The effect of time to post-operative weightbearing on functional and clinical outcomes in adults with a displaced intra-articular calcaneal fracture; a systematic review and pooled analysis

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Keywords: Weightbearing, Calcaneal fractures, Böhler, AOFAS

ABSTRACT

Background: Post-operative weightbearing guidelines for displaced intra-articular calcaneal fractures (DIACF) have been pragmatically developed in the past, however hardly adapted to current health care insights. A period of six to nine weeks of non-weightbearing is usually recommended. It is unknown whether an earlier start of weightbearing is advisable.
Objectives: The primary aim was to evaluate the effect of time to post-operative weightbearing on Böhler's angle. Secondary aims were to determine the effect on functional outcome (*e.g.,* The American Orthopedic Foot and Ankle Society Scale), post-operative pain score, complications (*e.g.,* infections, nonunion, implant removal), and revision surgeries. Finally, the effect of bone void filling on these outcomes was investigated.
Data source: A literature search was performed on January 24, 2017 in the Cochrane Library, Medline Ovid, Embase, Web of Science, Google Scholar, and CINAHL.
Literature selection: Studies reporting on operatively treated patients with a DIACF and time to weightbearing were eligible for inclusion. Studies were excluded when not reporting primary data, solely reporting on open fractures, bilateral fractures, or polytrauma patients. Based upon the time to starting partial weightbearing, patient cohorts were stratified into very early (0-4 weeks), early (4-6 weeks), intermediate (6-8 weeks), or late (8-12 weeks) start of partial weightbearing.
Data extraction: Two investigators extracted data independently using a predefined data sheet.
Results: After applying exclusion criteria, 72 studies remained eligible for analysis. Böhler's and Gissane's angles, calcaneal height, AOFAS, pain scores, and complications had overlapping confidence intervals in all weightbearing groups.
Conclusion: The adverse sequelae which are assumed to be associated with starting partial weightbearing already within six weeks after internal fixation of calcaneal fractures, is not supported by literature data. This systematic review suggests that early weightbearing does not result in impaired outcomes compared with more conservative weightbearing regimes.

INTRODUCTION

After fracture reduction of displaced intra-articular calcaneal fractures (DIACFs), it is important to avoid fracture displacement during rehabilitation. In order to maintain reduction, the initial guidelines developed by the Arbeitsgemeinschaft für Osteosynthesefragen (AO) described non-weightbearing until fracture healing was radiographically proven, back then usually after three months (1). Despite improved operation techniques and materials which allow earlier weightbearing without displacement or implant failure since then, the current guidelines are not much adjusted and non-weightbearing is often recommended for six to nine weeks (2-4). To reduce the risk of secondary displacement this period is followed by increased restricted weightbearing as tolerated (5).

Non-weightbearing is negatively contributing to long-term rehabilitation and associated high socio-economic costs (4-8), it also affects patients' physical conditions by decreasing muscle strength and bone mass (8-10). Early partial weightbearing might be a safe option, reduce these physical disadvantages and accelerate mental and physical recovery, daily activities, and work resumption (11). It is unknown whether early (progressive) weightbearing after calcaneal surgery is as safe as the often recommended start of weightbearing after six to nine weeks.

Objectives

The primary aim of this systematic review was to evaluate the effect of time to post-operative weightbearing on Böhler's angle in operatively treated adult patients with a closed DIACF. Secondary aims were to determine the effect of early weightbearing on post-operative pain, (wound related) complications, functional outcomes (*e.g.,* The American Orthopedic Foot and Ankle Society Scale (AOFAS)), and revision surgeries (*i.e.,* implant removal). Finally, the effect of bone void filling on these radiographic parameters, functional outcomes, complications, and revision surgeries was evaluated.

METHODS

Search strategy

This systematic review and pooled analysis was conducted following the PRISMA guidelines (12). To assess the methodological quality of studies, the methodological items for non-randomized studies (MINORS) instrument was used (13). The global ideal score is 16 for non-comparative studies and 24 for comparative studies (13). A literature search was performed on January 24, 2017 in the Medline Ovid, Cochrane Central Register of Controlled trials, Embase, Web of Science, Google Scholar, and CINAHL. The databases were searched on the terms related to 'weightbearing' combined with 'intra-articular', 'calcaneal fractures', and their abbreviations and synonyms. The full search strings per database are shown in Supplement Table 1.

Inclusion criteria were; studies reporting on patients with a displaced intra-articular calcaneal fracture that were treated operatively with internal fixation. Also, the moment at which weightbearing started had to be mentioned explicitly. Exclusion criteria were; studies that did not report primary data for the operatively treated patients, studies that solely reported on open fractures, bilateral fractures, or polytrauma patients, and studies that reported on fractures in patients with congenital deformities of the foot. Furthermore, non-clinical or clinical studies with a level of evidence higher than five according to Mahid *et al*. (*e.g.,* case reports (level VI), opinions (level VII)) were excluded (14). There was no language restriction or time period selection.

Selected studies were screened on title and abstract for the exclusion criteria by two investigators (ASDB and GVM) independently (15). Inconsistencies were resolved by consensus. If a full-text version of a manuscript was not available for the investigators, a request for the full-text version was sent to the author. If no response was received, a single reminder was sent after two weeks.

Data extraction

Two investigators (ASDB and GVM) extracted the data independently, again inconsistencies were resolved by consensus. Study design, patient characteristics, treatment characteristics, injury characteristics, radiographic parameters (*i.e.*, Böhler's and Gissane's angle pre-operatively, post-operatively, and at follow-up, and arthrosis), visual analog scale (VAS) for pain (16), complications (*e.g.,* superficial infection (*i.e.,* can be treated non-operatively, *e.g.*, using oral antibiotics), deep infection (*i.e.,* requiring surgical intervention, readmission or intravenous antibiotics) (17), necrosis, nonunion), functional outcomes (*e.g.,* AOFAS), implant removal (due to implant failure or symptoms), and weightbearing regimes (*i.e.*, time to partial weightbearing and full weightbearing) were extracted.

The time to partial weightbearing was stratisfied into four groups: very early (0-4 weeks), early (4-6 weeks), intermediate (6-8 weeks), and late (8-12 weeks). The time to full weightbearing was stratisfied into three groups: early (0-8 weeks), intermediate (8-12 weeks), and late (> 12 weeks).

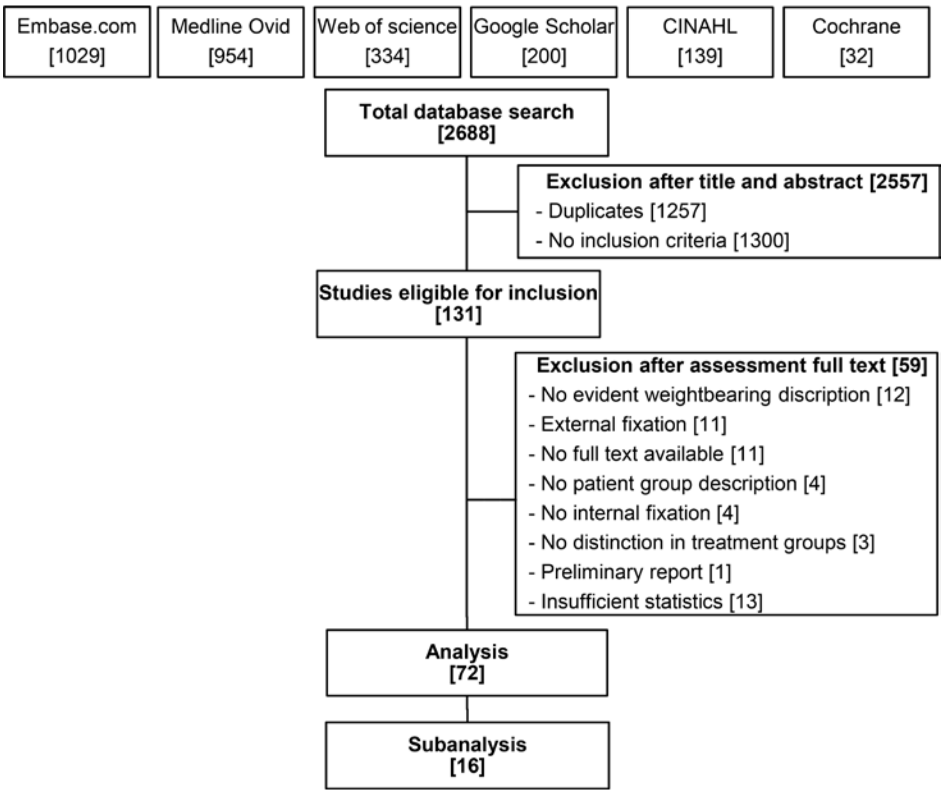
Statistical analysis

Radiographic parameters, functional outcome scores, and complication rates for both partial and full weightbearing were pooled using MedCalc for Windows, version 16.4.3 (MedCalc Software bvba, Ostend, Belgium; https://medcalc.org;2016 MedCalc). Pooled estimates are reported with their 95% confidence intervals (CI). Heterogeneity was quantified with Cochran's Q test and I^2 statistic, a fixed effects model was used when the I^2 was < 40%. A random effects model was used for the pooled analysis when the heterogeneity test was ≥ 40%. A subanalysis was performed for internal fixation combined with a bone void filling (*i.e.,* autologous, allogenic bone grafts or synthetic bone void fillers).

RESULTS

A total of 2,688 studies were found with the initial database searches (Figure 1). After removal of duplicate studies and selecting the studies on title and abstract, 131 studies remained. After reading the full-texts, 59 studies were excluded based on predefined exclusion criteria. In total, 72 studies (86 cohorts, 6,064 patients) were analyzed in this review. Patients were stratified into a partial, full, or both weightbearing groups. The partial weightbearing group analysis included 507 patients (nine cohorts) in the very early partial weightbearing group; 327 patients (six cohorts) in the early partial weightbearing; 1,461 patients (26 cohorts) in the intermediate partial weightbearing, and 1,964 patients (34 cohorts) in the late partial weightbearing group. In the full weightbearing groups 2,921 patients were analyzed; 318 patients (five cohorts) in the early full weightbearing; 871 patients (10 cohorts) in the intermediate full weightbearing; and 1,732 patients (34 cohorts) in the late full weightbearing group. A subanalysis of 16 studies (518 patients in 16 cohorts) was done for internal fixation combined with bone void fillers.

Figure 1. Flowchart of literature search



The pooled analysis included studies with different methodological quality (Supplemental Table 1): eight randomized controlled trials, 31 prospective studies (two case series, three case control and 26 cohort studies, with MINORS ranging from 3 to 21) and 33 retrospective studies (one chart review, four case series, and 28 cohort studies, with MINORS ranging from 5 to 20).

Radiographic parameters

Böhler's angles at three moments; pre-operative, post-operative, and at follow-up differed only marginal between the weightbearing groups (Figure 2 and Table 1). The 95% CI in pre-operative Böhler's angle overlapped in all partial weightbearing groups: early 7° [95% CI, -3-18] and late 4° [95% CI, 1-6°]. Also, in the post-operative Böhler's angle the 95% CIs overlapped 27° [95% CI, 26-29°] in the early and 27° [95% CI, 24-30°] in the late partial weightbearing group. In addition, overlap of the 95% CI was found in the Böhler's angle at final follow-up: 25° [95% CI, 23-27°], 23° [95% CI, 21-25°], and 24° [95% CI, 17-32] in the early, intermediate, and late partial weightbearing groups, respectively. There were not enough data to determine Böhler's angles in the very early partial weightbearing.

Table 1. Radiographic outcomes, functional outcomes, and, after partial weightbearing in patients with a DIACF

Outcome	Partial WB	N_s	N_p	N_f	Q	P-value	I^2 (95% CI)	Method	Pooled estimate
Böhler pre	Very early*								
	Early	3	76	76	1120	<0.001	99.8 (99.8-	Random	7.3 (-3.2-17.8)
	Intermediate	8	384	451	22	0.002	69 (34.4-85.0)	Random	3.1 (1.2-5.1)
	Late	6	333	407	67	<0.001	93(86.4-95.9)	Random	3.8 (1.1-6.4)
Böhler post	Very early*								
	Early	4	93	93	11	<0.001	73 (22.5-90.3)	Random	27.5 (25.8-29.1)
	Intermediate	8	553	577	29	<0.001	76 (52.1-88.0)	Random	28.4 (27.2-29.8)
	Late	5	317	391	67	<0.001	94 (88.9-96.8)	Random	26.7 (23.5-29.9)
Böhler FU	Very early*								
	Early	3	49	49	8	0.017	76 (19.1-92.6)	Random	25.0 (22.9-27.2)
	Intermediate	8	531	633	62	<0.001	89 (79.9-93.6)	Random	22.7 (20.7-24.6)
	Late	4	139	156	102	<0.001	97 (94.8-98.3)	Random	24.2 (16.6-31.8)
Gissane pre	Very early*								
	Early*								
	Intermediate*								
	Late	3	248	319	5476	<0.001	100 (100.0-	Random	112.4 (66.9-
Gissane post	Very early*								
	Early*								
	Intermediate	3	429	435	6	0.058	65 (0.0-89.9)	Random	119.2 (117.5-
	Late	3	248	319	49	<0.001	96 (91.2-98.1)	Random	121.5 (114.7-

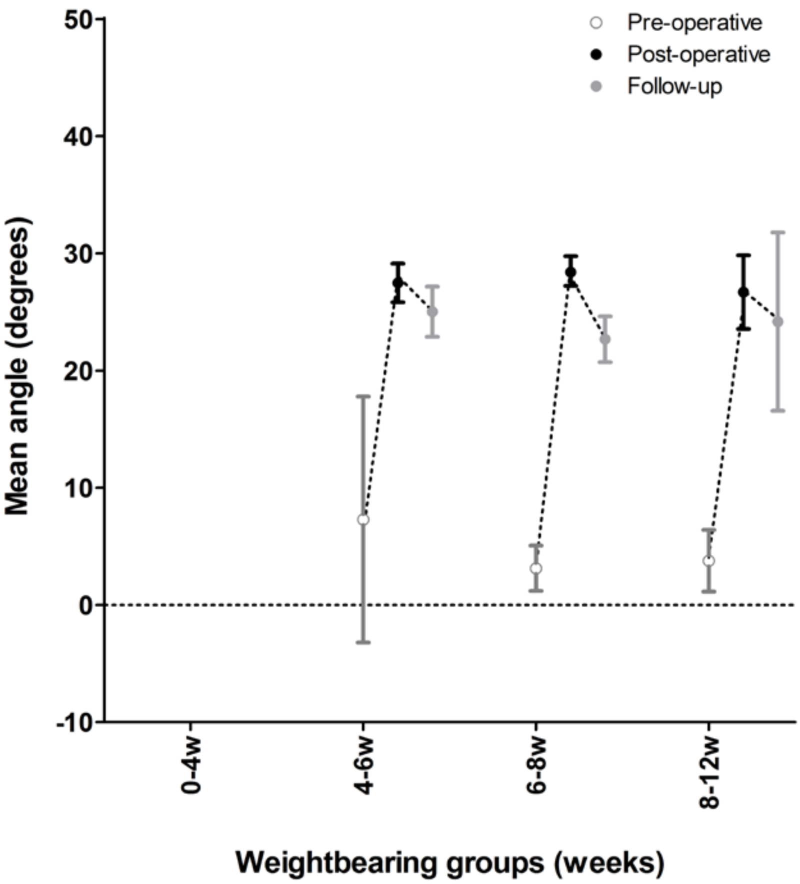
Gissane FU	Very early*								
	Early*								
	Intermediate	3	429	435	7	0.028	72 (5.6-91.7)	Random	122.9 (121.2-
	Late	2	92	109	22	<0.001	96 (86.9-98.5)	Random	119.5 (106.7-
CalcH pre	Very early								
	Early*								
	Intermediate	4	94	103	92	<0.001	97 (94.1-98.2)	Random	37.8 (33.1-42.4)
	Late*								
CalcH post	Very early*								
	Early*								
	Intermediate	5	469	478	134	<0.001	97 (95.1-98.2)	Random	44.3 (42.5-46.0)
	Late	2	187	241	7	0.010	85 (38-2-96.3)	Fixed	42.9 (40.3-45.5)
CalcH FU	Very early*								
	Early*								
	Intermediate	6	484	493	289	<0.001	95 (97.5-98.8)	Random	41.9 (39.4-44.5)
	Late*								
AOFAS	Very early*								
	Early	4	405	459	40	<0.001	90 (79.9-94.6)	Random	82.4 (78.0-86.8)
	Intermediate	7	557	566	122	<0.001	95 (92.1-97.0)	Random	80.7 (77.5-83.9)
	Late	6	486	559	48	<0.001	93 (84.0-96.5)	Random	83.2 (79.5-86.5)
VAS pain	Very early*								
	Early	2	64	64	2	0.180	44 (0.0-0.0)	Random	1.6 (1.3-1.9)
	Intermediate*								
	Late	2	107	125	123	<0.001	99 (98.5-99.6)	Random	5.2 (1.3-9.1)
Superficial infection	Very early	6	349	399	4	0.587	0 (0.0-67.1)	Fixed	6.9 (4.6-9.8)
	Early	4	545	572	27	<0.001	89 (74.4-95.2)	Random	8.9 (2.2-19.6)
	Intermediate	13	860	906	65	<0.001	82 (69.7-88.9)	Random	14.0 (8.9-20.2)
	Late	18	1241	1323	108	<0.001	84 (76.3-89.5)	Random	7.4 (4.1-11.5)
Deep infection	Very early	6	451	472	3	0.757	0 (0.0-53.2)	Fixed	1.6 (0.7-3.2)
	Early	3	374	425	20	<0.001	90 (72.9-96.2)	Random	2.6 (0.0-10.4)
	Intermediate	5	474	479	4	0.402	1 (0.0-80.6)	Fixed	6.0 (4.1-8.6)
	Late	14	984	1137	59	<0.001	78 (63.4-86.7)	Random	3.8 (1.6-6.8)
Necrosis	Very early	3	154	160	6	0.059	65 (0.0-89.9)	Fixed	3.7 (1.4-7.8)
	Early	3	117	125	2	0.331	9 (0.0-97.0)	Random	4.4 (0.4-12.4)
	Intermediate	5	259	287	9	0.054	57 (0.0-84.1)	Random	6.4 (2.4-12.1)
	Late	8	730	807	11	0.144	36 (0.0-71.6)	Fixed	5.5 (4.0-7.3)
Nonunion	Very early	3	190	210	0	0.914	0 (0.0-62.9)	Fixed	1.5 (0.3-4.4)
	Early*								
	Intermediate	3	113	122	0	0.944	0 (0.0-42.0)	Fixed	0.6 (0.0-4.3)
	Late*								
Implant	Very early	2	156	156	7	0.007	86 (45.4-96.6)	Random	5.9 (0.4-27.7)

removal	Early*								
	Intermediate	3	152	164	7	0.026	73 (7.4-91.9)	Random	12.7 (4.6-23.9)
	Late	9	479	520	22	0.006	63 (24.3-82.1)	Random	6.8 (3.5-11.2)
Arthrodesis	Very early*								
	Early*								
	Intermediate	4	469	481	10	0.023	68 (8.4-89.1)	Random	5.5 (2.1-10.3)
	Late	6	547	613	71	<0.001	93 (87.4-96.1)	Random	10.2 (2.4-22.5)

* Insufficient data available

Partial WB, time to partial weightbearing; N_p, number of operatively treated patients; N_s, number of studies; N_f, number of fractures; Böhler pre, Pre-operative Böhler's angle; Böhler post, Post-operative Böhler's angle; Böhler FU, Böhler's angle at follow-up; Gissane pre, Pre-operative Gissane's angle; Gissane post, Post-operative Gissane's angle; Gissane FU, Gissane's angle at follow-up; CalcH pre, Pre-operative calcaneal height; CalcH post, Post-operative calcaneal height; CalcH FU, Calcaneal height at follow-up; AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analog scale for pain (0-10).

Figure 2. Böhler's angle at different time points in the partial weightbearing groups



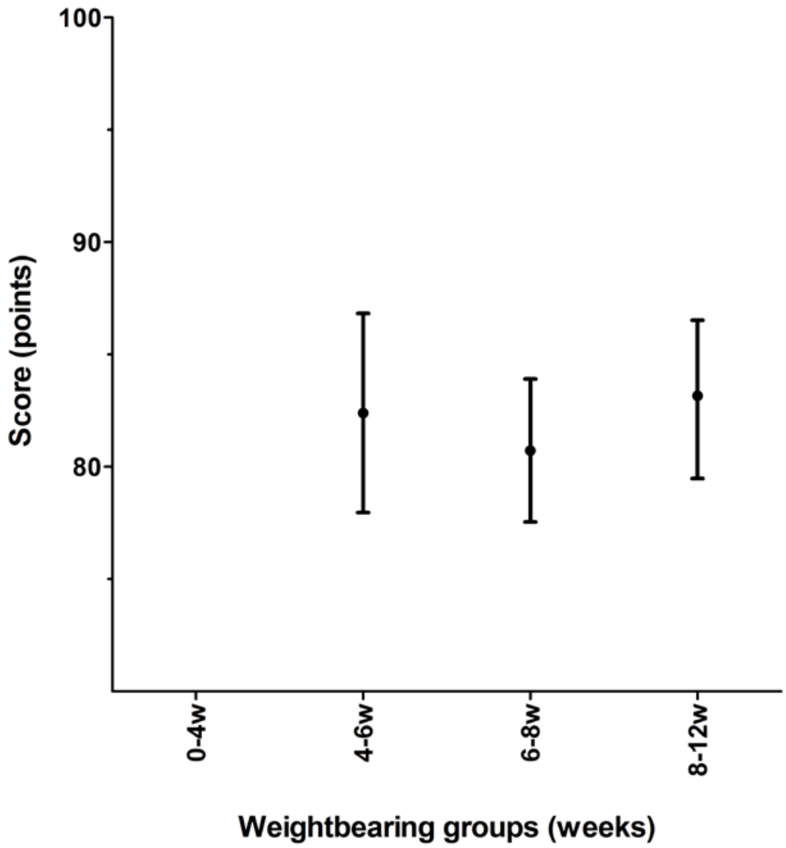
Time to partial weightbearing: very early (0-4 weeks), early (4-6 weeks), intermediate (6-8 weeks), and late (8-12 weeks).

The overlaps in CIs do not support a relation between the time to partial weightbearing and calcaneal height and the angle of Gissane (Table 1). No data were available for the very early and the early partial weightbearing groups. The post-operative angle of Gissane was 119° [95% CI, 118-121°] in the intermediate and 122° [95% CI, 115-128°] in the late partial weightbearing group. At follow-up, again overlap in confidence intervals was found in Gissane's angle: 123° [95% CI, 121-125°] and 120° [95% CI, 107-132°] in the intermediate and late partial weightbearing group, respectively. The post-operative calcaneal height data were only available in two weightbearing groups: intermediate; 44 mm [95% CI, 43-46 mm] and late partial weightbearing 43 mm [95% CI, 40-46 mm].

Functional outcomes

The AOFAS Ankle-Hindfoot Scale (18) was used as an instrument to measure functional outcome. In the very early partial weightbearing group insufficient data were available for analysis. In the other three groups the mean score was 82 points [95% CI, 78-87 points] in the early, 81 points [95% CI, 78-84 points] in the intermediate, and 83 points [95% CI, 79-87 points] in the late partial weightbearing group (Table 1). In all three groups, overlap in the 95% CI was found (Figure 3). Other patient reported outcome scores were reported in only a few studies and did not provide sufficient data for the individual weightbearing groups (Foot Function Index, ShortForm-36, EuroQol-5D, Lower extremity functional scale, Maryland Foot Score, Creighton-Nebraska Score, and short musculoskeletal functional assessment).

Figure 3. American Orthopedic Foot and Ankle Society (AOFAS) in partial weightbearing groups



Time to partial weightbearing: very early (0-4 weeks), early (4-6 weeks), intermediate (6-8 weeks), and late (8-12 weeks).

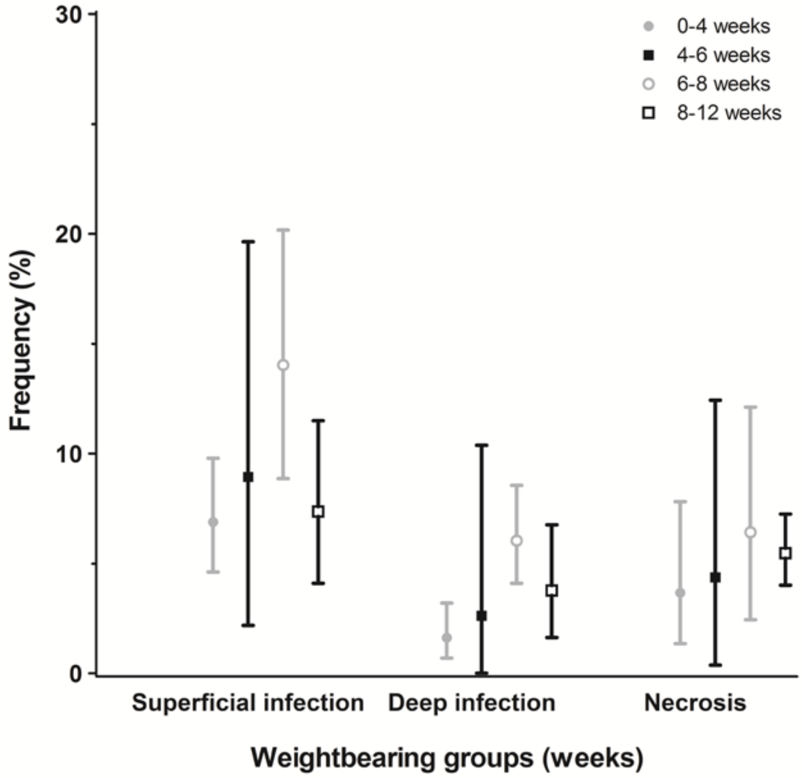
Pain

The 95% CIs of VAS pain scores overlapped in the early and the late partial weightbearing groups: 1.6 points [95% CI, 1.3-1.9 points] in the early and 5.2 points [95% CI, 1.3-9.1 points] in the late partial weightbearing group. In the other two partial weightbearing groups, insufficient data were available for analysis. Insufficient primary statistics were reported for other pain scores (NRS and Likert scale).

Complications and revision surgery

The 95% CIs of all complications, except for deep infections, overlapped in every weightbearing group (Figure 4 and Table 1). Most superficial infections were found in the intermediate partial weightbearing group: 14% [95% CI, 9-20%], however with consistently overlapping 95% CI of very early; 7% [95% CI, 5-10%], early; 9% [95% CI, 2-20%], and late; 7% [95% CI, 4-11%]. Also, the highest rate of deep infections were found in the intermediate partial weightbearing group: 6% [95% CI, 4-9%], compared with the lowest rate of 2% [95% CI, 1-3%] in the very early partial weightbearing group. The highest wound necrosis rate was noted in the intermediate partial weightbearing group (6% [95% CI, 2-12%]), compared with 4% [95% CI, 1-8%] in the very early; 4% [95% CI, 0-12%] in the early, and 5% [95% CI, 4-7%] in the late partial weightbearing group. Concerning the remaining VAS pain, nonunion, implant removal, or arthrodesis (for subtalar arthrosis), no analysis could be performed since insufficient data was available, or 95% CIs were consistently overlapping for the various weightbearing groups.

Figure 4. Complications in partial weightbearing groups



Time to partial weightbearing: very early (0-4 weeks), early (4-6 weeks), intermediate (6-8 weeks), and late (8-12 weeks).

Full weightbearing

The overlapping 95% CIs of the post-operative Böhler's angle, do not suggest a relation between the intermediate and late full weightbearing groups: 28° [95% CI, 25-32°] versus 28° [95% CI, 27-29°] (Table 2). Böhler's angle at follow-up was 22° [95% CI, 19-25°] for the intermediate and 24° [95% CI, 22-26°] in the late weightbearing group. Insufficient data on calcaneal height were available for the early full weightbearing group. But again no relation between the remaining full weightbearing groups could be noted. The 95% CI of the AOFAS in the intermediate full weightbearing group (86 points [95% CI, 84-89 points]) overlapped with that of the late full weightbearing group (82 points [95% CI, 79-85]).

Table 2. Radiographic outcomes, functional outcomes, and complications after full weightbearing in patients with DIACF

Outcome	Full WB	N_s	N_p	N_f	Q	P-value	I^2 (95% CI)	Model	Pooled estimate
Böhler pre	Early	2	248	291	20	<0.001	95 (84.9-98.3)	Random	6.2 (-3.1-15.4)
	Intermediate	3	73	76	7	0.026	72 (7.2-91.8)	Random	6.0 (1.5-10.5)
	Late	5	288	331	12	0.016	67 (14.8-97.3)	Random	1.6 (0.7-2.5)
Böhler post	Early*								
	Intermediate	3	73	76	11	0.004	82 (42.9-94.1)	Random	28.3 (24.8-31.9)
	Late	7	678	742	22	0.001	73 (41.2-87.3)	Random	28.3 (27.5-29.1)
Böhler FU	Early*								
	Intermediate	2	40	43	2	0.218	34 (0.0-0.0)	Fixed	21.9 (18.9-24.9)
	Late	5	485	485	48	<0.001	92 (83.7-95.8)	Random	24.1 (22.2-26.1)
Gissane pre	Early*								
	Intermediate*								
	Late*								
Gissane post	Early*								
	Intermediate*								
	Late	3	546	600	73	<0.001	97 (94.6-98.6)	Random	121.4 (117.6-
Gissane FU	Early*								
	Intermediate*								
	Late	2	390	390	4	0.036	77 (0.0-94.8)	Random	123.4 (121.6-
CalcH pre	Early*								
	Intermediate	2	40	40	1	0.432	0 (0.0-0.0)	Fixed	35.4 (34.1-36.6)
	Late*								
CalcH post	Early*								
	Intermediate	2	40	40	1	0.469	0 (0.0-0.0)	Fixed	42.8 (42.2-43.3)
	Late	4	577	631	13	0.005	76 (35.0-91.4)	Random	42.6 (41.9-43.3)
CalcH FU	Early*								
	Intermediate	2	40	40	14	<0.001	93 (76.3-97.9)	Random	40.6 (38.5-42.6)
	Late	2	390	390	0	0.814	0 (0.0-0.0)	Fixed	40.1 (39.6-40.5)
AOFAS	Early*								
	Intermediate	2	40	40	0	0.502	0 (0.0-0.0)	Fixed	86.1 (83.7-88.6)
	Late	7	576	578	160	<0.001	96 (94.2-97.6)	Random	81.6 (78.5-84.7)
VAS pain	Early*								
	Intermediate*								
	Late	3	121	128	58	<0.001	97 (92.8-98.3)	Random	2.2 (1.2-3.2)
Superficial infection	Early	3	223	242	1	0.646	0 (0.0-92.3)	Fixed	15.2 (11.0-20.4)
	Intermediate	9	499	527	10	0.266	20 (0.0-61.5)	Fixed	12.9 (10.2-16.0)
	Late	18	1319	1414	136	<0.001	88 (81.8-91.5)	Random	10.2 (6.0-15.4)

Deep infection	Early	4	241	261	2	0.544	0 (0.0-81.9)	Fixed	5.4 (3.0-8.8)
	Intermediate	5	521	564	5	0.258	25 (0.0-69.5)	Fixed	2.8 (1.6-4.5)
	Late	12	1023	1111	46	<0.001	76 (58.1-86.3)	Random	3.9 (1.7-6.8)
Necrosis	Early*								
	Intermediate	5	252	282	4	0.374	6 (0.0-81.6)	Fixed	6.7 (4.1-10.2)
	Late	9	502	528	17	0.030	53 (0.0-77.7)	Random	7.5 (4.4-11.4)
Nonunion	Early*								
	Intermediate	2	79	84	0	0.721	0 (0.0-0.0)	Fixed	0.6 (0.0-5.6)
	Late	4	224	248	0	0.954	0 (0.0-0.0)	Fixed	1.4 (0.3-3.9)
Implant removal	Early*								
	Intermediate	3	246	248	10	0.008	79 (34.6-93.5)	Random	8.7 (1.0-23.2)
	Late	5	322	337	8	0.096	49 (0.0-81.4)	Random	5.1 (2.2-9.0)
Arthrodesis	Early*								
	Intermediate*								
	Late	4	523	544	60	<0.001	95 (90.1-97.4)	Random	12.1 (2.4-27.9)

* Insufficient data available

Full WB, time to full weightbearing; N_p, number of operatively treated patients; N_s, number of studies; N_f, number of fractures; Böhler pre, Pre-operative Böhler's angle; Böhler post, Post-operative Böhler's angle; Böhler FU, Böhler's angle at follow-up; Gissane pre, Pre-operative Gissane's angle; Gissane post, Post-operative Gissane's angle; Gissane FU, Gissane's angle at follow-up; CalcH pre, Pre-operative calcaneal height; CalcH post, Post-operative calcaneal height; CalcH FU, Calcaneal height at follow-up; AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analog scale for pain (0-10).

Bone void fillers

To assess whether bone void filling would allow earlier weightbearing, a subanalysis was done for bone void fillers combined with internal fixation. For all outcomes (*e.g.,* radiographic parameters, complications, and revision surgery) in the bone void filling group, the very early and early partial weightbearing data was insufficient to analyze (Table 3). Information of the intermediate partial weightbearing bone void filling group was mostly available, the AOFAS score was 81 points [95% CI, 71-92 points]) in this group.

Table 3. Radiographic outcomes, functional outcomes, and complications after partial weightbearing in patients with DIACF treated with internal fixation combined with bone void filling

Outcome	Partial WB	N_s	N_p	N_f	Q	P-value	I^2 (95% CI)	Model	Pooled estimate (95% CI)
Böhler pre	Intermediate	2	N.S.	50	1	0.245	26 (0.0-0.0)	Fixed	1.6 (-2.2-5.4)
Böhler post	Intermediate	3	N.S.	252	4	0.117	53 (0.0-86.7)	Random	28.5 (26.6-30.3)
Böhler FU	Intermediate	3	N.S.	252	1	0.521	0 (0.0-94.9)	Fixed	25.3 (24.5-26.0)
CalcH post	Intermediate	2	222	224	0	0.737	0 (0.0-0.0)	Fixed	42.8 (42.5-43.2)
CalcH FU	Intermediate	2	222	224	11	0.001	90 (65.5-97.4)	Random	40.8 (39.2-42.4)
AOFAS	Intermediate	2	222	224	40	<0.001	97 (93.8-99.0)	Random	81.5 (71.3-91.7)
Superficial infection									
	Intermediate	6	334	347	17	0.004	71 (33.0-87.6)	Random	15.0 (7.7-25.1)
	Late	3	67	69	1	0.734	0 (0.0-89.2)	Fixed	2.5 (0.3-9.3)
Deep infection									
	Very early	2	37	39	1	0.295	9 (0.0-0.0)	Fixed	3.6 (0.2-14.6)
	Intermediate	2	233	237	0	0.955	0 (0.0-0.0)	Fixed	7.1 (4.2-11.1)
Necrosis	Intermediate	3	100	106	4	0.106	55 (0.0-87.3)	Random	8.7 (2.1-19.2)
Nonunion	Intermediate	2	90	99	0	0.836	0 (0.0-0.0)	Fixed	0.5 (0.0-4.5)
Implant removal									
	Late	2	49	51	1	0.271	17 (0.0-0.0)	Fixed	4.6 (0.8-14.2)
Arthrodesis	Intermediate	2	242	248	7	0.007	86 (44.7-96.5)	Random	8.3 (0.6-23.4)

Partial WB, time to partial weightbearing; N.S., Not specified; N_p, number of operatively treated patients; N_s, number of studies; N_f, number of fractures; Q, Q-value; I^2, Inconsistency; Böhler pre, Pre-operative Böhler's angle; Böhler post, Post-operative Böhler's angle; Böhler FU, Böhler's angle at follow-up; CalcH pre, Pre-operative calcaneal height; CalcH post, Post-operative calcaneal height; CalcH FU, Calcaneal height at follow-up; AOFAS, American Orthopaedic Foot and Ankle Society; VAS, visual analog scale for pain (0-10).

DISCUSSION

This systematic review shows that the 95% CIs of most outcomes overlapped. This might implicate that there is actually no relationship between the different weightbearing regimes and radiographic and clinical outcomes. However, because of the heterogeneity in terms of methodological designs, treatment, and weightbearing protocols, a spurious relation might be possible.

Limitations of this review are the heterogeneity in used outcomes and reported data, studies reporting no primary data (and therefore had to be excluded), the varying definition of partial weightbearing in the selected studies (*e.g.,* toe touching, walking with crutches; restricted partial weightbearing of 10 kg with increasing amount of weight), and the insufficient insights into (non-)weightbearing compliance. Unfortunately, due to the lack of (randomized) comparative studies this review was limited to studies with a low level of evidence, and to pooled analysis instead of a meta-analysis. Finally, not all study designs are comparable, as some studies also included bilateral and open calcaneal fractures. Above mentioned reduces the impact of conclusions in this review.

In this review, both Böhler's angle post-operatively as at follow-up were similar between the different partial weightbearing groups. This suggests that the loss of reduction measured by these Böhler's angles, is not influenced regardless of whether patients start partial weightbearing early or late. Outcomes in all partial weightbearing groups were comparable, suggesting that partial weightbearing within six weeks after surgery has similar effects on maintaining reduction, functional outcome, and complications as the current most commonly recommended weightbearing regimes; intermediate and late partial weightbearing (>6 weeks). In addition, these findings are supported by literature describing surgically treated ankle fractures and other lower extremity fractures. Which reported that early weightbearing regimes do not result in more negative effects on functional outcome, secondary displacement, loss of fixation, and complication rates than more conservative weightbearing regimes (3, 5, 12, 19, 20). A systematical review and meta-analysis showed that active exercises (compared to immobilization) and early weightbearing (compared to late weightbearing) after ankle surgery tends to accelerate return to work (11).

The authors acknowledge that the weightbearing-mechanism in patients with ankle fractures differ from weightbearing in patients with calcaneal fractures. However, Dehghan *et al.* (20) found no difference regarding wound complications, surgical site infections, fixation failure, or loss of reduction in unstable ankle fractures when weightbearing and range of motion exercises started after two weeks compared with non-weightbearing and cast immobilization for six weeks. Weightbearing guided by pain in patients with ankle fractures has shown to have similar functional results (activity limitation, range of motion, delayed union, infections, and adverse events) as patients with six weeks of non-weightbearing (19). Even complications linked to early weightbearing as secondary displacement, malunions, and arthrodesis are not significantly higher in early weightbearing groups (19, 20).

Bone void filling (*i.e.,* autologous, allogenic bone grafts or synthetic bone void fillers) aims to speed bone healing, and provides osteoconduction and osteoinduction. The use of such bone void fillers is often recommended for complex lower extremity fractures to speed up the healing process (21). Therefore, a bone void filling subanalysis was done (due too low numbers no specific bone void filler is analysed). Unfortunately, data were only available for the intermediate and late partial weightbearing groups. Therefore, no conclusions could be drawn from this subanalysis. Also locking plates are assumed to allow earlier weightbearing without displacement or implant failure (2, 22). A subanalysis on this group was not possible due to the limited number of studies.

With comparable results in the different weightbearing groups, the negative effects of non-weightbearing need to be addressed. Walking without weightbearing (*i.e.,* crutches) requires four times more energy than a normal walk (23). Furthermore, patients often start weightbearing sooner than their physician recommends (27.5% of the patients is not compliant), but this non-compliance does not increase the risk of complications (24). Since literature on patient compliance is scarce, it is not discussed in this review. Weightbearing compliance could be monitored via flexible shoe insoles. The insole includes pressure and force sensor that measure the force applied at key bearing points under the foot. Such a self-learning adaptive weightbearing monitoring system also can deliver electrical, mechanical, and/or audio feedback to encourage a patient to load the optimal target weight, the patient is given continuous feedback for improving rehabilitation (25, 26). Another recommendation for future research is the use of Virtual Stress Testing, which provide a non-invasive estimate of a healing bone through a CT scan and has the potential to provide a quantitative, objective measure to identify fractures who could safely handle bearing weight (27).

Prospective clinical studies are required to support this review data and to optimize post-operative weightbearing regimes. This review suggests that such studies could be conducted safely but should be performed using objective and validated parameters, and a weightbearing monitoring system (i.e., shoe insoles to monitor weightbearing compliance).

CONCLUSION

The adverse sequelae which are assumed to be associated with starting partial weightbearing already within six weeks after internal fixation of calcaneal fractures, is not supported by literature data. This systematic review suggests that early weightbearing does not result in impaired outcomes compared with the current (more conservative) weightbearing regimes.

Acknowledgements
We thank Mr. W.M. Bramer, Biomedical information specialist at the Erasmus MC (Rotterdam, The Netherlands) for performing the literature search.

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SUPPLEMENTAL MATERIAL

Embase.com: 1029 publications

('calcaneus fracture'/exp OR (calcaneus/de AND (fracture/de OR 'orthopedic fixation device'/exp OR 'fracture treatment'/exp)) OR ((calcane* OR heel OR os-calc*) NEAR/10 (fracture* OR trauma* OR screw* OR plate* OR fixat* OR orif OR crif OR arthrode* OR osteosynthes*)):ab,ti) AND ('immobilization'/exp OR 'mobilization'/exp OR 'weightbearing'/exp OR 'physical activity'/de OR walking/de OR 'standing'/de OR 'kinesiotherapy'/exp OR 'physical medicine'/de OR physiotherapy/exp OR 'physiotherapist'/exp OR rehabilitation/de OR Exercise/de OR (mobilizat* OR immobilizat* OR mobilisat* OR immobilisat* OR ((weight OR load) NEAR/3 bear*) OR weightbear* OR loadbear* OR axial-load* OR walking OR standing OR kinesiotherap* OR kinesitherap* OR exercis* OR ((movement* OR phys*) NEAR/3 (therap* OR treat* OR technique* OR medicine* OR activ*)) OR physiotherap* OR rehabilitat* OR ambulat*):ab,ti) NOT ([Conference Abstract]/lim OR [Letter]/lim OR (28)/lim OR [Editorial]/lim) NOT ([animals]/lim NOT [humans]/lim)

Medline Ovid: 954 publications

("calcaneus"/in OR (calcaneus/ AND (Fractures, Bone/ OR exp "Orthopedic Fixation Devices"/)) OR ((calcane* OR heel OR os-calc*) ADJ10 (fracture* OR trauma* OR screw* OR plate* OR fixat* OR orif OR crif OR arthrode* OR osteosynthes*)).ab,ti,kf.) AND ("immobilization"/ OR "Early Ambulation"/ OR "Weight-Bearing"/ OR "Exercise"/ OR walking/ OR "Exercise Therapy"/ OR "Physical and Rehabilitation Medicine"/ OR "Physical Therapy Modalities"/ OR "Physical Therapists"/ OR Rehabilitation/ OR (mobilizat* OR immobilizat* OR mobilisat* OR immobilisat* OR ((weight OR load) ADJ3 bear*) OR weightbear* OR loadbear* OR axial-load* OR walking OR standing OR kinesiotherap* OR kinesitherap* OR exercis* OR ((movement* OR phys*) ADJ3 (therap* OR treat* OR technique* OR medicine* OR activ*)) OR physiotherap* OR rehabilitat* OR ambulat*).ab,ti,kf.) NOT (letter OR news OR comment OR editorial OR congresses OR abstracts).pt. NOT (exp animals/ NOT humans/)

CINAHL EBSCOhost: 139 publications

(MH "Calcaneus Fractures" OR (MH calcaneus AND (MH Fractures OR MH "Orthopedic Fixation Devices+")) OR TI ((calcane* OR heel OR os-calc*) N9 (fracture* OR trauma* OR screw* OR plate* OR fixat* OR orif OR crif OR arthrode* OR osteosynthes*)) OR AB ((calcane* OR heel OR os-calc*) N9 (fracture* OR trauma* OR screw* OR plate* OR fixat* OR orif OR crif OR arthrode* OR osteosynthes*))) AND (MH "immobilization" OR MH "Early Ambulation" OR MH "Weight-Bearing" OR MH "Exercise" OR MH walking OR MH "Therapeutic Exercise" OR MH "Physical Medicine" OR MH "Physical Therapy" OR MH "Physical Therapists" OR MH Rehabilitation OR TI (mobilizat* OR immobilizat* OR mobilisat* OR immobilisat* OR ((weight OR load) N2 bear*) OR weightbear* OR loadbear* OR axial-load* OR walking OR standing OR kinesiotherap* OR kinesitherap* OR exercis* OR ((movement* OR phys*) N2 (therap* OR treat* OR technique* OR medicine* OR activ*)) OR physiotherap* OR rehabilitat* OR ambulat*) OR AB (mobilizat* OR immobilizat* OR mobilisat* OR immobilisat* OR ((weight OR load) N2 bear*) OR weightbear* OR loadbear* OR axial-load* OR walking OR standing OR kinesiotherap* OR kinesitherap* OR exercis* OR ((movement* OR phys*) N2 (therap* OR treat* OR technique* OR medicine* OR activ*)) OR physiotherap* OR rehabilitat* OR ambulat*)) NOT PT (letter OR news OR comment OR editorial OR congresses OR abstracts) NOT (MH animals+ NOT MH humans+)

Cochrane: 32 publications

(((calcane* OR heel OR os-calc*) NEAR/10 (fracture* OR trauma* OR screw* OR plate* OR fixat* OR orif OR crif OR arthrode* OR osteosynthes*)):ab,ti) AND ((mobilizat* OR immobilizat* OR mobilisat* OR immobilisat* OR ((weight OR load) NEAR/3 bear*) OR weightbear* OR loadbear* OR axial-load* OR walking OR standing OR kinesiotherap* OR kinesitherap* OR exercis* OR ((movement* OR phys*) NEAR/3 (therap* OR treat* OR technique* OR medicine* OR activ*)) OR physiotherap* OR rehabilitat* OR ambulat*):ab,ti)

Web of Science: 334 publications

TS=((((calcane* OR heel OR os-calc*) NEAR/9 (fracture* OR trauma* OR screw* OR plate* OR fixat* OR orif OR crif OR arthrode* OR osteosynthes*))) AND ((mobilizat* OR immobilizat* OR mobilisat* OR immobilisat* OR ((weight OR load) NEAR/2 bear*) OR weightbear* OR loadbear* OR axial-load* OR walking OR standing OR kinesiotherap* OR kinesitherap* OR exercis* OR ((movement* OR phys*) NEAR/2 (therap* OR treat* OR technique* OR medicine* OR activ*)) OR physiotherap* OR rehabilitat* OR ambulat*))) AND DT=(article) AND LA=(english)

Google Scholar: 200 publications

"calcaneus|calcaneal|calcis fracture|fractures|trauma|fixation|fixator" mobilization|immobilization|mobilisation|immobilisation|"weight|load bearing"|weightbearing|loadbearing|walking|standing|"physical activity|activities"|ambulation

SUPPLEMENTAL TABLE 1

Publication	Study design	MINORS	WB time	BVF	N_p	N_f	N Male (%)	Follow-up (months)
Duymus *et al.* (29)	Prospective case control	16	N.D.	N.D.	40	43	35 (88)	N.D.
Duymus *et al.* (29)_A	Prospective case control	16	6	Yes	20	22	N.D.	24.8
Duymus *et al.* (29)_B	Prospective case control	16	6	No	20	21	N.D.	22.7
Gamal *et al.* (30)	Prospective cohort	11	6-8	No	57	64	40 (70)	16
Hegde *et al.* (31)	Prospective cohort	3	6	No	23	23	22 (96)	N.A.
Li *et al.* (32)	RCT *	20	4-6	No	64	64	47 (74)	12
Li *et al.* (32)_A	RCT *	20	4-6	No	32	32	24 (75)	12
Li *et al.* (32)_B	RCT *	20	4-6	No	32	32	23 (72)	12
Long *et al.* (33)	Prospective cohort	13	8-12	No	23	23	8 (35)	13.7
Pompach *et al.* (34)	Prospective cohort	12	1	No	107	107	N.A.	12
Scott *et al.* (35)	Retrospective cohort	9	8	No	35	39	21 (60)	10
Zwipp *et al.* (36)	Prospective case control	8	6-10	No	103	106	89 (86)	12
Cao *et al.*(37)	Prospective cohort	7	3	No	33	33	25 (76)	21
Chen *et al.* (38)	Prospective cohort	4	8-12	N.D.	42	48	27 (64)	17
Farell *et al.* (39)	Retrospective case series	6	8	No	9	10	N.D.	2
Gomaa *et al.*(40)	Prospective cohort	12	6	No	52	61	43 (83)	31.4
Gusic *et al.* (41)	Retrospective cohort	19	N.D.	N.D.	103	105	82 (80)	12
Gusic *et al.* (41)_A	Retrospective cohort	19	6-8	No	16	N.D.	N.D.	N.D.
Gusic *et al.* (41)_B	Retrospective cohort	19	6-8	No	67	N.D.	N.D.	N.D.
Gusic *et al.* (41)_C	Retrospective cohort	19	6-8	Yes	20	N.D.	N.D.	N.D.
De Vroome *et al.* (42)	Retrospective case series	10	8-12	No	38	41	29 (76)	75.6
Griffin *et al.* (43)	RCT *	21	6	No	73	73	64 (88)	24
Hetsroni *et al.* (44)	Retrospective cohort	9	8-12	No	16	16	13 (81)	40
Kayali *et al. (45)*	Retrospective cohort	11	6-8	Yes	15	15	12 (80)	19
Sanders *et al*. (46)	Prognostic case control	11	12	No	93	108	73 (88)	182.5
Sivakumar *et al.* (47)	Retrospective cohort	6	10	N.D.	13	13	11 (85)	19.9
Su *et al*. (48)	Retrospective cohort	12	4-6	No	12	12	10 (83)	93.9

Vittore *et al.* (49)	Prospective cohort	8	1	Yes	20	20	11 (55)	12.3
Ågren *et al. (50)*	RCT *	21	6	N.D.	42	42	29 (69)	120
De Groot *et al.* (51)	Retrospective cohort	10	6-8	No	39	45	26 (67)	78
Gülabi *et al*. (52)	Retrospective cohort	8	10.4	Yes	26	27	21 (81)	34.4
Hammond *et al.* (53)	Prospective case series	9	8	No	14	17	N.D.	3
Jain *et al.* (54)	Prospective cohort	8	12	No	24	26	21 (83)	14.5
Naik *et al.* (55)	Prospective cohort	7	6	No	37	47	30 (81)	31.2
Singh *et al.* (56)	Retrospective cohort	20	N.D.	N.D.	390	390	N.D.	24
Singh *et al.* (56)_A	Retrospective cohort	20	6-8	Yes	202	202	152 (75)	24
Singh *et al.* (56)_B	Retrospective cohort	20	6-8	No	188	188	130 (58)	24
Wu *et al.* (57)	Retrospective cohort	13	N.D.	N.D.	329	383	307 (93)	12
Wu *et al.* (57)_A	Retrospective cohort	13	5.6	No	181	213	168 (93)	12
Wu *et al.* (57)_B	Retrospective cohort	13	9.4	N.D.	148	170	139 (94)	12
Chen *et al.* (58)	Prospective cohort	21	N.D.	N.D.	78	78	44 (56)	24
Chen *et al.* (58)_A	Prospective cohort	21	8	N.D.	40	40	24 (60)	24
Chen *et al.* (58)_B	Prospective cohort	21	6	Yes	38	38	20 (53)	24
DeWall *et al.* (59)	Retrospective cohort	15	N.D.	N.D.	120	125	N.D.	N.D.
DeWall *et al.* (59)_A	Retrospective cohort	15	8-10	No	41	42	35 (88)	24.7
DeWall *et al*. (59)_B	Retrospective cohort	15	8-10	No	79	83	66 (80)	21.9
Hyer *et al.* (2)	Retrospective cohort	13	4.88	No	17	17	12 (71)	237.7
Mostafa *et al.* (60)	Prospective cohort	12	8-10	Yes	18	18	16 (89)	24.1
Rammelt *et al.* (61)	Retrospective cohort	10	6-8	No	33	33	21 (88)	29
Wang *et al.* (62)	Prospective cohort	9	8	No	156	210	144 (92)	9.7
Demcoe *et al.* (63)	Retrospective chart review	10	8-12	No	246	278	207 (84)	6
Johal *et al.* (64)	RCT *	19	N.D.	N.D.	47	52	N.D.	N.D.
Johal *et al.* (64)_A	RCT *	19	6	Yes	N.D.	28	N.D.	12
Johal *et al.* (64)_B	RCT *	19	6	No	N.D.	24	N.D.	12
Kienast *et al.* (65)	Retrospective cohort	14	1	No	136	136	112 (82)	8.6
Rak *et al.* (66)	Prospective cohort	15	N.D.	N.D.	67	76	57 (85)	N.D.
Rak *et al.* (66)_A	Prospective cohort	15	8-12	No	N.D.	N.D.	N.D.	N.D.

Rak *et al.* (66)_B	Prospective cohort	15	8-12	No	N.D.	N.D.	N.D.	N.D.
Rak *et al.* (66)_C	Prospective cohort	15	8-12	No	N.D.	N.D.	N.D.	N.D.
Rak *et al.* (66)_D	Prospective cohort	15	6-8	No	N.D.	N.D.	N.D.	N.D.
Rak *et al.* (66)_E	Prospective cohort	15	6-8	No	N.D.	N.D.	N.D.	N.D.
Rak *et al.* (66)_F	Prospective cohort	15	6-8	No	N.D.	N.D.	N.D.	N.D.
Wee *et al.* (67)	Prospective cohort	8	4	Yes	10	12	9 (90)	7
Schepers *et al.* (68)	Prospective cohort	8	12	No	50	61	36 (72)	35
Walde *et al.* (69)	Retrospective case series	9	8	No	88	92	63 (72)	68.4
Zeman *et al.* (70)	Prospective cohort	7	0-4	N.D.	29	33	27 (93)	N.D.
Ibrahim *et al.* (71)	RCT *	16	6-8	No	15	15	11 (73)	180
Besse *et al.* (72)	Prospective case series	9	10	No	31	31	27 (84)	53
Stulik *et al.* (73)	Retrospective cohort	9	8.4	No	247	287	210 (85)	43.4
Elsner *et al.* (74)	Prospective cohort	11	0-4	Yes	18	19	13 (72)	22.3
Emara *et al.* (75)	Prospective cohort	15	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Emara *et al.* (75)_A	Prospective cohort	15	12	No	18	20	18 (90)	10.7
Koski *et al.* (76)	Retrospective cohort	7	6	No	126	148	101 (80)	10.7
Howard *et al.*(77)	RCT *	21	6	No	161	180	N.D.	N.D.
Buckley *et al.* (3)	RCT *	21	6	No	206	249	N.D.	N.D.
Geel *et al.* (78)	Retrospective cohort	8	6-10	No	29	33	22 (76)	20
Longino *et al.* (79)	Prospective case control	13	6	N.D.	40	40	38 (95)	29
Shuler *et al.* (80)	Retrospective cohort	11	12	N.D.	62	63	51 (82)	6
Tennent *et al.* (81)	Prospective cohort	10	6	N.D.	47	51	36 (77)	44
Park *et al.* (82)	Retrospective cohort	7	6	No	92	103	73 (79)	28
Schildhauer *et al.* (83)	Prospective cohort	7	N.D.	Yes	32	36	32 (100)	21
Rodriguez *et al.* (84)	Retrospective cohort	15	10-12	Yes	28	28	23 (82)	46
Strømsøe *et al.* (85)	Retrospective case series	8	6	Yes	40	46	28 (7)	N.D.
Burdeaux *et al.* (86)	Prospective cohort	6	8	No	53	61	36 (68)	52.8
Crosby *et al.* (87)	Retrospective cohort	8	8	No	21	23	15 (71)	26
Laughlin *et al.* (88)	Prospective cohort	11	8-12	No	31	33	27 (87)	18
Thordarson *et al.* (89)	RCT *	17	10	No	15	15	12 (80)	17

Chan *et al.* (90)	Retrospective cohort	9	6-8	Yes	31	35	29 (94)	44.3
Monsey *et al.* (91)	Retrospective cohort	7	8	Yes	18	18	14 (78)	32
Hutchinson *et al.* (92)	Retrospective cohort	8	8	No	43	47	29 (67)	N.D.
Bezes *et al.* (93)	Retrospective cohort	6	8	No	205	205	N.D.	39
Prats *et al.* (94)	Retrospective cohort	9	1	No	20	20	9 (45)	60
Sanders *et al.* (95)	Retrospective cohort	8	8	No	132	132	N.D.	29.3
Zwipp *et al.* (96)	Prospective cohort	10	1.5	No	141	157	98 (70)	36
Leung *et al.* (97)	Prospective cohort	11	6	No	59	64	53 (90)	10.6
Stephenson *et al.* (98)	Retrospective case series	5	8-12	No	12	14	9 (75)	22

*MINORS is usually used for non-randomized studies. No randomization was performed for weightbearing starting time.

Publications presented in chronological order, at the top the most recent studies. MINORS, methodological items for non-randomized studies; WB time, weightbearing time; BVF, Bone Void Filling; N_p, number of patients; N_f, number of fractures.