The primary arthrodesis for severely comminuted intra-articular fractures of the calcaneus: a systematic review

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Abstract

Introduction: Although open reduction and internal fixation via the extended lateral approach is currently considered gold-standard, severely comminuted calcaneal fractures might not be amendable for reconstruction. The primary aim of the current review study was to assess the functional outcome of the primary arthrodesis in the management of comminuted displaced intra-articular calcaneal fractures.

Method: The literature was searched for studies published between January 1st 1990 to December 1st 2010, to identify studies in which a primary arthrodesis was utilized for the treatment of displaced intra-articular calcaneal fractures between. The methodological quality of the included studies was assessed using the Coleman Methodology Score.

Results: Seven case series and one abstract were identified, reporting on 120 patients with 128 severely comminuted calcaneal fractures. Average follow-up time was 28 months and union rate 97 percent. Functional outcome was assessed using the modified AOFAS score in seven studies; with a weighted average of 77.4 (range 72.4 to 88). One study reported a 75 percent good to excellent outcome on the Paley score. Three studies reported on return to work, ranging from 75 to 100 percent. Overall reported wound complications occurred in 19.4%. The average Coleman Methodology Score was 56 (range 38 - 68) points.

Conclusion: The primary arthrodesis for the treatment of Sanders type-IV comminuted displaced intra-articular calcaneal fractures provides overall good results considering the severe nature of the injury. Therefore, in the process of choosing the best treatment modality for a severely comminuted calcaneal fracture, the primary arthrodesis should receive full consideration.

Introduction

Considering the long-term results after displaced intra-articular calcaneal fractures the initial treatment modality largely dictates the rate of secondary arthrodeses [13, 43]. The surgical fusion of the subtalar joint as salvage procedure following the painful sequela of a displaced intra-articular calcaneal fracture has a long history of over a century. The first subtalar arthrodesis is attributed to Nieny in 1905 [49] and a double arthrodesis was first described by Hoke in 1921, which became the first triple arthrodesis after Ryerson added the calcaneal-cuboid fusion in 1923 [15]. Bone-block distraction arthrodesis was introduced first by Carr in 1988 [7] and subtalar fusion including a corrective osteotomy was published first by Romash in 1993 [41].

Unhappy with the results of the treatment modalities of their time, several authors turned to primary or early arthrodesis of the subtalar joint after a displaced intra-articular fracture of the calcaneus instead of awaiting late arthritic complications.[5, 14, 17-19, 25, 36] One of the earliest descriptions of this technique is the primary subtalar arthrodesis by Van Stockum in 1912 [18]. Others extended the fusion and recommended an early triple arthrodesis [4, 11, 50]. An primary arthrodesis following anatomical correction, i.e. primary reconstructive arthrodesis, carries the name of Stulz, who credited Leriche for this technique in his article [8, 26, 47].

After the somewhat disappointing results from primary arthrodesis in the late Fifties, as delineated by Lindsay and Dewar, the primary fusion became less popular [18, 30]. Secondly the improving results from open reduction and internal fixation lowered the overall need for an arthrodesis. Recently however, for the severely comminuted fractures (e.g. the Sanders type-IV) the primary subtalar fusion after near-anatomical reconstruction of the calcaneus has regained attention [9, 23].

The aim of the current review study was to assess the functional outcome of the primary arthrodesis in the management of comminuted displaced intra-articular calcaneal fractures.

Material and method

A literature search was conducted to identify studies in which a primary arthrodesis was performed for the treatment of displaced intra-articular calcaneal fractures. The electronic databases up to January 1st 2011 of 'the Cochrane Library', 'Pubmed Medline', 'EMbase', and 'Google Scholar' were explored using the combination of the following search-terms and Boolean operators: ‘primary’ OR ‘early’ AND 'arthrodesis' OR 'fusion' AND ‘calcaneus’ OR 'calcaneal' OR 'calcis'. No restriction in language and publication date were applied in the initial search. However, only studies from 1990 to 2010 were included in the final analysis, older studies were considered having only historic value. Publications were requested at the university medical (internet) library and reviewed. In addition, a comprehensive search of reference lists of all identified articles was conducted to find additional studies. An article was found eligible when it concerned 1) the surgical treatment of acute displaced intra-articular calcaneal fractures, 2) usage of primary arthrodesis, with or without initial reconstruction, as surgical technique. Series in which more than one operative treatment modality was used, were included only if sufficient data on follow-up, union rates, and outcome could be extracted on those patients treated by primary arthrodesis.

The studies concerning the primary arthrodesis were tested for their methodological quality according to the Coleman Methodology Score [10]. This score was introduced in 2000 by Coleman et al. and assesses a study for methodological quality on ten items with zero points as minimum (worst quality) and 100 points as maximum (best quality with low influence of bias, confounding factors and chance) [10].

Results

Thirteen studies were excluded as they were published before 1990 (Table 1a). Three recent studies were excluded (Myerson 1995, Clare 2004, Hüfner 2007) being review studies or technical descriptions [9, 23, 35]. This gave a total of eight publications which were included in the analysis (Table 1b) [5, 16, 22, 24, 31, 33-34, 38]. One of these studies was an extended abstract published following a conference meeting [24].

Literature review

The seven case series and one abstract reported on 120 patients (average 15 per study; range 6 - 33) with 128 calcaneal fractures (average 16 per study; range 6 - 37).

With the exception of 1 study [5] all fractures were classified according to the Sanders computed-tomography classification system [42]. Considering the latter four fractures were classified as a type-III, the rest a Sanders type-IV.

The average time between the injury and the primary arthrodesis was reported in five studies, and varied between six and twenty-two days. The weighted average (dependent on number of patients) follow-up time was reported in all studies was 28 months (range 12 - 59 months). Union was reported in 124 out of 128 fractures, with a weighted average, depending on number of included fractures, of 97 percent.

Functional outcome was assessed using the American Orthopaedic Foot Ankle Society hindfoot (AOFAS) score [28] in seven studies; with a weighted average, depending on the number of included patients, of 77.4 points (range 72.4 to 88) out of a maximum of 94 points. One study reported a 75 percent good to excellent outcome on the Paley score [34].

Four studies reported on return to work, which ranged from 75 to 100 percent (31 patients out of 34) [5, 16, 22, 33].

Wound complications was distracted from seven studies and ranged from zero to 50 percent. In studies reporting on complications [5, 16, 22, 24, 31, 33, 38]. wound healing or infection occurred in 21 out of 108 feet (19.4%). This included seven cases of osteomyelitis, in which three amputations were necessary.

Coleman Methodology Score

The abstract [24] was not included in the calculation of the Coleman Methodology Score, leaving seven full-text manuscripts [5, 16, 22, 24, 31, 33-34, 38]. One study was a prospective study, all others were retrospective [31]. The average Coleman Methodology Score (Table 2) was 56 (range 38 - 68) points.

Discussion

This review study reports on the results of seven studies and an abstract in which early salvage of comminuted calcaneal fractures is performed via primary arthrodesis. With a union rate between 90 to 100 percent, the weighted average of the AOFAS score was 77.4 points (range 72.4 to 88) out of a maximum of 94 points.

In the studies from the authors of the classification systems; all Crosby-Fitzgibbons type-3 fractures treated non-operatively had a poor outcome [12] and 91 percent of the Sanders type-IV treated by ORIF had a fair or poor outcome [42]. This worse outcome with increasing comminution has been confirmed by several large studies [2, 6, 21, 29, 40, 48].

Because anatomical reconstruction of the subtalar joint in these severely comminuted fractures is frequently not possible, the secondary arthrodesis rates may be as high as 72 percent for the Sanders type-IV fractures [42]. Considering this need for a secondary arthrodesis, for Sanders type-IV displaced intra-articular calcaneal fractures a 5.5 times higher rate has been identified compared to less severe fractures [13]. These high-energy injuries have been shown to cause decreased chondrocyte viability [3]. This cartilage damage has been noted during early subtalar fusions[11, 14], and corresponds to higher rates of post-traumatic arthritis necessitating an arthrodesis at some point in time, even despite anatomical correction of the joint surface [3].

Only studies from 1990 to 2010 were included in the current systematic review. Seemingly arbitrarily, this restriction in publication date was chosen as from this time on more structured disease-specific outcome scores, CT-scanning and validated classifications were applied. Secondly, the less recent publications more frequently fused the subtalar joint without initial reconstruction of the overall anatomy [35]. Most

early procedures were performed via a limited posterolateral (Gallie) or Palmer approach [14, 17-19, 36]. More recent studies however, used an extended lateral approach with the emphasis on reconstruction followed by fusion [9, 23]. This is in concordance with the improved results of a secondary arthrodesis after initial open reduction compared with an initial non-operative treatment [39].

Improved results with initial attempt to reconstruct height and width have been noted previously [11, 19] and better functional outcome has been obtained more frequently in early fusions compared to delayed fusions [11, 22, 50-52].

There are only two studies comparing the results of primary arthrodesis with the outcome after ORIF. The first compared patients with a primary arthrodesis to a historic group of previously published secondary arthrodeses with similar follow-up time, showing almost 20 points difference in AOFAS score in favor of the primary arthrodesis [22]. The second study however, found similar outcome in cases with a primary and secondary arthrodesis [16]. One of the most recent developments is a minimal invasive primary arthrodesis performed via a small posterolateral approach; after overall anatomy reconstruction through ligamentotaxis [31-32]. This technique combines the minimal invasive approach for calcaneal fractures to restore height and width with the posteolateral Gallie approach to fuse the posterior talo-calcaneal joint [44-46].

The primary arthrodesis for the treatment of severe intra-articular calcaneal fractures is rare and complex surgery, which is only performed in non-reconstructable calcaneal fractures with severe damage to the subtalar cartilage. The number of Sanders type-IV ranges from 4 to 28% in the literature [2, 6, 27, 44]. Concomitantly, the percentage of all patients with a surgically treated intra-articular calcaneal fracture treated with a primary arthrodesis currently ranges from 0.4 to 15 percent (average about 5%) [5, 22-24, 53].

Current studies on primary arthrodesis are small and considerably flawed, which made a formal meta-analysis impossible. Therefore, data from the collected studies was presented in a descriptive manner without formal statistical analysis. Weighted averages and ranges were used because of the low number of patients in some studies. A multicenter prospective study comparing open reduction and internal fixation with the primary arthrodesis for Sanders type-IV calcaneal fractures is needed to determine the best treatment option for this seriously disabling injury. Currently, one prospective randomized trial comparing ORIF and primary fusion for Sanders Type-IV is running. Results of this study are expected for December 2013 (http://clinicaltrials.gov/show/NCT00679393).

In conclusion, the primary arthrodesis for the treatment of Sanders type-IV comminuted displaced intra-articular calcaneal fractures provides overall good results considering the severe nature of the injury. Therefore, in the process of choosing the best treatment modality for a severely comminuted calcaneal fracture, the primary arthrodesis should receive full consideration.

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Table 1a. Studies using primary arthrodesis in the treatment for DIACF, published before 1990

Author (year)	Patients [calcaneal #]	Time to fusion (median)	Follow-up months (range)	Union rate (%)	G+E (%)	Return to work (%)
Wilson (1927)[52]	16	12 weeks	N.A.	N.A.	90	90
Nutter (1930)[37]	Review					
Conn (1935)[11]	19 (triple)	5 weeks	N.A.	92	89	N.A.
Bankart (1942)[4]	2 (triple)	N.A.	N.A.	N.A.	100	N.A.
Armstrong (1943)[1]	Review					
Gallie (1943)[17]	50	N.A.	N.A.	98	N.A.	N.A.
Mumford (1943)[a][17]	14	N.A.	N.A.	N.A.	65	N.A.
Harris (1946)[19]	N.A.	10 days	N.A.	N.A.	N.A.	N.A.
Dick (1953)[14]	9 [10]	4 weeks	36 (12-60)	100	N.A.	100
Thompson (1959)[50]	25 [26] (triple)	days	46 (8-108)	100	96	100
Hall (1960)[18]	29 [31]	< 1 week	(21-120)	91	74	86
Harris (1963)[20]	Review					
Noble (1979)[36]	43 [47]	4-8 weeks	84 (6-240)	98	56 (91 +S)	95

DIACF; displaced intra-articular calcaneal fractures, N.A.; not available, G+E; Good and Excellent outcome,

+S; including satisfactory outcome

a. comment on study by Gallie 1943

Table 1b. Studies using primary arthrodesis in the treatment for DIACF, published after 1990

Author (year)	Patients [calcaneal #]	Classification	Time from injury in days (range)	Follow-up Months (range)	Union rate (%)	Modified AOFAS (0 - 94)	Return to work (%)	Wound complications
Myerson (1995)[35]	Review							
Buch (1996)[5]	14 [14]	Crosby-Fitzgibbons 2 Type-II 7 type-III 5 unclassified	14 (2-43)	26 (12-54)	100	72.4 (48-88)	92	4 (incl 1 SSG)
Flemister (2000)[16]	8 [8]	Sanders-IV	17 (9-30)	34 (24-55)	100	75	75	2 (incl 1 amputation)
Infante (2000)[24]	30 [30]	Sanders-IV (10 open fractures)	N.A.	38 (14-85)	93	78 (55-94)	N.A.	7 (incl 2 amputations)
Muratli (2001)[34]	17 [20]	Sanders-IV	N.A.	20 (10-32)	90	75% G+E	N.A.	N.A.
Hüfner (2001)[22]	6 [6]	Sanders 1 Type-III 5 type-IV	N.A.	59 (30-90)	100	88 (64-94)	100	1 (hematoma)
Clare (2004)[9]	review							
Morales (2006)[33]	6 [6]	Sanders 3 Type-III 3 type-IV	22 (10-35)	30 (13-47)	100	76 (68-85)	100	3
Hüfner (2007)[23]	review							
Potenza (2010)[38]	6 [7]	Sanders-IV	20	53 (30-60)	100	85 (78-91)	N.A.	0
López-Oliva (2010)[31]	33 [37]	Sanders-IV	6	12	100	76.6	N.A.	4 (incl 1 severe)

DIACF; displaced intra-articular calcaneal fractures, N.A.; not available, G+E; Good and Excellent outcome, incl.; including, SSG; split-thickness skin graft

Table 2. Coleman Methodological Score

Methodology criterion (min-max)	Buch	Flemister	Muratli	Hüfner	Morales	Potenza	López-Oliva
Part A:							
1. Study size (0–10)	0	0	4	0	0	0	4
2. Followup (0–5)	5	5	2	5	5	5	2
3. N procedures (0–10)	10	0	10	10	10	10	10
4. Type of study (0–15)	0	0	0	0	0	0	10
5. Diagnostic certainty (0–5)	5	5	5	5	5	5	5
6. Description of surgical technique (0–5)	5	5	3	5	5	5	5
7. Rehabilitation & compliance (0-10)	10	10	0	10	10	10	10
Part B:							
1. Outcome criteria (0–10)	7	7	4	7	7	7	7
2. Outcome assessment (0–15)	11	5	5	5	5	5	5
3. Selection process (0–15)	15	8	5	5	15	15	10
Total Coleman Methodology Score (0-100)	**68**	**45**	**38**	**49**	**62**	**62**	**68**

Scores for each of the 10 methods criteria for studies reporting the results of displaced intra-articular calcaneal fractures treated with a primary arthrodesis