nerve and increased length of operating time due to the meticulous technique required for preparation and closure of the wound.¹⁷⁻²²

Minimally invasive reduction and percutaneous fixation

To lower these complications, various minimally invasive procedures have been employed in clinical practice, including percutaneous reduction and internal fixation, arthroscopically assisted fixation and minimal incision techniques via medial, modified lateral, posterior or combined approaches.²³⁻²⁶ These techniques were mainly recommended for Sanders type II and type III fractures and good results have been reported in some studies.^{13,27} The quality of reduction is debatable after minimally invasive techniques and the additional use of subtalar arthroscopy may assist in a better estimation of fracture reduction and potentially improving the overall outcomes.^{23,25}

The economic impact of calcaneal fractures on patients and society is considerable and is a consequence of extended hospital stay, cost of treatment, residual pain, time to mobilization and delayed return to work.²⁸ Time to resume professional work could be as much as five to ten months,⁹ and a considerable number of patients may not be able to resume their pre-injury level of work.^{4,29} Current literature lacks a comprehensive review to assess the quality and

strength of available evidence to support the use of either surgical approach.

Methodology

The aim of this article is to systematically identify, assess for quality and synthesize research evidence available relating to the use of MIRPF *versus* ORIF for DIACFs. The objectives were to identify methodological studies comparing the practice of minimally invasive reduction techniques with the standard and traditionally used open reduction technique, evaluate the quality of the available studies against set criteria, synthesize the results of the studies and relate their implications to routine surgical practice in the management of calcaneal fractures.

Literature search

Inclusion criteria

Studies reporting the outcomes of acute (within three weeks), closed displaced intra-articular calcaneal fractures (Sanders types II, III and IV) in patients aged > 16 years, and comparing the outcomes of MIRPF with ORIF using the extensile lateral approach, were included.

Exclusion criteria

Studies were excluded if they reported the results of open calcaneal fractures, fractures associated with multiple other injuries and neurological or vascular injuries, non-operative treatment of calcaneal fractures, comparison of non-operative treatment with surgical treatment, open reduction alone or minimally invasive surgery alone.

Electronic database search

A search was performed from the years 2000 to 2016. The search was limited to articles in the English language only. The databases that were searched included MEDLINE (PubMed), Cochrane Library (Cochrane Systematic Reviews and Cochrane Bone, Joint and Muscle Trauma Group), Embase, ScienceDirect, Scopus and ISI Web of Knowledge.

Search strategy

The National Library of Medicine's (NLM) Medical Subject Headings (MeSH) terms were selected and used along with text words. MeSH terms provided a consistent way to retrieve information where different terms had been used by authors for the same concept.

Types of studies

Two types of relevant study designs were identified: RCTs and comparative retrospective studies, which directly compared the outcomes of the two surgical approaches. Retrospective studies were included in the review because of the limited types and number of studies available.

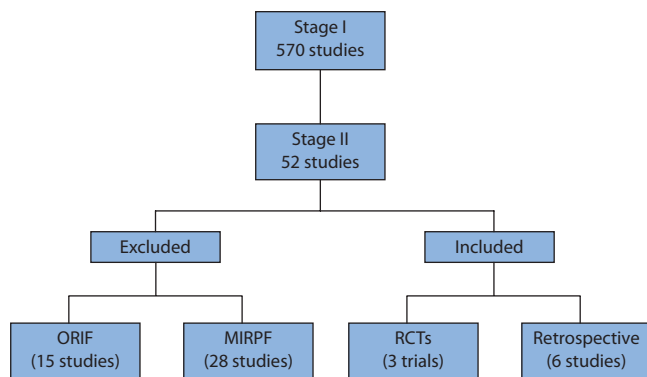


Fig. 1 Flow chart of selection of studies

Data extraction

Data extraction was carried out keeping the focus on maintaining quality and research objectives. A standardized extraction form (Microsoft Excel®, Microsoft®, Redmond, WA, USA) was used. The parameters used addressed the concepts of bias and variability and the quality of the reporting. Clear definitions for the responses of ‘yes’, ‘no’ and ‘unclear’ were recorded against each parameter (Table 1). Two of the authors (HM and JB) independently examined the titles and abstracts of the articles identified in the search as potentially relevant trials and studies and reached a consensus.

In the first stage, the apparent studies according to the title or abstract were identified. In the second stage, the studies that fulfilled the inclusion criteria were identified. Later, full texts of these articles were obtained. Endnote® (Thomson Reuters, New York, USA) software was used to organize and manage the articles throughout the process of manuscript preparation.

Appraisal of quality of studies

Two of the authors (HM and WM) independently examined the titles and abstracts of the articles for quality appraisal. PICO method (Population, Intervention, Comparison and Outcome) and CASP tools (Critical Appraisal Skills Programme) were used to appraise the selected studies and their results, examine their validity, analyse their results and appraise their applicability and generalizability in clinical practice.

A two-tailed *t*-test was used to analyse the significance of timing of surgery and incidence of wound-related complications in the two groups. Fisher’s exact test was used to analyse the categorical values in the data. A *p* value < 0.05 was considered significant. The reasons for inclusion and exclusion were documented for each study and there were no disagreements between the authors.

Results

In stage I, 570 articles were identified that related to surgical management of calcaneal fractures. In stage II, 52 articles were identified that related to the use of the two surgical techniques. Their titles and abstracts were reviewed, and by following the inclusion and exclusion criteria nine articles were selected for final inclusion (Fig. 1).

Combined results of RCTs and retrospective studies

The literature search identified three RCTs and six comparative studies, which directly compared the results of the two methods of fixation. Basic demographic data of the included studies is summarized in Tables 1 and 2. All the studies were approved by the relevant ethics committees and Institutional Review Board (IRB) of the individual institutions where they were performed and essential ethical standards were followed.^{13,14,16,18,22,30-33} Informed consent was obtained from all the patients in each study before their enrolment. All these studies had similar inclusion and exclusion criteria for patient recruitment. Displacement was defined as ‘more than 2 mm gap’ at the fracture site in eight studies and as ‘more than 1 mm gap’ in one study.³⁰ Patients with diabetes were excluded in one study¹³ and patients with alcohol excess and drug users were excluded in two studies.^{31,33}

Patient population and intervention

The nine included studies had a total of 1031 patients (average 114 per study; range 42 to 329) with 1102 displaced intra-articular calcaneal fractures (average 122; range 45 to 383) (Table 2). The weighted average follow-up was 33 months (12 to 77). Of these 1102 fractures, 602 (54.6%) were treated using MIRPF and 500 (45.4%) were treated with ORIF. The mean age of the patients in the minimally invasive group was 40 years and in the ORIF group it was 39 years.

Intervention based on fracture classification

All these studies defined the fracture types based on CT scans according to Sanders’ classification system. Table 3 describes the number of patients with each fracture type and the intervention based on their classification groups.

Duration from injury to surgery

All the studies provided the duration from injury to surgery. The average combined duration in the minimally invasive group was 6.8 days and in the open reduction group it was 9.4 days, which was not statistically significant (*p* > 0.05). The main decision factor in the timing of surgery described in all the studies was the condition of soft tissues (i.e. swelling, blisters) (Table 4).

Table 1. Quality appraisal of the included studies

Study	Study design	Sample size	Mean age (years)	Mean age (years)	Mean age (years)	Randomization	Inclusion/exclusion criteria	Fracture classification described	Surgical technique described	Wound complications described	Radiological assessment	Validated functional assessment	Statistical analysis	Mean follow-up (months)	Allocation bias avoided	Incomplete outcome data avoided	Assessment bias avoided	Selective reporting avoided	Observer bias avoided	Bias due to lack of power avoided
Xia et al	PR	108	38	37	37	Y	Y	Y	Y	Y	XR	Y	Y	19	N	N	N	N	Y	N
Kumar et al	PR	42	31	30	30	Y	Y	Y	Y	Y	CT	Y	Y	12	N	N	Y	U	Y	N
Chen et al	PR	78	31	32	32	Y	Y	Y	Y	Y	CT	Y	Y	24	Y	U	N	Y	Y	N
De Boer et al	R	110	44	41	41	N	Y	Y	Y	Y	XR	Y	Y	72	Y	N	N	Y	N	N
Kline et al	R	112	46	42	42	N	Y	Y	Y	Y	CT	Y	Y	30	Y	N	N	Y	N	N
Wu et al	R	329	39	41	41	N	Y	Y	Y	Y	SCT	Y	Y	12	Y	N	N	N	N	N
De Wall et al	R	120	40	41	41	N	Y	Y	Y	Y	SCT	Y	Y	23	Y	N	N	N	N	N
Weber et al	R	50	40	42	42	N	Y	Y	Y	Y	SCT	Y	Y	28	Y	N	N	N	N	N
Biz et al	R	82	53	46	46	N	Y	Y	Y	Y	Y	Y	Y	77	Y	Y	Y	Y	Y	Y

PR, prospective randomized controlled trial; R, retrospective; MIRPF, minimally invasive reduction and percutaneous fixation; ORIF, open reduction and internal fixation; XR, X-ray (plain radiograph); CT, computed tomography; SCT, selective use of CT; Y, yes; N, no; U, unclear

Wound-related complications

The average combined reported incidence of wound-related complications in patients treated with MIRPF was 4.3% (0 to 13%) compared with 21.2% (11.7% to 35%) in the ORIF group (p = 0.005) (Table 4). Infections were described in all studies as either superficial wound infection or deep bony infection.

RCTs versus retrospective studies

The three RCTs had a total of 228 patients (range 42 to 108) with 240 displaced intra-articular calcaneal fractures (range 45 to 117).^{13,30,34} The average follow-up was 18.3 months (12 to 24). The average duration was 2.5 years per trial (1.5 to 3.5). Six retrospective studies had a total of 803 patients (range 50 to 329) with 862 displaced intra-articular calcaneal fractures (range 50 to 383).^{16,18,22,31-33} The average follow-up was 40 months (12 to 77).

Randomization

In the RCTs by Xia et al¹⁴ and Kumar et al,³⁰ randomization methodology and protocols were clearly described; however, in the RCT by Chen et al,¹³ the patients were randomly allocated into two groups and the authors did not describe any specific randomization protocol.

Wound-related complications

Among the three RCTs, the combined incidence of wound-related complications was 0.8% (1 of 124 fractures) in patients treated with MIRPF compared with 18.9% (22 of 116 fractures) in patients treated with ORIF (p < 0.05). Among the retrospective studies, the combined incidence of wound-related complications was 5.2% (25 of 478 fractures) in patients treated with MIRPF in comparison with ORIF where it was 19.5% (75 of 384 fractures) (p < 0.05).

Functional outcomes

The authors in all three RCTs reported the functional outcomes based on commonly used functional scores. Xia et al¹⁴ and Chen et al¹³ used the Maryland Foot Score (MFS) and reported significantly better results in the MIRPF group than in the ORIF group (p < 0.01). Chen et al¹³ used the American Orthopaedic Foot and Ankle Society hind foot score (AOFAS) for functional assessment in their patients, based on which the patients in the MIRPF group obtained better functional scores than the ORIF group (91.7 vs 85.8, p < 0.01). Kumar et al³⁰ assessed the functional outcome using the Creighton Nebraska Health Foundation Assessment Scale (CNHFA).³⁵ The scores were better in the MIRPF group, although the differences were not found to be significant at six weeks after surgery but were found to be significantly better at the 12-week and 12-month follow-ups (p = 0.013). Among retrospective studies, the combined average AOFAS reported was 84.9 in the minimally invasive group and 81.3 in the ORIF

Table 2. Basic demographic data

Studies	Year published	Duration (years)	Type of study	Patients (n)	Fractures (n)	MIRPF	ORIF	Mean follow-up (months)
Xia et al	2014	3.5	RCT	108	117	64	53	19
Kumar et al	2014	1.5	RCT	42	45	22	23	12
Chen et al	2011	2.5	RCT	78	78	38	40	24
De Boer et al	2014	10	Retrospective case-control	110	110	61	49	72
Kline et al	2013	3	Retrospective case series	112	112	33	79	30
Wu et al	2012	6	Retrospective case-control	329	383	213	170	12
De Wall et al	2010	7.5	Retrospective case-control	120	125	79	41	23
Weber et al	2008	11	Retrospective case-control	50	50	24	26	28
Biz et al	2016	7	Retrospective case-control	82	87	68	19	77
Total				1031	1102	602	500	33

MIRPF, minimally invasive reduction and percutaneous fixation; ORIF, open reduction and internal fixation; RCT, randomized controlled trial

Table 3. Intervention based on fracture classification

Studies	Type 2 treated with MIRPF	Type 2 treated with ORIF	Type 3 treated with MIRPF	Type 3 treated with ORIF	Type 4 treated with MIRPF	Type 4 treated with ORIF
Xia et al	39	31	25	22	0	0
Kumar et al	7	9	2	10	6	11
Chen et al	29	32	9	8	0	0
De Boer et al	46	38	12	10	2	1
Kline et al	20	42	13	27	0	0
Wu et al	115	92	74	61	24	17
De Wall et al	32	19	27	15	5	1
Weber et al	20	20	15	19	0	0
Biz et al	29	8	21	10	18	1
Total	337	291	198	182	55	31

MIRPF, minimally invasive reduction and percutaneous fixation; ORIF, open reduction and internal fixation

Table 4. Wound-related complications and timing of surgery

Studies	Wound complications MIRPF (n (%))	Wound complications ORIF (n (%))	Injury to surgery MIRPF (days)	Injury to surgery ORIF (days)
Xia et al	Nil	10 (15)	7.4	7.4
Kumar et al	Nil	7 (30)	8.6	12.4
Chen et al	1 (1.2)	5 (12.5)	5	10
De Boer et al	8 (13)	8 (16)	2	6
Kline et al	2 (6)	23 (29)	10	15
Wu et al	4 (1.8)	20 (11.7)	5.7	5.7
DeWall et al	5 (6)	15 (35)	9.3	13.6
Weber et al	1 (4.2)	4 (15.3)	8	8
Biz et al	5 (7.3)	5 (26.3)	5.5	7
Total	25 (4.3)	93 (21.2)	6.8	9.4

MIRPF, minimally invasive reduction and percutaneous fixation; ORIF, open reduction and internal fixation

group ($p = 0.83$).^{22,31-33} The average mental component of Short-Form 36 (SF-36) was similar in the two groups without any significant differences in the three studies ($p = 0.49$, $p = 0.86$ and $p = 0.05$, respectively).^{16,18,31,33} The studies that analysed the Foot Function Index (FFI) found the results to be clinically better in the minimally invasive group but the results did not reach statistical significance.^{16,18,22,31-33} The EuroQol-5D (EQ-5D) utility score was analysed by De Boer et al³¹ and the Visual Analogue Scale (VAS) score was assessed by De Boer et al and Kline et al.¹⁶ However, none of these scores were reported to be significantly different in the two groups.

All three RCTs assessed the subtalar and the ankle joint movements in their patients after surgery and reported the

results to be significantly better in the minimally invasive group ($p < 0.01$).^{13,14,30} Among the retrospective studies, only two studies analysed the subtalar joint motion after surgery.^{18,31} De Boer et al reported 61% patients with stiffness in the minimally invasive group compared to 85% in the ORIF group ($p = 0.003$). In contrast, De Wall et al did not find any significant difference in the range of motion of the ankle and the subtalar joints in either group.

Return to work

Kumar et al³⁰ reported that the average time to return to work in their patients treated with MIRPF was 14 weeks and in patients treated with ORIF was 16 weeks. The other two RCTs did not analyse return to work duration.^{13,14}

Only one retrospective study assessed the duration to return to work after surgery.³¹ It was an interesting finding that a significantly higher number of patients returned to work in the ORIF group compared with the patients in the MIRPF group (96% vs 75%, respectively, $p = 0.04$). Another retrospective study reported 82.3% of patients who managed to return to work in the ORIF group compared with 58.7% in the MIRPF group; however, the authors did not comment on the duration to return to work.³³

None of the RCTs described the duration of completion of fracture healing in their analysis. However, there were no reported nonunions. None of the RCTs assessed the outcomes of calcaneal fractures specifically in relation to smoking or diabetes, which are considered two of the important risk factors for potential post-operative complications.^{19,36}

Discussion

Various authors have reported better results of clinical and functional outcomes after minimally invasive surgery compared to the open approach; however, it is difficult to establish robust evidence to support their findings.^{23,34,37-44} All the included studies in this review had a similar distribution of age, gender and fracture characteristics. The authors reported the outcomes of clinical, radiological and functional parameters using patient-reported outcome measures. The patient groups were comparable except in three studies where they were significantly disproportionate.^{16,18,25}

Risk of bias

Overall, all the studies had methodological flaws that put them at either 'unclear' or 'high' risk of bias for multiple domains. Two RCTs were at low risk of bias in their blinding methods as they were performed either by lottery method before obtaining CT scans³⁰ or by coin tossing without any influence of the treating surgeons.¹⁴ One RCT insufficiently described methodology of its blinding process.¹³ All comparative studies were at high risk of bias as no blinding was carried out due to their retrospective design. There was a low risk of allocation bias in one trial due to lack of influence of the operating surgeons in either treatment group.¹⁴ Table 1 describes various other types of bias identified in these studies.

Effects of treatment

All the authors in the included studies have reported variable outcomes based on the functional scores. The RCTs reported the functional outcomes to be significantly better in patients treated with minimally invasive techniques.^{13,14,30} The retrospective studies did not find a statistically significant relation with treatment, either in the overall scores or in the individual subdomains between

the two treatment groups. However, there was a trend noticed towards slightly better scores in the minimally invasive group in all these studies.

Conclusion

Overall, the quality of the evidence is limited. Three trials had a small sample size. The retrospective studies had a relatively larger patient population but were limited due to flaws in their study design. The traditional surgical approach for displaced intra-articular calcaneal fractures with ORIF via the extensile lateral approach has been considered to provide better exposure of the anatomy of the fractures; however, it does carry significantly higher risk of wound-related complications (11.7% to 35%) despite the use of meticulous technique. Studies have reported the MIRPF to be an effective and safe alternative to obtain comparable clinical, functional and radiographic results with significantly lower incidence of wound-related complications (0 to 13%). The authors acknowledge that the present literature lacks robust evidence in their support due to various forms of bias and reporting flaws. In order to obtain robust evidence, ideally we require a high-quality RCT with a large number of patients and strict protocols; however, it is not always possible to randomly allocate patients with varying severity of fractures to a particular form of treatment.

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ICMJE CONFLICT OF INTEREST STATEMENT

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