Displaced Articular Calcaneus Fractures: Classification and Fracture Scores: A Preliminary Study

Thos Harnroongroj MD*, Bavornrit Chuckpaiwong MD*,
Chayanin Angthong MD*, Pongtep Nanakorn MD*,
Narumol Sudjai BSc*, Thossart Harnroongroj MD*

*Department of Orthopedics Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok, Thailand

Objective: *To review and group configurations of displaced articular calcaneal fracture advantaged for classification and radiographic fracture scores.*

Material and Method: *Between 2002 and 2011, medical records and radiographs of patients who sustained acute displaced articular calcaneal fractures were reviewed. The calcaneal fracture configurations were grouped as avulsion, bending, burst, or combination. Radiographic displaced articular calcaneal fracture score was designed to include Bohler and Gissane angles, degrees of posterior subtalar joint line parallel, degrees of varus, and burst. The calcaneal fracture score was modified as power of the fracture response to treatment (PFRT). Prevalence of the fracture types, pre- and post-reduction fracture scores including PFRT were studied and statistically analyzed.*

Results: *Sixty-four patients had 77 acute displaced articular calcaneal fractures. The classification consisted of type I avulsion, type II compression bending, type III compression burst, type IV avulsion burst, and type V bending burst. Type IV is the most common. The radiographic calcaneal fracture scores were 10 points. Pre-, post-reduction calcaneal fracture scores and PFRT of type I, II, III, IV, and V were 4.17 (0.41), 0 and 1 (0), 4.63 (2.13), 0.50 (0.93) and 0.84 (0.35), 6.94 (2.05), 3.18 (1.38) and 0.50 (0.27), 8.03 (1.12), 3.03 (2.42) and 0.62 (0.30), and 7.22 (2.11), 3.00 (2.50) and 0.59 (0.29) respectively. Statistical analysis showed significant difference ($p < 0.05$). PFRT for screw and pin fixation of type I plus II, IV, and V were 1.00 (0) and 1.00 (0), 0.64 (0.27) and 0.60 (0.36), and 0.54 (0.28) and 0.51 (0.45) respectively. PFRT for plate of type III was 0.54 (0.16). PFRT for casting of type I plus II, III, and IV were 0.50 (0.71), 0.27 (0.46), and 0.35 (0.33) respectively.*

Conclusion: *The classification consisted of five types, which were based on injury mechanisms as avulsion, bending, and burst. The radiographic calcaneal fracture scores contained 10 points and were used for determining complexity of the fractures. PFRT was used for evaluating efficacy of fracture treatment.*

Keywords: *Displaced articular, Calcaneal fracture configuration, Compression load, Avulsion, Bending, Burst, Parameters, Fracture scores, Power of fracture responses to treatments*

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Calcaneus is the largest and irregular shaped tarsal bone. It consists of various parts and is responsible for different functions of the foot. Fractured calcaneus is a common fracture of the foot. The fracture often involves articular surfaces, anatomical structures, and alignment of calcaneus. There are many classifications of the calcaneal fracture[1-6]. Classification is based on fracture line, anatomy, and fracture fragments from bone pieces or columns. The fracture is classified as Essex Lopresti and Rowe classification. Sander and Crosby developed a classification by using coronal CT scan of calcaneus[1,6]. However, the classifications do not include all the important aspects of calcaneus. Management of a fractured calcaneus is still difficult to classify[7,8] because of the evaluation of pre- and post-reduction of the fracture[9]. Therefore, the authors developed another simple classification of displaced articular calcaneal fracture including fracture scores and its modification.

Correspondence to:
Harnroongroj Thossart, Department of Orthopedics Surgery, Faculty of Medicine Siriraj Hospital, Mahidol University, Bangkok 10700, Thailand.
Phone: 0-2419-7968-9
E-mail: tmthr@mahidol.ac.th

Material and Method

The present study was carried out after receiving the certificate of ethic approval from the Siriraj Institutional Review Board.

Between 2002 and 2011, the authors reviewed medical records and radiography of patients who sustained acute displaced articular fracture calcaneus. Inclusion criteria were all ages, both genders, and all acute displaced articular fracture of calcaneus. The fractures included displaced intra-articular surfaces and fracture that resulted in displaced articular surfaces even if the fracture did not extend into articular surfaces of the subtalar joints. Non-displaced, old fracture, pathologic fracture of calcaneus, incomplete medical records and radiographs of calcaneus, and patient who took bisphosphanate were excluded.

The principle of the classification was based on response of the calcaneus to vertical compression load from talus into calcaneus as avulsion, bending, and burst[10,11]. An avulsion fragment is defined as a fracture fragment that occurs from the force of the tendoachillis tendon. The fracture includes the superior part of calcaneus from tendoachillis insertion at posterior tubercle and extends anteriorly to posterior facet of calcaneus (Fig. 1A). A bending fragment is defined as a fracture fragment that includes posterior tubercle below tendoachillis insertion and extends anteriorly to facets of calcaneus. The bending fragment has no lateral, medial cortex, transverse, or longitudinal fracture of the fragment and functions as a bending lever (Fig. 1B). Burst of the calcaneus is defined as a comminuted fracture of lateral and/or medial corticies and/or longitudinal fracture of the calcaneus that increases calcaneal width (Fig. 1C). The calcaneal fracture was classified in five types of fracture by Professor. Dr. Thossart Harnroongroj (Fig. 2). Type I avulsion consists of only avulsion fragment. The type I is expected as the fracture involving Bohler, Gissane angles, and posterior facets joints. A fracture of this type has neither bending nor burst component and no varus deformity of calcaneus. Type II compression bending consists of bending fragment with no avulsion and no burst component. The type II is expected as a fracture involving Bohler, Gissane angles, and facets and varus angle of the calcaneus. Type III compression burst consists of only burst component. Specific characteristics of type III are posterior facet joint depression as thalamic fragment either with or without subsidence of talus. The type III is expected as a fracture involving Bohler, Gissane angles, facets, varus angle of calcaneus, and burst of the calcaneus. This type has no avulsion and no bending fragments. Type IV avulsion burst combines type I and III. This type consists of avulsion and burst components of the calcaneus. The avulsion fragment

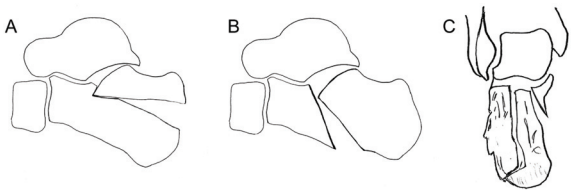

Fig. 1 The fracture components consist of avulsion (A), bending (B), and burst (C)

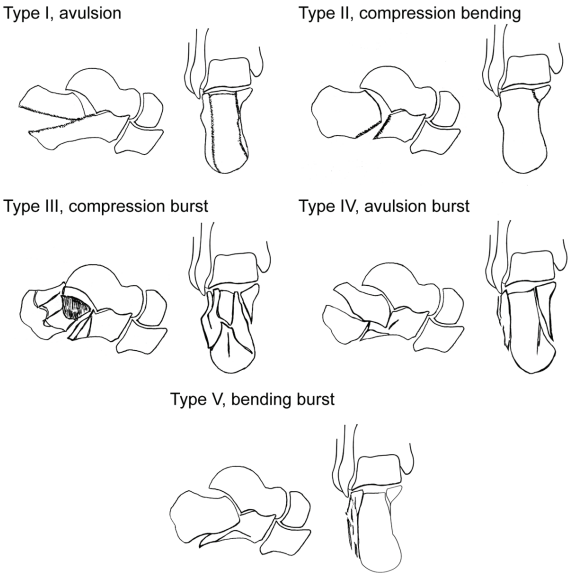

Fig. 2 Five types of displaced articular calcaneal fracture configurations

is similar to type I. The burst occurs at a part of the calcaneus below the avulsion fragment. Type IV involves Bohler, Gissane angles, facets, varus angle, and burst of the calcaneus. Type V bending burst is similar to type IV but the bending fragment site is a superior part of the calcaneus where the fracture begins at the posterior tubercle below the tendoachillis insertion. Therefore, the bending fragment is larger than avulsion fragment type IV. The burst involves part of the calcaneus below the bending fragment. The expected fracture of this type involves calcaneal parameters as in type IV.

In practice, an axial view radiograph of the calcaneal fracture will be considered whether there is a burst component of the fracture. If no burst is found, the fracture should be classified type I or II. On the other hand, there is a burst component, the fracture should be classified type III, IV, or V. After that, the lateral view radiograph is considered to determine

whether there is avulsion or bending component. Then, the fracture can be definitely classified.

After the calcaneal fracture is classified, an evaluating system for qualifying the calcaneal fracture configuration is necessary. Thus, a radiographic calcaneal fracture score was developed by Professor Dr. Thossart Harnroongroj using calcaneal fracture parameters that included Bohler and Gissane angles, parallel of posterior subtalar joint, varus angle, and burst of the calcaneus. The score of calcaneal fracture parameters are weighed based on anatomy and functions of each parameter (Table 1).

The calcaneal fracture parameters were measured by using axial and lateral views of the calcaneus. From the lateral view radiograph, Bohler and Gissane angles[11-13] were measured and scored. The score is weighed as 1 point when the Bohler angle is less than 20 and Gissane angle is less than 95 degrees or including posterior subtalar joint depression. On the other hand, if both angles are equal to or more than that stated above, the score is zero. The posterior subtalar is evaluated by drawing two lines along the posterior facet of the talus and the calcaneus, and then the angle between the lines is measured. If it is more than 5 degrees, including the posterior subtalar joint depression as the thalamic fragment, and more than 2 mm articular surface of posterior facet step-off, it is scored at 3 points. If it is less or equal to 5 degrees, it is scored at zero. The varus angle of the calcaneus is measured from the axial view radiograph of the calcaneus. Because of the obliquity of the medial cortex and the ill-defined irregularity of the lateral cortex of the calcaneus in axial view radiograph, and in case of communited fracture of the calcaneal corticies, the determination of the long axis of the calcaneus is unreliable. Therefore, the calcaneal long axis is efficiently determined from the longitudinal bone trabeculae of the calcaneus in the axial view radiograph.

In cases of type IV and V, the fracture configuration may cause displacement of the upper and lower fragments resulting in overlapped longitudinal bone trabecular. Therefore, longitudinal bone trabeculae is selected from a lower fragment as the long axis of the calcaneus. The first line as the long axis of calcaneus is obtained by a line parallel the longitudinal bone trabeculae of the calcaneus. The long axis of the tibia and fibula cannot be demonstrated in axial view radiograph of the calcaneus. Therefore, an axial view radiograph of the calcaneus at vertical foot position was selected. An apex of lateral cortex curvature of lateral malleolus is used as a reference for the measurement of the calcaneal varus angle. The second line is drawn perpendicularly to the apex of lateral cortex curvature of lateral malleolus. Then, a third line is perpendicularly drawn to the second line. The varus angle of the calcaneus is obtained from the angle that forms between the first and the third line (Fig. 3). When, the varus angle is more than 10 degrees, is scored at 2 points and less or equal 10 is scored at zero.

Table 1. Radiographic calcaneal fracture scores

Calcaneal fracture parameters	Scores
Bohler angle	
≥ 20°	0
< 20°	1
Gissane angle	
≥ 95°	0
< 95° or posterior facet depression	1
Parallel of posterior subtalar joint	
≤ 5°	0
> 5°, 2 mm articular surface step-off or posterior facet depression	3
Varus angle of calcaneus	
≤ 10°	0
> 10°	2
Burst	
No	0
Yes	3
Total	10

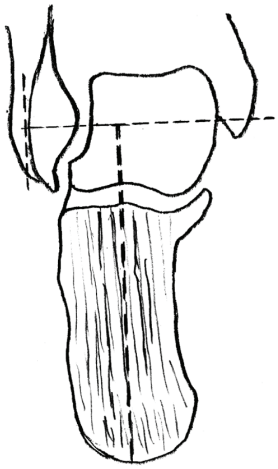

Fig. 3 Degree of varus deformity of calcaneus is measured from axial view of calcaneus by using lateral malleolus as a reference and longitudinal bone trabeculae as long axis of calcaneus

The authors considered the burst of calcaneus from the initial axial view radiograph of the calcaneus when there are displaced fractures of lateral and/or medial corticies and/or longitudinal fracture.

However, determination of calcaneal burst still has a problem of unequal magnification of pre- and post-reduction axial view radiographs. Therefore, degree of calcaneal burst is determined in terms of ratio. The widest distance of burst calcaneus is compared with the widest distance of a stable form fragment as a ratio of the calcaneal burst. The stable form fragment is identified by using pre- and post-operative axial view radiograph of calcaneus. Then, find out a fragment that appears to be the same shape at both pre- and post-reduction axial view radiographs. The stable form fragment may be either a free fracture fragment or a part of the posterior calcaneal tubercle. The widest of the stable part of the posterior tubercle of the calcaneus or of the stable form fragment in both pre- and post-reduction axial views radiographs are measured. The burst of calcaneus is determined by the widest distance between displaced lateral and medial corticies that was measured by drawing two lines through maximal displacement of the fracture pieces of lateral and medial corticies of calcaneus and parallel with long axis of calcaneus. Then, a line is draw perpendicular to both lines and measured as the calcaneal width. The widest of the stable form fragment or stable part of posterior tubercle is measured by the same technic. Then, the calcaneal burst ratio is obtained and compared between both pre- and post-reduction (Fig. 4). If the pre-reduction axial view radiograph showed no burst component of the fracture, the score is zero. If there is a burst component of the fracture, the score is 3 points for the burst calcaneal fracture parameter. On the other hand, if the post-reduction burst ratio is less than the burst ratio of the pre-reduction radiograph, the post-reduction burst is scored to be zero and to be 3 points for more than or equal to the initial burst ratio. Therefore, the total calcaneal fracture score is 10 (Table 1). The score of the fracture depends on number and deformity of the fracture parameters.

In the present study, the expected maximal calcaneal fracture scores of each fracture types were evaluated. Demographic data of the patients were recorded and included sexes, ages, sites, causes of injuries, and associated injuries. Then, axial and lateral view radiographs of the calcaneal fracture at pre-reduction, immediate post-reduction, and 1 to 2 year post-reduction were studied by using a picture achiving and communication system (PACS) for both the fracture configurations and measurement of calcaneal fracture parameters. The fracture configurations were classified and the calcaneal fracture scores were done by two experienced orthopedic surgeons. Consequently, interobserver reliability of the classification and fracture score were reliable. Pre- and post-reduction fractures configuration were evaluated by the fracture scores. Surgical treatment of each of fracture types in term of fixation by screw, pin, plate, and cast were recorded. The fractures were sequentially sorted by type and severity by using the fracture scores. Improving fracture score after reduction was calculated by different scores of pre- and post-reduction. Ratio of improving fracture score with the pre-reduction scores was defined as the power of fracture responding to treatment (PFRT). When the PFRT is closed to 1, it means that the post reduction fracture configuration is closest to the normal anatomy. Prevalence and 95% confidence interval of the fracture types were evaluated and calculated in percentages. Pre- and post-reduction fracture scores and PFRT were statistically analyzed by Student's t-test and one-way ANOVA. Moreover, PFRT of the fracture types with pin, screw, plate fixation, and casting were calculated with 95% CI. A p-value of less than 0.05 was considered statistically significant.

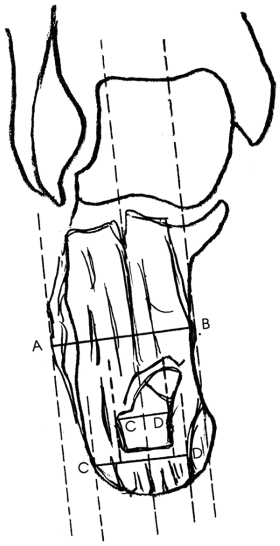

Fig. 4 Burst of calcaneal fracture is measured. AB is the width of calcaneal burst fracture, CD is the width of stable shape fragment. The burst of calcaneal is determined as ratio of AB to CD

Results

The expected abnormal calcaneal fracture parameters and fracture score of the fractures type I, II, III, IV, and V are shown in Table 2. The expected severity of the fracture configuration of the fracture type could be sequentially sorted from minimal to maximal fracture scores as type I, II, III, IV, and V. Type I and II fracture without burst has less score than type III, IV, and V fracture with burst component. Type I, avulsion was the expected simplest fracture configuration with the least score of 5 while the fracture configuration of type III, IV, and V had a maximum score of 10

Sixty-four patients sustained 77 acute displaced articular fracture calcaneus, 36 right and 41 left sides. Ages ranged from 18 to 70 years old (average 41.64, SD 13.40), 52 males and 12 females (Table 3). Causes of injuries consisted of 56 fall from height and eight from traffic accident. Associated injuries included seven vertebral body fractures (T_{12} to L_3), two of which had paraplegia and traumatic cauda equina syndrome. They also included three hip fractures (2 left and 1 right), four superior pelvic rami fractures (2 left and 2 right), one right patellar fracture, one right femoral shaft fracture, two right tibial shaft fractures, two right non-displaced talar neck fractures, one fracture left ulnar and radius shafts, one tarsal navicular fracture, one acute hand injury, one right twelfth rib fracture, one right lung pneumothorax, and one head injury.

The review data of 77 fracture of the calcaneus showed that interobserver reliability of calcaneal fracture classification and radiographic calcaneal fracture scores were Kappa value of 0.86 and 0.82 respectively. In Table 3, there were six of type I, eight of type II, 17 of type III, 37 of type IV, and nine of type V. Prevalence of type I, II, III, IV, and V

Table 2. The expected abnormal calcaneal fracture parameters and expected fracture scores of types of calcaneal fractures

Types of the classification	Bohler angle	Gissane angle	Degree of posterior subtalar joint line	Varus angle	Burst	Fracture scores
I	✓	✓	✓	-	-	5
II	✓	✓	✓	✓	-	7
III	✓	✓	✓	✓	✓	10
IV	✓	✓	✓	✓	✓	10
V	✓	✓	✓	✓	✓	10

Table 3. The demographic data of patients and prevalence of calcaneal fracture types

	Fracture types					Total
	I	II	III	IV	V	
Gender	n = 6	n = 6	n = 14	n = 31	n = 7	n = 64
Male	5	5	11	24	7	52
Female	1	1	3	7	0	12
Age (yrs)						
Mean (SD)	44.67 (12.80)	40.67 (17.60)	43.86 (13.21)	40.29 (13.47)	41.43 (13.19)	41.64 (13.40)
Range	30-61	19-69	25-70	18-68	24-57	18-70
Fracture sites	n = 6	n = 8	n = 17	n = 37	n = 9	n = 77
Left	6 (100%)	4 (50.0%)	8 (47.06%)	20 (54.05%)	3 (33.33%)	41 (53.25%)
Right	0	4 (50.0%)	9 (52.94%)	17 (45.95%)	6 (66.67%)	36 (46.75%)
Prevalence % (n/total)	7.79 (6/77)	10.39 (8/77)	22.08 (17/77)	48.05 (37/77)	11.69 (9/77)	
95% CI	2.91, 16.19	4.59, 19.45	13.42, 32.98	36.52, 59.74	5.49, 21.03	
Techniques	n = 6	n = 8	n = 17	n = 37	n = 9	n = 77
Screw	6	2	3	18	6	35
Pin	0	3	1	11	3	18
Plate	0	1	10	2	0	13
Cast	0	2	3	6	0	11

Fig. 5 A 26 year old male patient who fell from the height and sustained right calcaneal fracture, type I: avulsion. Pre-reduction axial view showed no burst and no varus deformity of calcaneus. Lateral view showed 22° Bohler, 118° Gissane angle. 8° of posterior subtalar joint lines. The prereduction score was 3. Postreduction lateral view radiographs showed that reduction of the fracture was done and fixed with 2 screws. Bohler and Gissane's angles were 28°, 129°. Angle of degrees of posterior subtalar joint lines are 4°. The postreduction calcaneus fracture screw was zero. The PFRT was 1

Fig. 6 A 19 year old male who fell from 5 meter height and sustained right calcaneal fracture, type II compression bending. Prereduction axial view radiograph of the right calcaneus showed no burst and 13° varus deformity. Lateral view showed Bohler, Gissane angles and degree of posterior subtalar joint lines were 17°, 92° and 1° respectively. Prereduction fracture score were 4. Postreduction radiographs showed the fracture was reduced and casting. An axial view radiograph showed 9° varus of calcaneus. Lateral view radiograph showed Bohler, Gissane angles and degree of posterior subtalar joint lines were 24°, 91° and 0° respectively. Postreduction fracture score was 1. The PFRT was 0.75

were 7.79% (95% CI 2.91, 16.19), 10.39% (95% CI 4.59, 19.45), 22.08% (95% CI 13.42, 32.98), 48.05% (95% CI 36.52, 59.74), and 11.69% (95% CI 5.49, 21.03) respectively. The type IV is the most common and type I is the rarest (Fig. 5-9). Seventy-seven fractures were reduced. Eighteen fractures were fixed by percutaneous pinning. Thirty-five were fixed by percutaneous screw fixation. Thirteen were treated by open reduction and plating. Eleven fractures were treated by casting. In Table 4, showed that average pre-reduction calcaneal fracture scores of type I, II, III, IV, and V were 4.17 (0.41) (95%CI 3.74, 4.60), 4.63 (2.13) (95%CI 2.84, 6.41), 6.94 (2.05) (95%CI 5.89, 7.99), 8.03 (1.12) (95%CI 7.65, 8.40), and 7.22 (2.11) (95%CI 5.60, 8.84), respectively. Average post-reduction calcaneal fracture score of type I, II, III, IV, and V were 0, 0.50 (0.93) (95% CI -0.27, 1.27), 3.18 (1.32) (95% CI 2.47, 3.89), 3.03 (2.42) (95% CI 2.22, 3.83), and 3.00 (2.50) (95% CI 1.08, 4.92) respectively. The statistical analysis showed significant differences of pre- and post-reduction fracture scores of all fracture types ($p < 0.05$). Average of improving fracture scores after reduction of type I, II, III, IV, and V were 4.17 (0.41) (95% CI 3.74, 4.60), 4.13 (2.36) (95% CI 2.15, 6.10), 3.77 (2.14) (95% CI 2.67, 4.86), 5.00 (2.54) (95% CI 4.15, 5.85), and 4.22 (2.39) (95% CI 1.66, 5.01) respectively. Average PFRT of type I, II, III, IV, and V were 1.00 (0), 0.84 (0.35) (95% CI 0.54, 1.13), 0.50 (0.27) (95% CI 0.36, 0.64), 0.62 (0.30) (95% CI 0.52, 0.72), and 0.59 (0.29) (95% CI 0.37, 0.81) respectively. The clinical severity of fracture types could sequentially be sorted by using minimal to maximal pre-reduction fracture scores as type I, II, III, V, and IV (Fig. 5-9). Type

Fig. 7 A 49 year old male patient fell from the height and sustained right calcaneal fracture type III compession burst. Prereduction axial view radiograph of calcaneus showed the fracture with 2.25 burst ratio and 14 degrees varus of calcaneus. Lateral view showed 1° Bohler. There was posterior subtalar joint depression with subsidence of talus. Pre-reduction fracture score was 10. Postreduction radiographs of calcaneus showed that the fracture was reduced and fixed by plate and screws. Axial view radiograph showed reduction of the fracture with 1.46 burst ratio and 18° varus of calcaneus. Lateral view radiograph showed 10° Bohler, 105° Gissane angles and 1° posterior subtalar joint line. Postreduction fracture score was 3 and the PFRT was 0.70

Fig. 8 A 60 year old female patient who fell from the height and sustained right calcaneal fracture type IV, avulsion burst. Prereduction axial radiograph showed the fracture with 2.04 burst ratio and 12° varus calcaneus. Lateral views showed 14° reverse Bohler, 89° Gissane angles and 31° posterior subtalar joint lines. Prereduction fracture score was 10. Postreduction radiographs of the calcaneus showed that the fracture was reduced and fixed with 2 screws. Axial view showed that the fracture was reduced with 1.71 burst ratio and 9° varus of calcaneus. Lateral view showed 13° Bohler, 106° Gissane angles and 2mm articular surface of posterior subtalar joint step-off. Postreduction fracture score was 4 and The PFRT was 0.6

I was the best fracture configuration and type IV was the worst. Post-reduction fracture score of fracture types were sorted minimum to maximum scores as type I, II, V, IV, and III. Type I has the best result of fracture reduction and type III has the worst. These results were confirmed by PFRT (Table 4). In Fig. 10 and Table 5, mean of pre- and post-reduction fracture scores showed that type I and II had similar characteristics with no statistical significant differences of pre, post-reduction fracture scores and PFRT ($p > 0.05$). Graph of types III, IV, and Vshowed another similar characteristics and without statistically significant differences of pre-, post-reduction fracture scores and PFRT ($p > 0.05$) (Table 5). However, type III, IV, and V were significantly different from type I and II ($p < 0.05$) (Table 5).

The results showed that five types of the calcaneal fracture could be regrouped into two groups; group 1, the fracture without burst component, consisted with type I and II, and Group 2, the fracture with burst component, consisted of type III, IV, and V (Fig. 5-9).

Table 6 shows the responses of the fracture to treatment with various implant fixation, evaluated by PFRT. Fracture configuration of type I and II responded to fixation with pin and screw with 1.0 PFRT. The PFRT of type III with plate was 0.54 (0.16) (95% CI 0.42, 0.66) and of type IV with screw and pin fixation

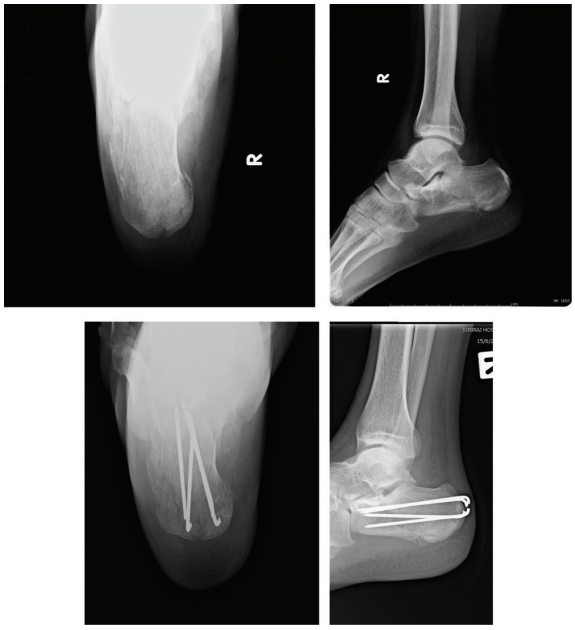

Fig. 9 A 25 year old male patient who fell and sustained right calcaneal fracture type V, compression bending burst. Pre-reduction axial view radiographs of the right calcaneus showed the fracture with 2.31 burst ratio and 1° varus of calcaneus. Lateral view showed 15° Bohler, 113° Gissane angles, and 16° posterior subtalar joint lines. Pre-reduction fracture score was 7. Post-reduction radiographs showed the fracture was reduced and fixed with 3 pins. Axial view radiograph showed reduction of the fracutre with 2.22 burst ratio and 1° varus of calcaneus. Lateral view showed 16° Bohler, 126° Gissane angles, and 14° posterior subtalar joint lines. Post-reduction fracture scores was 4 and the PFRT was 0.4

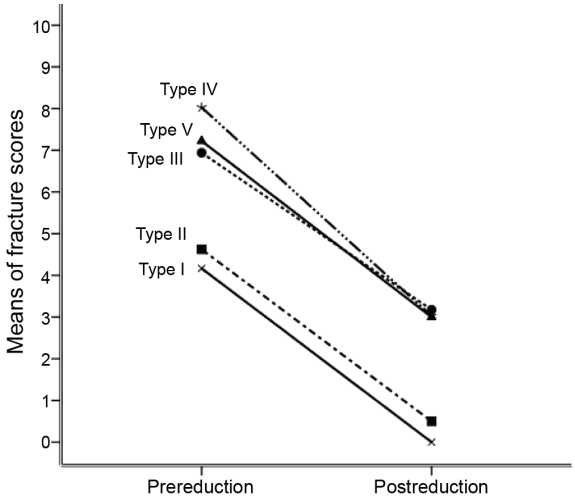

Fig. 10 Means of fracture scores in each type of fracture. Five types of the calcaneal fractures can be regrouped into group without burst (type I and II) and group with burst (type III, IV and V)

were 0.64 (0.27) (95% CI 0.51, 0.77) and 0.60 (0.36) (95% CI 0.36, 0.84) respectively. The PFRT of type V with screw fixation was 0.54 (0.28) (95% CI 0.24, 0.83). Casting achieved the worst PFRT when compared with pin and screw fixation in type I, II, IV, and V and with plate fixation in type III.

Discussion

The classification of displaced articular calcaneal fractures, which are based on the calcaneus responding to the vertical compression load in the form of three components, namely avulsion, bending, and burst[8,9], is simple and has benefit for reduction of the fracture by reverse mechanism of the injury[11,14]. Determination of the classification uses only axial and lateral views radiographs of the calcaneus. The axial view is used for determining burst component and varus angle of the calcaneus. The lateral view is used for determining angles of Bohler, Gissane, parallel of posterior subtalar joint space and in case of posterior facet joint depression with or without subsidence of talus into the calcaneus.

Management of displaced articular calcaneal fracture depends on type of the fracture[14-17]. Perfect fracture reduction including articular surfaces and shape of the calcaneus provides good results[18-20]. Therefore, all anatomical parts of the calcaneus[21] related to the fracture should be included as parameters of the fracture scores including Bohler and Gissane angles, varus angle, parallel of posterior subtalar joint space, and burst of the calcaneus. The calcaneal fracture parameters were scored, based on anatomy and functions of each parameter. The scores can be modified for evaluation of severity of fracture configuration in term of grading such as excellent, good, fair, and poor. Moreover, the evaluation and comparison of fracture configuration between pre- and post-reduction of the fracture can be accomplished. Other modification of the calcaneal fracture score is used to determine response of the fracture to various method of treatments such as pining, plating, screw fixation, and casting, which are evaluated in terms of PFRT as shown in the present study.

The classification is sequentially sorted from simple to severe fracture configurations by using

Table 4. Pre- and postreduction fracture scores, improving fracture score and PFRT of five types calcaneal fractures

Type	Prereduction fracture score		Postreduction fracture score		p-value	Mean improving fracture score		PFRT	
	Mean (SD)	95% CI	Mean (SD)	95% CI		Mean (SD)	95% CI	Mean (SD)	95% CI
I (n = 6)	4.17 (0.41)	3.74, 4.60	0	-	<0.001	4.17 (0.41)	3.74, 4.60	1.00 (0)	-
II (n = 8)	4.63 (2.13)	2.84, 6.41	0.50 (0.93)	-0.27, 1.27	0.002	4.13 (2.36)	2.15, 6.10	0.84 (0.35)	0.54, 1.13
III (n = 17)	6.94 (2.05)	5.89, 7.99	3.18 (1.38)	2.47, 3.89	<0.001	3.77 (2.14)	2.67, 4.86	0.50 (0.27)	0.36, 0.64
IV (n = 37)	8.03 (1.12)	7.65, 8.40	3.03 (2.42)	2.22, 3.83	<0.001	5.00 (2.54)	4.15, 5.85	0.62 (0.30)	0.52, 0.72
V (n = 9)	7.22 (2.11)	5.60, 8.84	3.00 (2.50)	1.08, 4.92	0.001	4.22 (2.39)	1.66, 5.01	0.59 (0.29)	0.37, 0.81

n = number of patients

Table 5. Statistical analysis compared pre-, postredcution fracture scores and PFRT of type I and II, among type III, IV and V and combination of type I and II compared with type III, IV and V

Types	Prereduction fracture scores		Postreduction fracture scores		PFRT	
	Mean (SD)	p-value	Mean (SD)	p-value	Mean (SD)	p-value
I (n = 6)	4.17 (0.41)	0.570	0 (0)	0.170	1.00 (0)	0.239
II (n = 8)	4.62 (2.13)		0.50 (0.93)		0.84 (0.35)	
III (n = 17)	6.94 (2.05)	0.051	3.18 (1.38)	0.969	0.50 (0.27)	0.389
IV (n = 37)	8.03 (1.12)		3.03 (2.42)		0.62 (0.30)	
V (n = 9)	7.22 (2.11)		3.00 (2.50)		0.59 (0.29)	
I-II (n = 14)	4.43 (1.60)	0.031	0.29 (0.73)	<0.001	0.91 (0.27)	0.001
III (n = 17)	6.94 (2.05)		3.18 (1.38)		0.50 (0.27)	
I-II (n = 14)	4.43 (1.60)	<0.001	0.29 (0.73)	<0.001	0.91 (0.27)	<0.001
IV (n = 37)	7.03 (1.12)		2.89 (2.15)		0.58 (0.31)	
I-II (n = 14)	4.43 (1.60)	0.031	0.29 (0.73)	0.007	0.91 (0.27)	<0.001
V (n = 9)	6.22 (2.11)		2.89 (2.21)		0.53 (0.32)	

n = number of patients

calcaneal fracture scores. Type I and II are simple fractures with low fracture scores because the fracture consists of either avulsion or bending components while type III, IV, and V fracture configurations are complicated by burst component. The study showed that five types of the classification could be regrouped into two groups without and with burst component. Group without burst component consists of type I, and II, and the other group with burst component consists of type III, IV, and V. The present study showed that type I and II are simple fracture configuration with low pre-reduction fracture score and have results of fracture reduction with lesser post-reduction fracture score and higher PFRT. It also shows that type III, IV, and V are complicated because of the burst configurations with higher pre- and post-reduction fracture score and low PFRT. The present study showed that post-reduction fracture score of type III, IV, and V were very narrowly scattered and there was no significant difference as shown in a graph of Fig. 10 and Table 5. However, the fracture score of type III, IV, and V were statistically significantly worse than of type I and II including, both pre-and post-reduction fracture scores as shown in Table 5. This can be explained because the fracture type III, IV, and V had burst component that created more severe deformities of calcaneal fracture parameters and lead to problems of reduction. The present study showed that type III, compression burst, had special characteristics of the highest post-reduction score

Table 6. Techniques of fracture fixation and PRFT of group without burst (type I and II) and burst groups(type III, IV and V)

Technique	PFRT			
	Type I-II (n = 14)	Type III (n = 17)	Type IV (n = 37)	Type V (n = 9)
Screw	n = 8	n = 3	n = 18	n = 6
Mean (SD)	1.00 (0)	0.50 (0.17)	0.64 (0.27)	0.54 (0.28)
95% CI	-	0.09, 0.91	0.51, 0.77	0.24, 0.83
Pin	n = 3	n = 1	n = 11	n = 3
Mean (SD)	1.00 (0)	0	0.60 (0.36)	0.51 (0.45)
95% CI	-	-	0.36, 0.84	-0.61, 1.63
Plate	n = 1	n = 10	n = 2	
Mean (SD)	0.71	0.54 (0.16)	0.60 (0.25)	-
95% CI	-	0.42, 0.66	-1.62, 2.82	
Cast	n = 2	n = 3	n = 6	
Mean (SD)	0.50 (0.71)	0.27 (0.46)	0.35 (0.33)	-
95% CI	-5.85, 6.85	-0.88, 1.41	0.01, 0.69	

and least PFRT. This means that the type III fracture configuration is the most difficult to treat when compared among all the types of fractures[17,19, 22,23].

Type I and II, pin or screw fixation provided 1.0 PFRT and may be an appropriate implant for fracture treatment. The fracture configuration consists of avulsion or bending component that respond well to screw or pin fixation[11,14]. Type III, IV, and V are groups of fractures with burst component and plate fixation provided 0.54 PFRT of type III. Therefore, plate might be an appropriate implant for type III. The mechanism of plate fixation is effective for reduction of the burst[17]. Screw and pin fixation provided 0.64 and 0.60 PFRT of type IV and 0.54 and 0.51 of type V respectively. Screw and pin might be appropriate implants for type IV and V. Because type IV and V consisted of avulsion and bending as a major component, they responded well to screw and pin fixation including the burst component below the avulsion or bending fragment, which is reduced by ligamentotaxis[24]. Cast for fracture treatment showed the lowest PFRT when compared with screw, pin, and plate (Table 6). Therefore, casting should be used for treatment of fracture configuration of calcaneus with low pre-reduction fracture score.

In the authors' preliminary study, 77 fracture were calcaneus. They were classified into five types. A study using more fracture of each type is needed for statistical analysis, especially type I and II. Therefore, the authors describe the present study as results of observation and included 95% CI. However, the present study showed that there were statistical significant differences between groups with and without burst. The authors think that further study is necessary, and with adequate samples for statistical analysis.

The fracture classification and radiographic calcaneal fracture scores were evaluated by using axial and lateral view radiographs of calcaneus, which is a routine radiographic technique that is fast and inexpensive. However, using CT scan for fracture of calcaneus and correlation of the radiographic fracture score with ankle foot functions should be further studied.

In conclusion, the present study provides a simple classification of displaced articular fracture of calcaneus that benefits fracture management. Radiographic calcaneal fracture scores have the capacity for qualification and comparison, and can be modified for severity grading of fracture configuration. Moreover, the efficacy of treatment techniques of the fracture can be evaluated in terms of PFRT.

Potential conflicts of interest

None.

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กระดูกส้นเท้าหักชนิดที่มีการเคลื่อนของผิวกระดูกข้อต่อ: การจัดกลุ่มของกระดูกส้นเท้าหักและคะแนนของกระดูกหักจากภาพถ่ายรังสีเอกซเรย์

ทศ หาญรุ่งโรจน์, บวรฤทธิ์ จักรไพวงศ์, ชญานิน อ่างทอง, พงษ์เทพ ณ นคร, นฤมล สุดใจ, ทศศาสตร์ หาญรุ่งโรจน์

วัตถุประสงค์: *ศึกษา acute displaced articular calcaneal fracture configurations เพื่อพิจารณาในการจัดกลุ่มของกระดูกส้นเท้าหักในแบบต่าง ๆ และ ออกแบบ fracture scores เปรียบเทียบ complexity ของ fracture configuration ในแต่ละ type โดยการใช้ fracture scores*

วัสดุและวิธีการ: *ศึกษาย้อนหลังผู้ป่วย acute displaced articular calcaneal fractures ระหว่างปี พ.ศ. 2545-2554 ในการจัดกลุ่มของ fracture configuration เพื่อออกแบบ fracture classification โดยอาศัย fracture pattern ที่เกิดจาก compression load ต่อกระดูกส้นเท้า และ radiographic calcaneal fracture scores ถูกออกแบบด้วยการใช้พารามิเตอร์ ดังต่อไปนี้ คือ Bohler, Gissan angle, ความขนานกันของผิวข้อ posterior subtalar, varus angle และ burst (ในเทอมของเพิ่มความกว้าง) ของส้นเท้านำค่า fracture scores ที่ได้มาใช้เปรียบเทียบ complexity ของ fracture configurations ในแต่ละกลุ่มของ classification และดัดแปลง fracture scores ให้เป็นอัตราส่วนระหว่าง fracture scores ที่เปลี่ยนแปลงหลังการทำ reduction กระดูกหักเปรียบเทียบกับ fracture scores ก่อนการทำ reduction ซึ่งถูกนิยามเป็น power of fracture responding to treatment (PFRT) และใช้ PFRT ในการประเมินผลของการคืนรูปจากการจัดกระดูกหักกับ fixation techniques ของแต่ละ fracture types นำผลที่ได้มาเปรียบเทียบความแตกต่างทางสถิติ*

ผลการศึกษา: *ผู้ป่วย acute displaced articular calcaneal fracture มีจำนวน 64 ราย และ 77 fractures ทำการจัดกลุ่มของ classification ได้ 5 types ดังนี้ คือ type I avulsion, type II compression bending, type III compression burst, type IV avulsion burst และ type V bending burst type IV พบมากที่สุด radiographic calcaneal fracture scores มีค่าเต็ม 10 คะแนน fracture scores ก่อน-หลังการทำ reduction และ PFRT ของแต่ละ fracture types มีดังนี้ คือ type I, 4.17 (0.41), 0 และ 1 (0), type II, 4.63 (2.13), 0.50 (0.93) และ 0.84 (0.35), type III, 6.94 (2.05), 3.18 (1.38) และ 0.50 (0.27), type IV, 8.03 (1.12), 3.03 (2.42) และ 0.62 (0.30) และ type V, 7.22 (2.11), 3.00 (2.50) และ 0.59 (0.29) ตามลำดับ ผลการวิเคราะห์ทางสถิติ พบว่า fracture scores ทั้งก่อนและหลังการทำ reduction และ PFRT ของแต่ละ types มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$) เทคนิคการใช้ screw และ pin fixation ให้ค่า PFRT สูงใน type I & II, type IV และ type V ส่วนการใช้ Plate fixation ให้ค่า PFRT สูงใน type III สำหรับ cast ให้ค่า PFRT ต่ำที่สุดในทุก ๆ types ของ fractures*

สรุป: *Displaced articular calcaneal fracture จัดกลุ่มได้ 5 types โดยยึดหลักของกลไกการหักของกระดูกในเทอม avulsion, bending และ burst radiographic calcaneal fracture scores ใช้ 5 calcaneal fracture parameters มีคะแนนเต็ม 10 ซึ่งสามารถนำไปใช้เปรียบเทียบ complexity ของ fracture configuration ของแต่ละ type ของ classification ทั้งก่อนและหลังการทำ reduction และได้ค่า PFRT ในการประเมินการประสิทธิภาพของ reduction และ fixation techniques ต่าง ๆ ของ fracture แต่ละ types*