Clinical research

3D CT scan assessment of the outcome of displaced intra-articular calcaneal fractures: operative versus non-operative treatment

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Abstract

Introduction: Computed tomography (CT) scan is helpful in identifying bone deformities resulting from intraarticular calcaneal fractures such as loss of calcaneal height, increased width of calcaneal wall, and disruption of the posterior articular facet. The aim of this study is to compare the result of spiral CT scan assisted analysis of calcaneum anatomy, articular congruity and onset of arthritic changes with intraarticular calcaneal fractures in patients treated either operatively or conservatively.
Material and methods: Twenty patients were recruited, 9 in the operative group and 11 in the conservative group. CT scan of the injured foot and ankle were taken followed by detailed functional assessment based on the American Orthopaedic Foot & Ankle Society Score (AOFAS) and Maryland Foot Score (MFS). Calcaneal height, length and width were measured to assess the functional and radiological outcome in the patients. The presence and severity of arthritic changes were reviewed.
Results: The calcaneal height, length and width were relatively restored in the operative group compared to the conservative group. A significantly larger posterior articular facet step was seen in the conservative group with accelerated onset and significantly higher (p = 0.001) grade of arthritis in the subtalar joints apart from having significantly higher (p = 0.038) incidences of calcaneocuboid arthritis. The operative group showed significant improvement (p = 0.009) in functional outcome based on MFS scoring system.
Conclusions: Operative intervention with calcaneal locking plate provides good framework for near anatomical bone healing and redistributes the mechanical forces on the foot resulting in improved pain, function and alignment in patients.

Key words: articular step, arthritic, calcaneus, American Orthopaedic Foot and Ankle Society Score, Maryland Foot Score.

Introduction

The calcaneus is the most frequent tarsal bone to be fractured in trauma (60%) [1]. Trauma studies showed that the prevalence of intra-articular calcaneal fractures was 75% while the remainder were extra-articular. The commonest mechanisms of calcaneal fracture include axial loading, motor vehicle accidents and falls from height [2].

The morbidity considered in the outcome of intra-articular fractures of the calcaneus is related to the posterior talar articular facet involvement, as described by the Sanders system, which classifies these fractures into four types, based on the number of fracture fragments at the widest point of the posterior articular facet [3].

The treatment of calcaneal fractures remains controversial, partly because of problems with different classification systems, indications for operative treatment, and different assessments of the clinical and radiological results.

Plain radiographic imaging (anteroposterior, axial and lateral) of the foot and ankle is sufficient to diagnose extra-articular calcaneal fractures with respect to Böhler and Gissane angles, calcaneal width and height.

A number of studies have examined the correlation between Böhler's angle and the functional outcome of displaced intra-articular calcaneal fractures, but the results have been inconsistent [4]. The limitation of Böhler's angle as a prognostic indicator is probably due to large variation of its normal value (25° to 40°) as well as variation within the individual (between the left and right foot) [5].

Hence, for intra-articular fractures with subtalar involvement, many studies have stressed the need to delineate the exact fracture pattern in order to institute correct therapy. Fracture of the subtalar joint should be treated like any other intra-articular fracture by anatomical reduction, rigid fixation and early mobilization [6]. Inherent subtalar congruity is essential in relieving the ankle from rotational forces during walking and preventing the onset of secondary degenerative arthritis [7].

Computed tomography (CT) scan is the best available method to identify the major bony deformities resulting from intra-articular calcaneal fractures such as loss of calcaneal height, increased width with outward bulging of the lateral calcaneal wall, and disruption of the posterior articular facet [8]. Brunner *et al.* proposed the Munich classification of calcaneal fractures based on spiral CT assessments with the help of radiologists [9]. This classification differentiates six categories (I to VI) of fractures according to joint involvement, number of posterior facet fragments, and extent of fragment displacement. The classification is shown in Table I.

The higher the hierarchy of fracture classification, the worse is the prognosis. Furthermore, suffixes A, B, C and D were added to indicate posterior articular facet displacement of > 2 mm (A), widening of the heel below the fibular notch (B), reduction in calcaneal height of more than 10% (C) and finally calcaneocuboid angle axis shift above 10° (D).

Displaced intra-articular fractures require surgical intervention within 3 weeks. In the 1980s, conservative surgery such as closed reduction and percutaneous pinning was advocated due to fewer complications, better soft tissue healing and decreased intraoperative time.

Ultimately, operative reduction should meet the principle of restoring the height, length and width of the fractured calcaneus, and anatomical reconstruction of the subtalar and calcaneocuboid joint surfaces [10]. The three-dimensional calcaneal anatomy needs to be restored, rather than selective reduction of the posterior facet joint, which was previously deemed sufficient.

Material and methods

This study was a prospective cohort analysis of the management outcome of calcaneal fractures in two groups of patients: group 1 that was treated by open reduction and locking plate fixation, and group 2 with conservative management. It was conducted in Pusat Perubatan Universiti Kebangsaan Malaysia.

Table I. Modified Munich classification

Class	Description	Recommended treatment
I	Extra-articular fracture without displacement	Conservative
II	Extra-articular fracture with displacement (A); heel widening (B); reduction in height (C); calcaneocuboid axis shift (D)	Operative
III	Intra-articular fracture without displacement	Conservative
IV	Intra-articular fracture, two posterior facet fragments, with displacement: posterior facet displacement (A); heel widening (B); reduction in height (C); calcaneocuboid axis shift (D)	Operative
V	Intra-articular fracture, three posterior facet fragments, with displacement: posterior facet displacement (A); heel widening (B); reduction in height (C); calcaneocuboid axis shift (D)	Operative
VI	Intra-articular fracture, ≥ 4 posterior facet fragments, with displacement: conservative posterior facet displacement (A); heel widening (B); reduction in height (C); calcaneocuboid axis shift (D)	Conservative

A total of 20 patients were recruited from 2011 to 2016, nine in the operative arm (group 1) and eleven in the conservative arm (group 2). The selected patients were Malaysian, male or female, aged 18–65 years, with post-traumatic closed unilateral intra-articular calcaneal fractures with intra-articular displacement of 2 mm or more such as Sanders type II or III. Exclusion criteria included all cases of open or pathological calcaneal fractures, coexistent or previous foot trauma and arthritis, bilateral calcaneal fracture and coexistent head injury.

All 9 patients underwent open reduction and primary calcaneal locking plate fixation within 14 days of trauma via the extensile lateral approach. In this group, the preoperative CT findings, intra- and post-operative complications, physiotherapy and method of ambulation were noted. A total of 11 patients were recruited for the conservative treatment (group 2) in this study.

Patients were contacted and reviewed at the orthopedic clinic. A CT scan of the injured foot and ankle will be done (1 to 4 years after trauma) followed by a detailed functional assessment based on the American Orthopaedic Foot and Ankle Society Score (AOFAS) and Maryland Foot Score (MFS) of the patients' affected limb. Informed consent was obtained from the patients for the access of relevant data and radiographs from previous admissions.

In this study, all the 9 patients in the operative group had an immediate post-trauma CT scan in their records while only 7 out of 11 from the conservative group had a post-trauma CT scan for comparison with the current scan. They were then classified appropriately as per the Modified Munich classification to assess its accuracy in predicting the mode of management and outcome.

Three main measurable CT parameters of the calcaneus were identified and subsequently compared as a benchmark to relate the functional and radiological outcome in patients. These include the calcaneal length, width and measured calcaneal height. In all cases, the opposite calcaneus was not available for comparison. For the first 2 parameters, the immediate post-trauma CT value and current CT value were recorded and the difference computed. There was no issue in the comparison of patients with post-trauma and current CT scans. However, for the 4 patients in the conservative group who did not have a post-trauma CT scan, true lateral X-ray parameters were used as a benchmark for comparison. A single measured height from the current CT was used to calculate the difference in average calcaneal height between the groups.

The assessment of the post-operative articular congruity and arthritic changes that could be seen on the CT scan in the subtalar joint was difficult. The posterior calcaneal articular facet step, being a significant anatomical reduction reference and predictor of mid- to long-term foot function and morbidity, was also measured in the current CT scans of all patients [11]. Finally, the presence and severity of arthritic changes in the talocalcaneal, calcaneonavicular and calcaneocuboid joints were evaluated meticulously with the help of a musculoskeletal radiologist. The widely accepted Knirk and Jupiter articular step grading was used to minimize bias and aid data analysis [12]. The articular step scoring system is shown in Table II while the relevant demographic details of patients involved are shown in Table III.

Functional outcome progression in all 20 patients was assessed individually by the principal researcher using the AOFAS and MFS questionnaire. On the day of the scheduled CT scan, immediate post-trauma AOFAS and MFS scoring followed by current post-trauma/post-operative scoring was performed.

The American Orthopaedic Foot and Ankle Society (AOFAS) hindfoot score of 0 to 100 was developed by Kitaoka *et al.*, consisting of subjective scoring of function, pain and foot alignment along with objective assessment based on physical examination [5]. The Maryland Foot Score is a subjective scoring system which assesses patients' discomfort during activity and rest, ability to walk, return to work, duration of absence from duty and change in shoe size at any given time. An overall rating of excellent (90–100), good (80–89), fair (65–79) and poor (below 64) is then given [13].

Ethical approval

Ethical approval was obtained from the hospital ethical committee before initiation of the study.

Table II. Knirk and Jupiter articular step scoring system (1986)

Grade	Posterior facet articular congruity (mm step off)	Arthritic changes
0	0 to 1	None
1	1 to 2	Slight joint-space narrowing
2	2 to 3	Marked joint space narrowing, osteophyte formation
3	> 3	Bone on bone osteophyte formation, cyst formation

Table III. Relevant demographic details of patients

Factor	Conservative		Locking calcaneal plate		Fisher's exact test	
	N	%	*N*	%	χ^2	*P*-value
Gender:						
Female	1	20.0	4	80.0		0.127
Male	10	66.7	5	33.3		
Ethnicity:						
Malay	6	54.5	5	45.5	0.034	0.983
Chinese	4	57.1	3	42.9		
Indian	1	50.0	1	50.0		
Smoking:						
No	5	41.7	7	58.3		0.197
Yes	6	75.0	2	25.0		
Modified Munich:						
III	2	66.7	1	33.3	0.283	0.868
IV	5	50.0	5	50.0		
V	4	57.1	3	42.9		
Complication (immediate):						
Deep infection; debrided	0	0.0	1	100.0	8.430	0.038*
Lateral malleolus sore	1	100.0	0	0.0		
Nil	10	66.7	5	33.3		
Superficial surgical infection	0	0.0	3	100.0		
Ambulation method:						
Crutches	6	42.9	8	57.1		0.157
Wheelchair	5	83.3	1	16.7		
Physiotherapy:						
No	8	88.9	1	11.1		0.010*
Regular	3	27.3	8	72.7		
Arthritis grade:						
0	1	25.0	3	75.0	17.285	0.001*
1	1	14.3	6	85.7		
2	6	100.0	0	0.0		
3	3	100.0	0	0.0		
Talonavicular joint arthritis:						
No	4	40.0	6	60.0		0.370
Yes	7	70.0	3	30.0		
Calcaneocuboid joint arthritis:						
No	6	40.0	9	60.0		0.038*
Yes	5	100.0	0	0.0		

**Significant p < 0.05.*

Results

A total of 20 patients participated and completed the functional assessment questionnaires and underwent an elective CT scan (2–4 years post-operatively) to assess the anatomical restoration, posterior articular facet congruity and arthritic changes

in the injured calcaneus. This included nine patients in the operative (group 1) and eleven in the non-operative arm (group 2). The repeat CT scan in all these patients showed radiological union.

The mean age of patients in the operative arm was 41 years, while in the conservative arm it was 52.18 years. The male gender, being more at risk of trauma, formed a majority of 75%, with 10 in the conservative and 5 in the operative arm. The simplified modified Munich classification (A–D abbreviations removed) was used to study the fracture distribution of all patients. Three patients were of class III, while the remaining 17 were of classes IV and V (8 in the operative and 9 in the conservative group). However, this class distribution may not be accurate, as 4 of the 11 patients in the conservative group did not have any immediate post-trauma CT for comparison and the Munich class was deduced from radiographs.

Four patients in the operative group had immediate post-operative complications with three superficial surgical site infections which resolved with antibiotics and one wound breakdown which required wound debridement. Only 1 of the 11 patients in the conservative group developed a lateral malleolus pressure sore due to prolonged boot slab immobilization. Table IV shows the descriptive analysis results of the patients involved.

As regards immediate post-operative ambulation, 6 of the 11 patients in the conservative group used crutches while 5 were wheelchair-bound, compared to 8 out of 9 in the operative group who ambulated with crutches, emphasizing the enhanced mobility offered by surgical intervention. Likewise, the compliance with regular physiotherapy was much better in group 1 than group 2, which indirectly translated into better functional outcome scores on current review.

The dynamically changing anatomical parameters of the calcaneus during healing were the main focus in this study. The calcaneal length, being the main contributor in the foot arches,

Table IV. Descriptive analysis of patients (*N* = 20)

Parameter	Mean	Std. dev.	Min.	Max.	Median	25th percentile	75th percentile	IQR
Age	47.15	14.53	23	66	46.00	35.25	63.75	28.50
X-ray	26.40	4.87	18	36	26.50	22.25	30.00	7.75
Böhler's immediate post-op.	27.10	6.41	18	40	25.50	22.00	33.00	11.00
Böhler's angle (current)	28.40	5.53	18	36	29.00	24.00	33.00	9.00
Cal length (post-op.)	80.85	4.96	72	90	82.00	76.25	84.50	8.25
Cal length (current)	82.85	4.69	76	91	84.00	78.00	85.00	7.00
Cal width (post-op.)	42.90	3.16	37	49	42.50	40.25	45.75	5.50
Cal width (current)	44.15	3.05	36	48	44.00	42.00	46.75	4.75
Arthritis grade	1.40	0.99	0	3	1.00	1.00	2.00	1.00
VAS pain score	2.85	1.18	0	5	3.00	2.00	3.75	1.75
AOFAS (post-op.)	71.50	6.71	56	82	71.00	68.00	76.00	8.00
AOFAS (current)	75.70	8.42	60	88	76.00	70.00	83.50	13.50
MFS (post-op.)	72.10	7.89	58	86	70.50	65.75	80.00	14.25
MFS (current)	76.05	9.32	62	90	74.00	69.25	86.00	16.75
Absolute foot height	83.65	5.21	73	91	84.50	80.00	88.00	8.00
Articular facet step	1.55	0.94	0	3	2.00	1.00	2.00	1.00
Calcaneal height	44.05	3.56	38	50	44.00	41.25	46.75	5.50
Diff AOFAS (current – post op.)	4.20	5.27	–8.00	14.00	6.00	2.00	6.00	4.00
Diff_MFS (current – post-op.)	3.95	3.89	–6.00	12.00	4.00	2.00	6.00	4.00
Diff Böhler's	0.70	3.23	–4.00	6.00	1.00	–2.00	4.00	6.00
Diff calcaneal length	2.00	3.64	–4.00	9.00	2.00	–0.75	3.75	4.50
Diff calcaneal width	1.25	2.73	–5.00	6.00	2.00	–1.00	2.75	3.75

was compared immediately after trauma and on current review, and as expected, better mean improvement and preservation in length were seen in the operative group (3.22 mm) compared to the conservative group (1.00 mm).

Another significant difference noted was the effect of the calcaneal plate in maintaining the calcaneal width in the operative group (the mean change noted was 0.76 mm) compared to the conservative group, which had issues of calcaneal widening and lateral foot pain on prolonged weight bearing (mean increase in width of 1.73 mm). Since all current CT scans were done without weight bearing, mean measured calcaneal height was used as a reference of bony subsidence at any given time, averaging 46.89 mm in group 1 compared to 41.73 mm in group 2.

Intraoperative use of image intensifier ensures a more accurate 3 dimensional reconstruction of the fractured calcaneus, which is reflected by a significantly larger posterior articular facet step (measured in mm) seen in the conservative group compared to the operative group. This factor directly contributes to an accelerated onset and significantly higher grade of arthritis in the subtalar joints of the conservative group compared to the operative group. Another important point to note was the significant correlation between articular facet step and severity of subtalar arthritis in the conservative group, while the operative group did not show any correlation. This is possibly explained by the protective effect of the calcaneal mesh plate, which reduces the rate of subsidence and retards the onset of subtalar arthritis, which usually sets in by 18 months of injury. Tables V–VII show the comparison of mean change of variables, the difference of articular facet step and arthritic grade and the Pearson correlation result respectively.

The axial and coronal cut of the spiral CT of the foot and ankle enables the assessment of adjacent subtalar joints in detail. The incidence of talonavicular arthritis in the conservative group

Table V. Difference of mean change of variables

Variable	Option	*N*	Mean	Std. deviation	*t*	*P*-value
AOFAS score (current – immediate post-op.)	Conservative	11	2.36	5.99	–1.83	0.084
	Locking calcaneal plate	9	6.44	3.28		
MFS score (current – immediate post-op.)	Conservative	11	2.00	3.69	–2.94	0.009*
	Locking calcaneal plate	9	6.33	2.69		
Böhler's angle (current – immediate post-op.)	Conservative	11	–0.55	2.73	–2.06	0.054
	Locking calcaneal plate	9	2.22	3.27		
Calcaneal length (current – immediate post-op.)	Conservative	11	1.00	2.53	–1.39	0.181
	Locking calcaneal plate	9	3.22	4.52		
Calcaneal width (current – immediate post-op.)	Conservative	11	1.73	2.20	0.86	0.402
	Locking calcaneal plate	9	0.67	3.32		

Table VI. Comparison of articular facet step and arthritic grade

Variable	Option				χ^2	*P*-value
	Conservative (group 2)		Locking calcaneal plate (group 1)			
	N	%	*N*	%		
Arthritis grade:						
0	1	25.0	3	75.0	17.29	0.001*
1	1	14.3	6	85.7		
2	6	100.0	0	0.0		
3	3	100.0	0	0.0		
Posterior articular facet step [mm]:						
0	0	0.0	3	100.0	16.09	0.001*
1	1	16.7	5	83.3		
2	7	87.5	1	12.5		
3	3	100.0	0	0.0		

Table VII. Pearson correlation

Option	Factor	Articular facet step	
		r	*P*-value
Conservative	Arthritis grade	0.742	0.009*
Locking calcaneal plate	Arthritis grade	0.500	0.170

**Significant p < 0.05.*

(which is expected within 1–2 years of trauma) was much higher at 70% compared to a mere 30% in the operative group. A very significant finding to note was the detection of calcaneocuboid arthritis in the conservative group (5 out of 11 patients) compared to nil in the operative group, implicating the effect of calcaneal malunion and articular surface depression, which occur when treated conservatively. Patients with operative reduction show improved calcaneal length and less widening overtime immediately post-operative or trauma as shown in Figures 1 and 2 compared to patients undergoing conservative treatment.

As for the functional outcome assessment, as expected, the operative group showed a significantly higher range of improvement (mean difference between immediate post-operative score and current score on the day of the interview) both for the AOFAS and MFS scoring systems compared to the conservative groups, as shown in Figures 3 and 4. The mean score improvement was 2 both for MFS and AOFAS scores in group 2 compared to an average of 6 points seen in both AOFAS and MFS in group 1. The mean current AOFAS score for group 1 was 82.22 compared to group 2 with 70.36. The mean current MFS score was 83.56

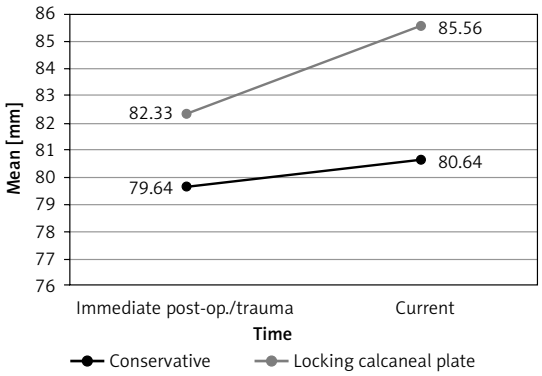

Figure 1. Calcaneal length – improved length with operative reduction

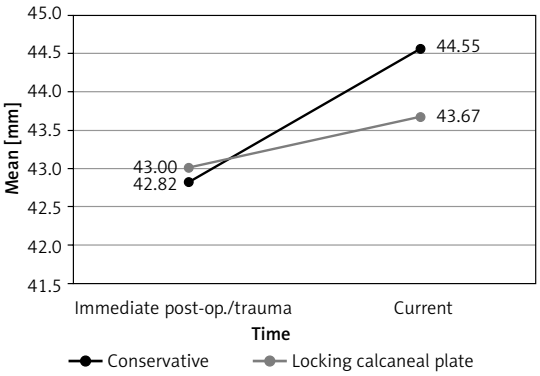

Figure 2. Calcaneal width pattern – less widening over time seen in the operative group

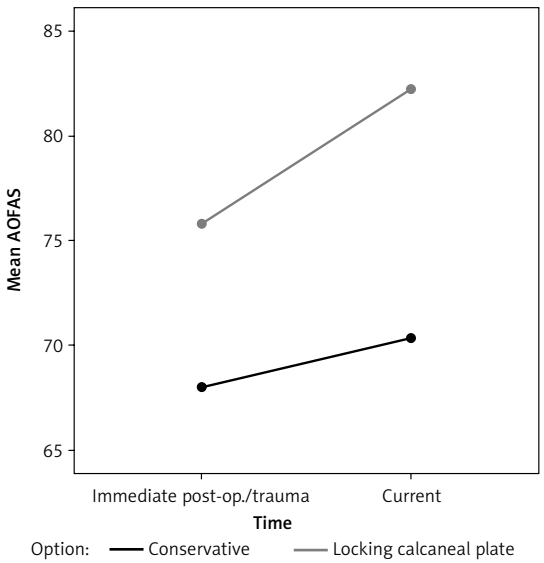

Figure 3. AOFAS trend in both groups

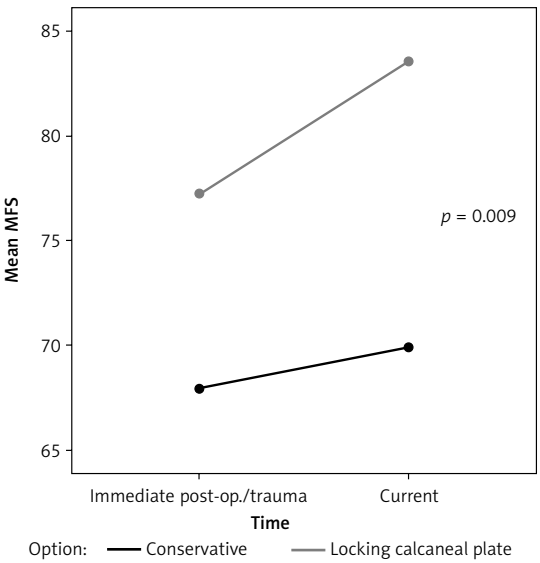

Figure 4. MFS trend in both groups

for group 1 and 69.91 for group 2. This relative difference seen in patients' satisfaction outcome is consistent with the significantly higher grades of subtalar arthritis seen in group 2 compared to group 1.

Discussion

The use of the CT scan as a preoperative tool in management of intra-articular fractures helps classify and identify the severity of comminution and delineate the major fracture fragments, subtalar joint incongruity, and possible soft tissue structures needing operative repair. Imaging tools such as CT are more accurate and hence are required for more accurate diagnosis and surgical planning [14]. Numerous comparative analyses of fracture reduction with plain radiograph versus CT scan have proven that CT is more sensitive in detection of a gap or articular step, and hence is an accurate predictor of early arthritic changes [7].

In 1992, a retrospective comparison of medium term outcome (average: 2.4 years) between operated and non-operated groups of intra-articular calcaneal fractures among 69 patients in Hong Kong showed significantly improved activity, pain, range of movement and regression of hind foot swelling in the operated group. Radiologically, articular congruity was better preserved with milder arthritic changes seen in the operated group [15]. In this prospective study, one of the notable limitations was the small sample size. Besides that, the unavailability of immediate post-trauma CT for all patients (especially the conservative arm) as a comparison with current CT may have caused some interpretation bias. The singly measured calcaneal height (with no opposite side for comparison) may not be an accurate indicator of severity and rate of bony subsidence. The assessment of functional outcome based on AOFAS and MFS score mean improvement may also be slightly inaccurate as the immediate post-trauma scores were deduced from the best recall of the patient. The pooled results indicated no significant differences between the 2 groups with regard to the functional results.

Another important fact was that all the CT scans of the foot and ankle in this study were performed for 0.625-mm slices, a pitch of 0.5625, and 200 mA exposures. This was a far cry from the actual capacity of the latest multichannel helical CT scans, which can provide thinner sections and more detailed reconstructions of the calcaneus. Hence the detailed analysis of soft tissue impingement (for example peroneal or flexor tendon entrapment and irritation) could not be thoroughly analyzed. In all patients of the operated group, there were no screws in the intra-articular space or obvious hardware malposition. Weight bearing with an intra-articular screw might have otherwise resulted in post-operative pain or accelerated degenerative changes had the screws not been identified and removed.

Intraoperative 3D imaging is found to be useful in evaluating the congruence of joints and the placement of implants in calcaneal fractures [16]. Apart from that, repeating the current CT scan which was done for all patients benefited them, especially those in the conservative group, in helping detect the early onset and grading of arthritis and involvement of the subtalar joints. The notable arthritis of the calcaneocuboid and talonavicular joints explains the persistent lateral foot pain and the irregular valgus and varus stress the effect on the foot that was seen more in the conservative group than the operative group. These follow-up CT findings are essential in the planning of future arthrodesis procedures for better functional outcomes.

The operative group manifested a relatively high complication rate of 44% compared to the conservative group – a frequent drawback in the decision for open reduction among surgeons. In the extensile lateral approach, wound dehiscence and necrosis remains a dreadful drawback with a quoted incidence of 14% [12]. Deeper infections (average: 1.3–7%) need thorough debridement and targeted antibiotic therapy to prevent any likelihood of morbid osteomyelitis. The incidence of complications was significantly higher in the operative group than in the non-operative group, and the rate of subtalar arthrodesis was significantly lower the operative group. Current evidence on whether operative treatment is superior to non-operative treatment for displaced intra-articular calcaneal fractures is still insufficient [17].

A notable finding in this study was the direct proportion and significant correlation between the posterior articular facet step off and the severity of arthritis which set in. Acute articular injury triggers chondrocyte death (apoptosis or necrosis) and dysfunction, which in turn incites an inflammatory cycle, releasing pro-inflammatory mediators and reactive oxygen species. The inflamed synovium is immersed with increased levels of nitrous oxide, tumor necrosis factor, and interleukin (IL)-1, which cause accelerated chondrocyte damage, matrix degeneration and irreversible arthritis [18]. In the future, targeted biologic therapy and tissue engineering strategies may help halt the progression of post-traumatic arthritis.

In traumatic injury of the calcaneus, unaddressed cartilage damage severely affects the joint congruity, stability, and alignment. Cadaveric studies show up to 300% increases in contact stresses of joints with articular step off [15]. The combination of instability and articular surface incongruity will result in asymmetrical joint over-

load and accelerated arthritis. Hence early surgical intervention for intra-articular fractures is recommended to achieve anatomic reduction. Intra-operative three-dimensional CT and fluoroscopy will help in accurate articular reduction and prevent intra-articular hardware placement and related risks of revision surgery [10].

The limitations of 2 dimensional fluoroscopy have contributed to the rise of arthroscopic assisted fixation of the calcaneus. Besides providing direct visualization of the articular surface, this surgical approach helps diagnose and treat associated osteochondral and ligamentous injuries, perform joint lavage and remove unwanted debris [10]. Setbacks include higher costs, and risk of compartment syndrome related to fluid extravasation and swelling. Numerous studies have shown no superior functional outcome.

The major bony deformities resulting from calcaneal fractures are loss of calcaneal height, increased width with outward bulging of the lateral calcaneal wall (blow out), and disruption of the mechanical axis of the hindfoot [15]. Correction of these deformities is the major goal of treatment. Operative reduction helps restore the calcaneal height (increase of less than 2 mm seen in the conservative group) to a near anatomical extent and helps maintain the lateral foot arch. Besides that, the locking plate provides a protective mesh for healing and remodeling. The construct prevents deformation that occurs with cyclic loading and hence a much slower rate of subsidence compared to that when managed conservatively [18].

Realignment of the posterior facet articular surface is important if one is to reduce the likelihood of post-traumatic arthritis. Computed tomography is the best available method to identify the major bony deformities following calcaneal malunion [10]. Malunion can present as a deformed foot with limited dorsiflexion range. If post-operative pain does not resolve, possible flexor tendon entrapment or irritation by prominent lateral to medial screws, especially at the level of the sustentaculum tali, should be ruled out.

With most articular fractures, on prolonged weight bearing, the vertical force through the talus carries this unit inferiorly and posteriorly while displacing the cartilage lateral wall of the calcaneus outward. This causes broadening of the heel with narrowing of the space between the calcaneus and lateral malleolus, causing the typical lateral impingement. There can be gradual loss of calcaneal height and posterior talar collapse into the posterior calcaneus, which can be treated with distraction bone block subtalar arthrodesis [11].

The conservative group was found to have a significantly larger articular facet step, resulting in early and accelerated talonavicular and calcaneocuboid arthritis. Operative management despite the considerable risk of complications helps provide a framework for near anatomical bone healing and redistributes the mechanical forces on the foot, indirectly retarding occurrence of bony collapse, subsidence, soft tissue impingement and subtalar arthritis. In order to ensure a more satisfactory outcome in surgically managed patients, intraoperative 3 dimensional assessments of the calcaneal parameters is a must and can be achieved with fluoroscopy and specific Broden's view.

In conclusion, despite the limitations in sample size and availability of uniform radiological comparison, this study managed to highlight the importance of a post-traumatic or post-operative 3D CT scan in detecting posterior articular facet incongruity, and hence the emphasis to promptly detect subtalar arthritic changes during the early follow-up period of comminuted intra-articular fractures.

Conflict of interest

The authors declare no conflict of interest.

References

1. Buckley RE, Tough S. Displaced intra-articular calcaneal fractures. J Am Acad Orthop Surg 2004; 12: 172-8.
2. Hyer CF, Atway S, Berlet GC, Lee TH. Early weight bearing of calcaneal fractures fixated with locked plates: a radiographic review. Foot Ankle Spec 2010; 3: 320-3.
3. Griffin D, Parsons N, Shaw E, et al. Operative versus non-operative treatment for closed, displaced, intra-articular fractures of the calcaneus: randomised controlled trial. BMJ 2014; 349: g4483.
4. Ibrahim T, Rowsell M, Rennie W, Brown AR, Taylor GJ, Gregg PJ. Displaced intra-articular calcaneal fractures: 15-year follow-up of a randomised controlled trial of conservative versus operative treatment. Injury 2007; 38: 848-55.
5. Kitaoka HB, Schaap EJ, Chao EY, An KN. Displaced intra-articular fractures of the calcaneus treated non-operatively. Clinical results and analysis of motion and ground-reaction and temporal forces. J Bone Joint Surg Am 1994; 76: 1531-40.
6. Loucks C, Buckley R. Bohler's angle: correlation with outcome in displaced intra-articular calcaneal fractures. J Orthop Trauma 1999; 13: 554-8.
7. De Boer AS, Van Lieshout EM, Den Hartog D, Weerts B, Verhofstad MH, Schepers T. Functional outcome and patient satisfaction after displaced intra-articular calcaneal fractures: a comparison among open, percutaneous, and nonoperative treatment. J Foot Ankle Surg 2015; 54: 298-305.
8. Sanders R, Vaupel ZM, Erdogan M, Downes K. Operative treatment of displaced intraarticular calcaneal fractures: long-term (10–20 years) results in 108 fractures using a prognostic CT classification. J Orthop Trauma 2014; 28: 551-63.
9. Linsenmaier U, Brunner U, Schöning A, et al. Classification of calcaneal fractures by spiral computed tomography: implications for surgical treatment. Eur Radiol 2003; 13: 2315-22.
10. Franke J, Wendl K, Suda AJ, Giese T, Grützner PA, von Recum J. Intraoperative three-dimensional imaging in the

treatment of calcaneal fractures. J Bone Joint Surg Am 2014; 96: e72.
11. Daftary A, Haims AH, Baumgaertner MR. Fractures of the calcaneus: a review with emphasis on CT. Radiographics 2005; 25: 1215-26.
12. Joshi J, Gupta A, Menon H, Patel M, Lakhani D. Functional outcome of surgically treated sanders types II, III, IV calcaneal fractures: an observational study. IJSS J Surg 2015; 2: 1-7.
13. Richter M, Zech S, Geerling J, Frink M, Knobloch K, Krettek C. A new foot and ankle outcome score: Questionnaire based, subjective, Visual-Analogue-Scale, validated and computerized. Foot Ankle Surg 2006; 12: 191-9.
14. Leung KH, Fang CXS, Lau TW, Leung FKL. Preoperative radiography versus computed tomography for surgical planning for ankle fractures. J Orthop Surg 2016; 24: 158-62.
15. Leung KS, Yuen KM, Chan WS. Operative treatment of displaced intra-articular fractures of the calcaneum. Medium-term results. Bone Joint J 1993; 75: 196-201.
16. Gwak HC, Kim JG, Kim JH, Roh SM. Intraoperative three-dimensional imaging in calcaneal fracture treatment. Clin Orthop Surg 2015; 7: 483-9.
17. Luo X, Li Q, He S, He S. Operative versus nonoperative treatment for displaced intra-articular calcaneal fractures: a meta-analysis of randomized controlled trials. J Foot Ankle Surg 2016; 55: 821-8.
18. Ågren PH, Wretenberg P, Sayed-Noor AS. Operative versus nonoperative treatment of displaced intra-articular calcaneal fractures: a prospective, randomized, controlled multicenter trial. J Bone Joint Surg Am 2013; 95: 1351-7.