

Assessment of Functional Outcome of Surgical Fixation of Calcaneal Fracture Using Calcaneal Plate, K-Wires and CC screws

Dr A.Manikandarajan¹, Dr.Gurumoorthy. M², Dr Dhanpal Singh³,
Dr G.Thanigaivelan⁴

^{1,2}Assistant Professor, Department of Orthopaedics, Rajah Muthiah Medical College and Hospital, Chidambaram

³Professor, Department of Orthopaedics, Rajah Muthiah Medical College and Hospital, Chidambaram

⁴Post graduate, Department of Orthopaedics, Rajah Muthiah Medical College and Hospital, Chidambaram

Corresponding Author

Dr Dhanpal Singh

Professor, Department of Orthopaedics, Rajah Muthiah Medical College and Hospital, Chidambaram

ABSTRACT

Introduction: Calcaneal fractures are the most common of all tarsal fractures. The treatment of displaced intraarticular fractures is controversial. Earlier, these fractures were treated conservatively. Now-a-days these fractures are being treated surgically using various modalities.

Purpose:

1. To analysis the radiological and functional outcome of surgical fixation of open and closed displaced intraarticular fractures and post operative complications
2. To determine whether it is beneficial in maintaining restoration of Bohler's and Gissane angles, calcaneal height and anatomical articular reconstruction.

Material and methods: This study included patients age between 18-60 years. A sample of 20 patients with Intraarticular displaced or comminuted calcaneal fractures were selected, evaluated and operated in Rajah Muthiah Medical College and Hospital, Chidambaram between July 2019 to October 2021. All the patients underwent surgery, fixed with anatomical plates or k wires or CC screw. Follow up was done clinically and radiologically at 6 weeks, 12weeks, 6 months, and 1 year.

Results: Out of 20 patients, 17 had intraarticular fractures and 3 had comminuted fractures following fall from height, out of which 9 patients treated with calcaneal plate and 6 patients with k-wires and five patients with CC screw. Out of 20, 11 had excellent results with Modified Maryland Foot Score more than 90, 8 had good results with score of more than 75. 1 fair of score less than 75 and 11 recovered without complications, 5 with subtalar arthritis and 4 with Heal Pain.

Conclusion: From our study we conclude that surgical fixation of calcaneal fractures offers excellent post operative functions with early mobilisation, early union and less complications.

Keywords: Calcaneal Fracture, Heal Bone, Surgical fixation, Modified Maryland Foot Score, Bohler's and Gissane angles, calcaneal multifragmentary LCP.

Introduction

Calcaneal fractures accounts 65 percent of all tarsal injuries.⁽¹⁾ Calcaneal fractures account for roughly 2% of all fractures. The majority of them (60 percent to 75 percent) are intraarticular. 10% have been associated with spine fractures, while 26% associated with other extremities injuries. Several of these fractures involves both the calcaneum. 90 percent of calcaneal fractures occur in between the ages of 26 and 53. High-energy trauma, such as a fall from a great height or a road traffic accidents is the most common cause of displaced intra-articular calcaneal fractures. Male workers are more likely to be affected. As a result, the functional outcome of a calcaneal fracture has a significant socioeconomic impact on worker families.

The best way to treat calcaneal fractures is still up in the air.⁽⁴⁾ A time of intensive surgical fixing of these fractures, followed by a period of resorting to closed treatment approaches, illustrates the manner of treatment of these fractures. Till the end of 19th century calcaneal fractures treated non operatively with rest and limb elevation. Advanced imaging techniques picked interest in repairing this bone's deformed architecture. Percutaneous k-wire, percutaneous screw, non-locking compression plate, and locking compression plate are all options for calcaneal fracture treatments. The debate between operative and non-operative therapies is still going on, although recent research and other publications have swung the scale in favour of surgery.

Malunion, peroneal tendon dysfunction, post-traumatic arthritis, ankle and heel pain, and exostoses have all been linked to non-operative treatment.⁽⁶⁾⁽⁹⁾

The choice between non-surgical and operational intervention is still up for debate. Surgery is usually performed within two weeks following injury if a minimally invasive approach is chosen. Fracture pieces become harder to handle beyond this, and we learned that with percutaneous reduction and fixation or the sinus tarsi method, you don't have to wait for skin wrinkles.⁽⁷⁾ But only think for open reduction is to wait till wrinkle sign to appear before surgery to avoid skin complications. We looked at the clinical and radiological outcomes of surgically treated calcaneal fractures in this study.

Aim and Objective:

- To analysis the radiological and functional outcome of surgical fixation of displaced intraarticular fractures.
- To look for post operative complications
- To analyse whether it is beneficial in maintaining restoration of Bohler's, Gissane angles, calcaneal height and articular reconstruction.

Material and Methods:

Cases of intra articular and displaced calcaneal fracture treated surgically with calcaneal plate, cancellous screw and k wires satisfying inclusion and exclusion criteria treated in Rajah Muthiah Medical College and Hospital, Annamalai University, Chidambaram during the period July 2019 to October 2021.

Initially all the case records (20 cases) of intra-articular calcaneal fracture treated surgically at Rajah Muthiah medical college and Hospital will be studied and all cases admitted and treated surgically during the study period (July 2019 to October 2021) will critically assessed to determine

1. Intra-operative blood loss.
2. Duration from the day of surgery to mobilization.

3. Infection rates.
4. Duration of stay at hospital.
5. Implant failure rates.

Inclusion Criteria:

- All open and closed calcaneal fracture
- Intra articular displaced or Comminuted calcaneal fracture with sanders type II to IV

Exclusion Criteria:

1. Diabetic neuropathy
2. Significant coexisting diseases, with contradiction to any anaesthesia

This is a retrospective and prospective clinical study from JULY 2019 to OCTOBER 2021. A minimum of 20 cases will be studied. Patients will be followed up for a minimum period of 6 months. With each follow up clinical and radiological evaluation will be done. Functional outcomes were evaluated by **MODIFIED MARYLAND FOOT SCORE**,⁽¹⁹⁾ with excellent defined as 90 - 100 points, good as 75 – 89 points, fair as 50 – 74 points and poor as <50 points.

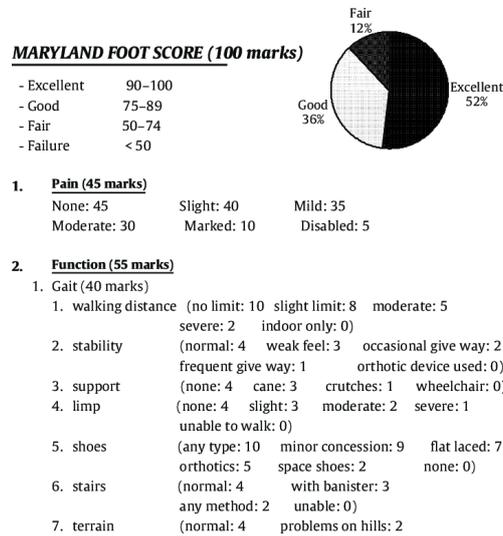


Fig-1: Modified Maryland Foot Score

Essex-Lopresti:⁽¹²⁾ Described two distinct fracture patterns

Joint-Depression

Secondary fracture line exit just posterior to posterior facet Posterior calcaneal Tuberosity NOT attached to Posterior Facet

Tongue-Type

Secondary fracture line exit through posterior surface. Posterior calcaneal Tuberosity attached to Posterior Facet

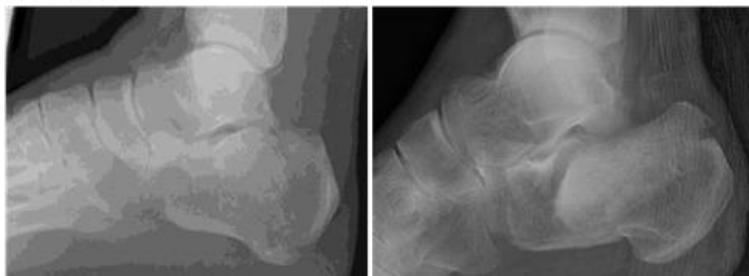


Fig- 2 : Joint-Depression, Tongue-Type

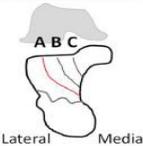
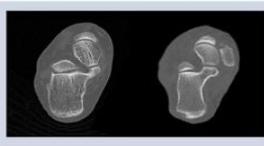
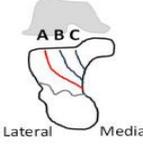
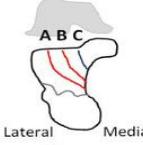
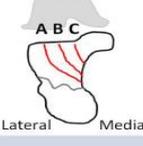
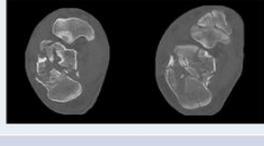
Sanders System Label (# image)	Description	Illustration	Example CT Images
Type I (153)	Non displaced or displacement less 2mm		
Type II (221)	2 articular pieces from a single fracture lines Subtype: IIA, IIB, IIC		
Type III (178)	3 articular pieces from 2 fracture lines Subtype: IIIAB, IIIBC, IIIAC		
Type IV (208)	4 or more articular pieces		
Total (760)			

Fig- 3: Sanders classification of calcaneal fracture⁽³⁾

Timing of Surgery:

The ideal time is 8 to 15 days after injury, soon after the subsidence of swelling in the foot and ankle. Clinically the “WRINKLE SIGN” helps in predicting the timing of surgery,

Surgical Procedure:-

Lateral Approach⁽²⁾:- Patient on lateral position or easy lateral position. The goal of the incision was to expose the entire lateral surface of the calcaneum to the level of the calcaneocuboid joint. The incision was made just lateral to the Achilles tendon and carried vertically to the superior pole of the calcaneum. The incision was then curved gently following a line where the thinner skin of the lateral side of the hindfoot met the skin of the heel pad.

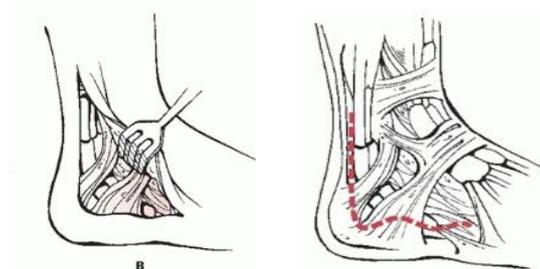


Fig- 4: Lateral Approach skin incision

Reduction Technique

The surgical tactic that will be used to identifies a step-by-step process for the reduction maneuver. Generally, one begins by identifying the “constant” fragment, i.e. the sustentacular fragment, which remains attached to the talus and does not displace.⁽⁵⁾

Joystick placement

A Schanz screw is inserted into the posterior (or tuberosity) fragment from lateral to medial, going through both cortices. It will serve as a joystick to aid in the reduction.

The next step is the reduction of the tuberosity fragment to the “constant” medial sustentacular fragment and is held in position with 2 K-wires and directed superiorly and anteriorly into the “constant” medial fragment. Ensuring that there is no varus of the hindfoot. Now reduce the lateral articular piece. It needs to be elevated in order to successfully reconstruct the articular surface of **the posterior facet**. Then Insert of the subchondral lag screw(s) which will stabilize the articular surface. Taking care of the hindfoot, to remain in neutral, or in slight valgus, in the axial view. Varus of the hindfoot must be avoided. when drilling the hole for the lag screw, the drill bit must be directed carefully in these three direction.

- a) Lateral to medial
- b) Posterior to anterior
- c) Cephalad to caudal

No touch technique

To avoid post op skin complications, a thick skin flap is raised and 1.8 mm K-wire inserted to the talus to reflect the skin as it decreases unnecessary retraction and blood vessel compromise.

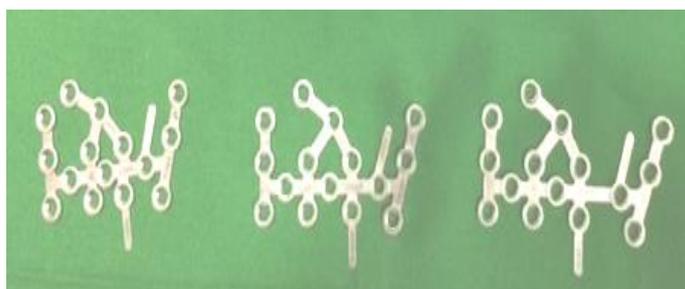


Fig- 5: Anatomical Locking Plate

Percutaneous fixation:- To achieve reduction, under image intensifier control, one or two 2-mm K-wires were inserted from the calcaneal tuberosity toward the subtalar joint. Then, during closed reduction, using the K-wires like a joystick by external manoeuvres and a leverage technique with axial stress onto the pins down the distal side, restoration of Böhler’s angle was attempted. Fluoroscopic images in lateral and axial radiographic views allowed the evaluation of the anatomical reduction. Final stabilization was obtained with other 2-mm K-wires or with cannulated cancellous screws (Synthes, 6.5 mm and 4 mm in diam.), inserted in the same posterior-anterior direction. In some cases, for better support of the thalamic region, a latero-medial screw was introduced through the incision used for the talar joint reduction. Screw fixation was performed being careful to avoid the protrusion of the screw head. A compression dressing was applied on the operated side for 48 h after surgery. Patients were kept non-weight-bearing for 4 weeks during which passive and active ankle ROM exercises were allowed 15 days after screw fixation or 30 days when K-wires were used.

Post-Operative Protocol and Follow Up

All patients were immobilized in posterior plaster splint and limb was elevated. Drain was removed after 48 hours and first wound inspection done on 2nd day. If soakage present early wound inspection done. Suture removal done after 13th day (13 to 18th day). After suture removal below knee cast applied.

After Suture Removal

All patients were regularly followed up once a month for first three months.
Once in Two months for next six months.

Bohler's and Gissane angles were drawn in followup x-rays.

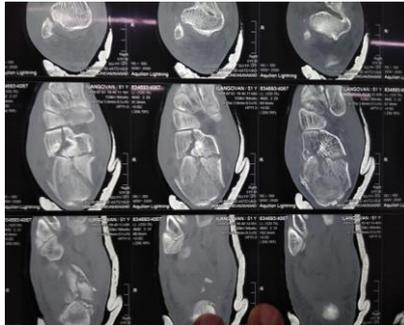
CASE ILLUSTRATION

A 50 Year old male came to casualty with alleged H/o fall from height and Diagnosed to have fracture right calcaneum (Sanders type 3)

Preop x-ray



CT ankle and foot



Intra op image



Immediate post op x-ray



One month follow up



6th month follow up



6th month range of movements



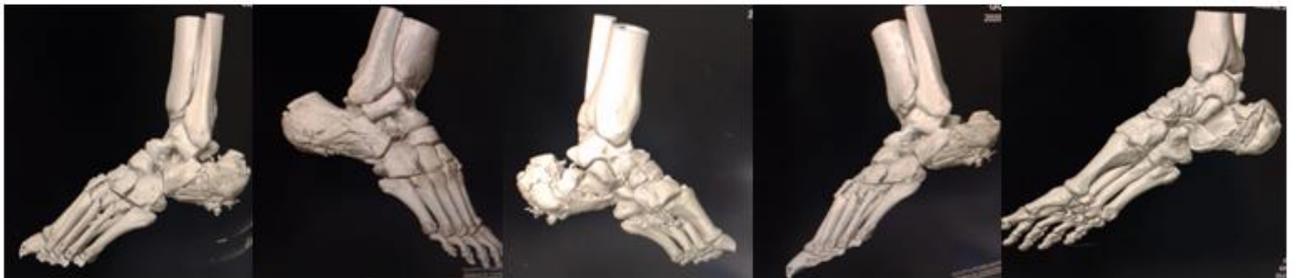
Case illustration II

A 55 year old male came to casualty with alleged H/o fall from height 1st floor and diagnosed to have Bilateral calcaneal fracture. Associated with Lisfranc's fracture dislocation and 1st, 2nd, 3rd, 4th metatarsal fracture left foot.

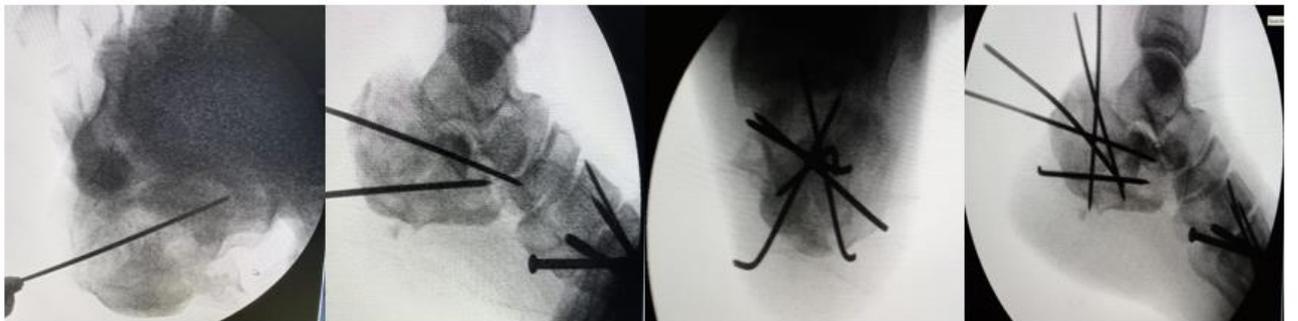
Pre op x-ray



Pre op CT scan



C-Arm images



Immediate Post op x-ray:-



One month follow up



4th month k wire exit status



4th month follow up range of movements



Case illustration III

Mr. Sundar

- 33 years male
- h/o fall from 8 feet height
- Right calcaneal fracture

Pre op x-ray



4th month

Immediate post op x-ray



6th month



Post implant exit



Post op range of movement

Plantor Flexion



Dorsi flexion



Heal width



RESULTS

Table 1: Age distribution

Age	Mean	S.D
	39.95	13.39

Table 1 represents age of the study patients. The mean age was 39.95 ± 13.39 years.

Table 2: Mode of injury

Mode of injury	N	%
Fall from height	17	85
RTA	3	15
Total	20	100

Mode of injury is shown in Table 2. The most common mode of injury was fall from height, 85%. Road traffic accident was reported in 15%.

Table 3: Diagnosis

Diagnosis	N	%
Right calcaneal fracture	7	35
Left calcaneal fracture	7	35
Bilateral calcaneal fracture	6	30
Total	20	100

Diagnosis of the condition is shown in Table 3. 35% each had right and left calcaneal fracture. Bilateral calcaneal fracture was diagnosis in 30% of the study patients.

Table 4: Essex lopressti classification

Essex lopressti classification	N	%
Joint depression	10	50
Tongue type	10	50
Total	20	100

Essex lopressti classification is shown in Table4. Join depression was obscured in 50% and Tongue type was the feature in 50% of the patients.

Table 5: Sander's classification

Sander's classification	N	%
Type II	6	30

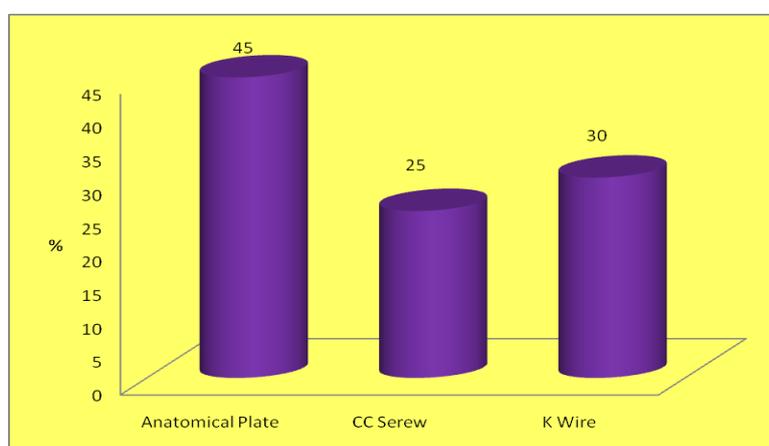
Type III	11	55
Type IV	3	15
Total	20	100

Sander's classification is shown in Table 5. Type III was common classification noted in 55% of the study patients. Type II classification was identified in 30% and Type IV classification was the finding in 15% of the patients.

Table 6: Implant used

Implant used	N	%
Anatomical plate	9	45
CC screw	5	25
K-wire	6	30
Total	20	100

The type of implant is shown in Table 6. Anatomic plate was the common implant used in 45% of the patients followed by K wire (30%) and CC screw (25%).

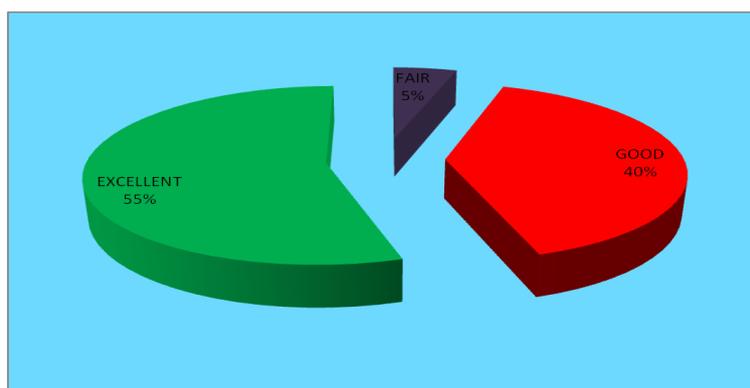


Graph-1: Implant used

Table 7: Modified mary land foot score

Modified mary land foot score	N	%
Excellent	11	55
Good	8	40
Fair	1	5
Total	20	100

Modified mary land foot score is presented in Table 7. The majority had excellent score, 55%. Foot score of good was achieved in 40% of the patients. 5% had fair score.

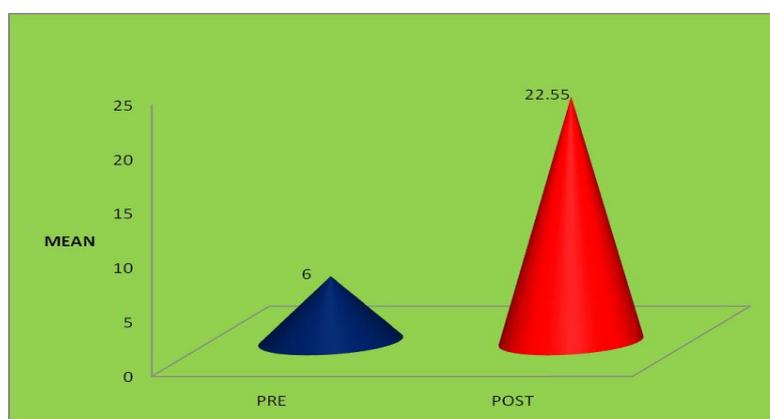


Graph-2: Modified mary land foot score

Table 9: Bohler's Angle – Pre and Post surgery comparison

Bohler's Angle	Mean	S.D	Paired sample 't' test	
			t	p
Pre	6.00	1.68	29.34	0.001
Post	22.55	2.93		

The pre and post comparison of Bohler's angle is presented in Table9. The mean pre angle was 6 ± 1.68 and it was improved significantly to 22.55 ± 2.93 following the treatment, $t = 29.34$, $p = 0.001 < 0.05$.

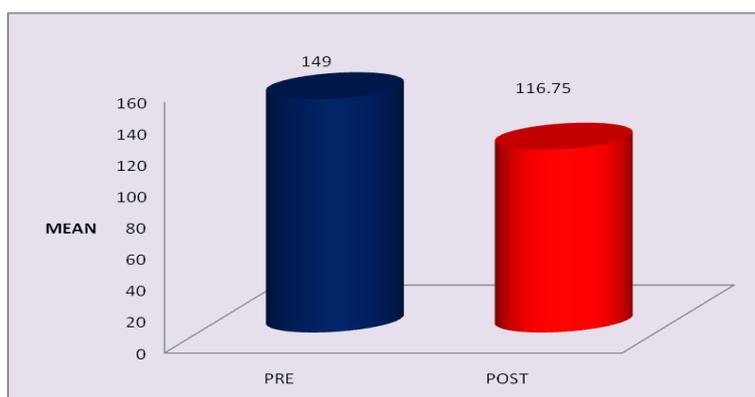


Graph-3: Bohler's Angle – Pre and Post surgery comparison

Table 10: Gissane angle – Pre and Post surgery comparison

Gissane angle	Mean	S.D	Paired sample 't' test	
			t	p
Pre	149.00	7.88	17.62	0.001
Post	116.75	6.74		

The comparison of pre and post Gissane scores is shown in Table10. The mean pre score was 149.00 ± 7.88 and it was significantly reduced to 116.75 ± 6.74 following the treatment, $t = 17.62$, $p = 0.001 < 0.05$.



Graph-4: Gissane angle – Pre and Post surgery comparison

Table 11: Width – Pre and Post surgery comparison

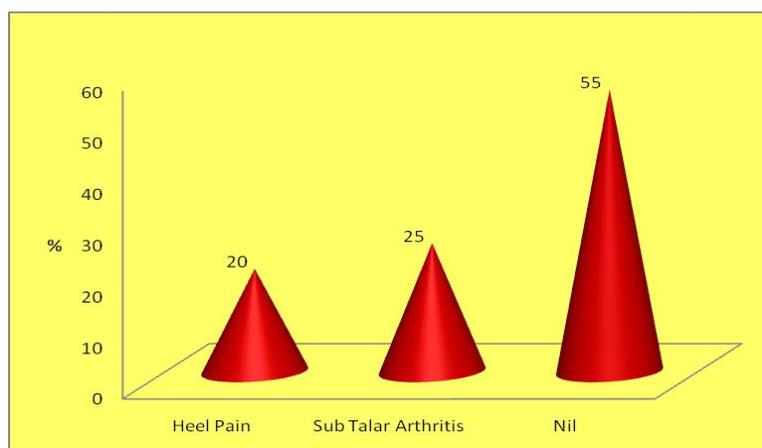
Width	Mean	S.D	Paired sample 't' test	
			t	p
Pre	55.85	4.13	4.22	0.001
Post	51.85	4.26		

The pre and post comparison of width is shown in Table 11. The mean pre width was 55.85 ± 4.13 and it was reduced significantly to 51.85 ± 4.26 after the treatment, $t = 4.22$, $p = 0.001 < 0.05$.

Table 8: Complications

Complications	N	%
Heel pain	4	20
Sub talar arthritis	5	25
Nil	11	55
Total	20	100

The complication of the study patients is presented in Table 8. The majority of the patients had not associated with any complications (55%). Sub talar arthritis was identified in 25% and heel pain was reported in 20%.



Graph-5: Complications

DISCUSSION

The famous quote by McLaughlin compared open reduction and fixation of a calcaneal fracture to “nailing of a custard pie to the wall”

Fractures of calcaneum are the most common tarsal bone fractures with overall incidence of 2% of all fractures with displaced intra-articular fractures comprising 60%-75% of the cases. Intra-articular fractures occur after eccentric axial loading of the talus on the calcaneus. The first widely accepted classification was proposed by Essex lopresti⁽¹²⁾ in 1952 based on involvement of sub-talar joint. Soeur and Remy⁽²¹⁾ devised a classification system for intra-articular fractures in 1975 based on mechanism of injury and taking sustentacular fragment as the key to surgery. With the advent of CT scan, a new classification system was developed by Crosby and Fioztgibbns⁽¹⁵⁾ based on posterior facet. Sanders et al⁽³⁾ proposed a classification system based on coronal view of CT scan, in which 3 fracture lines A,B,C Separate the posterior facet of the calcaneus into 4 potential pieces.

The literature review says it is the most widely accepted classification as it considers both fracture pattern and also guides further treatment course.⁽⁸⁾ 78 Operatively 14 treated patients with sanders type 2, 3 & 4 have better outcome with respect to pain, return to work, heel width, gait abnormalities and radiographic outcomes than patients treated conservatively. Open 14 reduction and internal fixation with calcaneal Locking plate through an extended lateral approach is the mainstay of treatment. Due to the risk of wound dehiscence, CRIF with Cancellous screws is preferred. A clear idea about indication, contraindications and the timing of surgery are important. Pre-operative CT scans are essential. Sub talar incongruity or penetration of implants into the joint may cause late arthritis during long term follow up.

The period of study was between July 2019 to October 2021 at Rajah Muthiah Medical College, Chidambaram. Although the period of study was short, studies have shown that early function is comparable to final long term outcome. We studied functional and radiological outcome in 20 patients of which 9 fractures were treated by ORIF with P.O, 5 fractures were treated by CRIF with Cancellous screws and 6 fractures by CRIF with K wires. The average follow up period was 12 months ranging from 6 to 18 months. The mean age in our study is 39 years and most commonly observed mode of injury was injury due to

fall. Bilateral calcaneal fracture is more commonly observed fracture type in my study. In classification of fracture according to Essex lopessti classification, joint depression type fracture was most commonly observed and it accounts for about 50%, followed by tongue type. In sanders classification of fracture, Type III is the most commonly observed type which corresponds to about 55% followed by type II (30%) in our study. In our study, pre op Bohler's angle of less than 20 degree was restored to normal range (20 to 40 degree) in 18 patients. The P value for pre op and post op value of Bohler's angle was 0.001(<0.05) and the P value for angle of Gissane was 0.001 (<0.05) showing that restoration of Bohler's plays a significant role in functional outcome than angle of Gissane as also observed in the studies. Conducted by Joseph D. Isaacs et al⁽²⁰⁾ in 2013 and Vishal et al⁽²²⁾ in 2016. Among 20 fractures pre operative varus >15 degree were 13 fractures and post operatively it was corrected and reduced.

Joseph D. Isaacs et al⁽²⁰⁾ concluded that Bohler's angle serves as a useful screen tool in calcaneal fractures. Vishal et al concluded that ORIF of clinical fractures yielded good clinical outcome if Bohler's angle more than 10 degree is achieved. It was also noted in the study that there was a significant correlation between Bohler's angle and angle of Gissane AOFAS score (P less than 0.01).

In our study majority of patient did not develop any post operative complication (55%) only 4 patients developed heel pain and 5 patients had subtalar arthritis which corresponds to 20% and 25% respectively. out of 20 patients 9 treated with ORIF with plate osteosynthesis were taken up for surgery after wrinkling of skin appeared, surprisingly we didnot get any wound complications post operatively. The study conducted by A.K Singh et al⁽¹⁶⁾ it was concluded that intraarticular fractures treated with internal fixation and bone grafting, patients were able to return to full weight bearing earlier than those treated without bone grafting. However the long term efficacy in both the groups was similar showing that patients treated without bone grafting have functional outcome as good as patients treated with bone grafting. But in our study all patients were treated with multifragmentary locking compression plate⁽¹³⁾⁽¹⁴⁾ without bone grafting and mobilization was achieved early. Functional outcome was found to be better in majority of the patients without bone grafting. In our study of 20 patients, 11 patients had excellent outcome, 1 had fair outcome and 8 had good outcome based on modified Maryland score.

Future Directions and Innovations

In future the focus should be on developing refined percutaneous, minimally invasive techniques. New plates like polyaxial locking plates can be useful. Multidirectional screw locking with non parallel is possible. The plate itself does not possess a thread, but a lip, and the screw with extra thread in the head cuts and thread into the plate at an angle determined by the surgeon. Due to increasing thread diameter, the screw locks in this position. The plate can be moulded as the plate and screw is made of titanium of different hardness grade. Since the plate is softer than screws and a special screw driver is needed to tighten the screws and ensure that they cut a thread into the lip of the plate.

Bioabsorbable Implants and Screws

Evolution of bioabsorbable implant has made many professionals to apply them in selected calcaneal fractures. The problems of the metallic implants are high infection rate, irritability of plate and later need for implant removal make the option of bioabsorbable implants theoretically attractive, Zang⁽¹⁸⁾ and colleagues have used bioscrews and prospectively

compared them with plates in 97 randomized patients over a two year period. 88 They found acceptable results at a followup of an average 23 months. Bioabsorbable implants may not be strong enough to withstand the stress of these displaced calcaneal fractures and their indications in complex calcaneal fractures are hence limited now. Min⁽¹⁷⁾ and colleagues have used bioabsorbable pins for calcaneal fracture; however they need long follow up and assessment in calcaneal fractures.

CONCLUSION

In displaced intra-articular fractures of calcaneum osteosynthesis by open reduction and internal fixation with locking plate using extensile lateral approach after adequate preoperative planning gave early functional recovery with acceptable results. Careful consideration of the surgical technique is a must.

The above method not only restored anatomical height, width of calcaneum, but also its Bohler's and Gissiane's angles, which allows early mobilization. The timing of the surgery is a vital determinant for the treatment outcome and determined by subsidence of edema and appearance of wrinkle sign. Those cases which were taken up for fixation early within 12 days had good results than those which were operated later.

If for other reasons operation is done after three weeks, it causes not only soft tissue healing problems and high infection rate but also intraoperative difficulty in fracture reduction may occur, as the fracture starts consolidating. Hence it is better to delay surgery till soft tissue heals and during this presurgical period patients should be managed by splinting with proper padding and limb elevation. To conclude intra articular calcaneal fractures are complex fractures which are difficult to stabilize and manage, and surgical fixation of calcaneal fractures offers excellent post operative functions with early mobilisation, early union and less complications. Reconstruction of subtalar anatomy prevents subtalar arthritis & maintains the foot biomechanics.

The reason behind the improved results with open reduction and internal fixation in our series may be due to less traumatic techniques that is no touch technique and stronger but malleable implants. Also locking plates for calcaneum decrease the need for bone graft, allow early weight bearing and it provides rigidity especially in osteoporotic cancellous bone. High cost and steep learning curve are the present limitations.

REFERENCES

1. Rockwood & Green's fractures in Adults. Fifth Edition.
2. Campbell's Operative Orthopaedics Ninth Edition, Edited by Terry Canale.
3. Displaced intra articular fractures of calcaneum by Roy Sanders. JBJS 82-A, No.2, Feb. 2000.
4. Management of calcaneal fractures in Adultus by Therman et al. CORR No.353, pp.107-124, August, 1998.
5. Biomechanics of calcaneal fractures. CORR NO.388, pp.218-224, July, 2001.
6. Complications of intraarticular calcaneal fractures by EDWARD. V.A. et al. CORR No.391, pp.7-16, October, 2001.
7. Wound healing risk factors after ORIF of calcaneal fractures by FRANKLIN SHULER et al. OCNA, Vol.32, No.1, January, 2001.
8. Asik, M. Sen C. Surgical management of intraarticular fractures of the calcaneus. Arch. Orthop. Trauma. Surg. 2002, Jul: 122(6) : 354-9.
9. Lim EV, Leung JP. Complications of intraarticular calcaneal fractures. Clin, Orthop. 2001 Oct. (391) : 7-16.

10. O'Farrell DA, O'Byrne JM, McCabe JP, et al. Fractures of the os calcis: improved results with internal fixation. *Injury* 1993;24(4):263-5.
11. Leung KS, Chan WS, Shen WY, et al. Operative treatment of intra-articular fractures of the os calcis— the role of rigid internal fixation and primary bone grafting: preliminary results. *J Orthop Trauma* 1989;3(3):232-40.
12. Essex-Lopresti P. The mechanism, reduction technique, and results in fractures of the os calcis. *Br J Surg* 1952; 39:395-419.
13. Calcaneus Fractures: A Review Article John D. Maskill, MD, Donald R. Bohay, MD, John G. Anderson, MD Operative treatment of intra-articular calcaneal fractures with calcaneal plates and its complications Vaclav Rak, Daniel Ira, and Michal Masek.
14. Operative treatment of intra-articular calcaneal fractures with calcaneal plates and its complications. Vaclav rak, Daniel Ira, and Michal Masek.
15. Crosby LA, Fitzgibbons T. Computerized tomography scanning of acute intra-articular fractures of the calcaneus. A new classification system. *J Bone Joint Surg Am.* 1990 Jul;72(6):852-9. PMID: 2133368.
16. Surgical treatment of displaced intra-articular calcaneal fractures: is bone grafting necessary? AK Singh, K Vinay *Journal of Orthopaedics and Traumatology* 14 (4), 299-305, 2013
17. Effect of sustentaculum screw placement on outcomes of intra-articular calcaneal fracture osteosynthesis: a prospective cohort study using 3D CT Minfei Qiang, Yanxi Chen, Kun Zhang, Haobo Li, Hao Dai *International Journal of Surgery* 19, 72-77, 2015
18. Biomechanical comparison of modified Calcanail system with plating fixation in intra-articular calcaneal fracture: a finite element analysis Ming Ni, Duo Wai-Chi Wong, Wenxin Niu, Yan Wang, Jiong Mei, Ming Zhang *Medical engineering & physics* 70, 55-61, 2019
19. Yeung Yip-Kan, Ho Yuen-Fong, Percutaneous Fixation of Displaced Calcaneal Fracture, *Journal of Orthopaedics, Trauma and Rehabilitation* 15 (2011) 5-9.
20. The diagnostic accuracy of Böhler's angle in fractures of the calcaneus Joseph D Isaacs, Mohammed Baba, Phil Huang, Michael Symes, Maurice Guzman, Haren Nandapalan, Terence Moopanar, Steve Marchallick, Zoltan Szomor *The Journal of emergency medicine* 45 (6), 879-884, 2013.
21. Fractures of the calcaneus with displacement of the thalamic portion Robert Soeur, Robert Remy. *The Journal of bone and joint surgery. British volume* 57 (4), 413-421, 1975
22. Open reduction and internal fixation of displaced calcaneum, intra-articular fractures by locking calcaneal plate Shams Gulrez Santosha, Arambam Mahendra Singh, Sanjib Waikhom, Vishal Pakhrin, Sagnik Mukherjee, Rajkumar Debbarma, Prabhu Shrinivas Prashant *Journal of clinical and diagnostic research: JCDR* 10 (12), RC18, 2016.