

FUNCTIONAL OUTCOME OF INTERNAL FIXATION FOR DISPLACED INTRA-ARTICULAR CALCANEAL FRACTURE

Saket Jati¹, Dev Padia²

¹Professor, Department of Orthopaedics, Sri Aurobindo Institute of Medical Sciences, Indore.

²Third Year Postgraduate Student, Department of Orthopaedics, Sri Aurobindo Institute of Medical Sciences, Indore.

ABSTRACT

BACKGROUND

There are always difference of opinion in the importance of Bohler's angle in evaluating the severity of displaced intra-articular calcaneal fractures and predicting the functional outcome following surgical fixation. The purpose of this research, the relationship exists between Bohler's angle and the injury severity of displaced calcaneal fractures and between surgical improvement of Bohler's angle and its practical outcome.

MATERIALS AND METHODS

Patients were treated surgically for unilateral closed displaced intra-articular calcaneal fractures from May 2014 to October 2016 were identified. The Bohler's angles of bilateral calcaneus were measured and was compared to the dimension of the uninjured foot was used as its normal control. The difference in the value of Bohler's angle measured preoperatively or after surgery between the angle of the damaged foot and that of the contralateral calcaneus was calculated, respectively. The change in Bohler's angle by ratio was calculated by dividing the variation in the value of Bohler's angle between bilateral calcaneus by its typical control. The injury severity was assessed according to Sanders classification. The functional outcomes were assessed using American Orthopaedic Foot and Ankle Society hindfoot scores.

RESULTS

30 patients were included into the study with a mean follow-up duration of 30 months. According to Sanders classification, the fracture pattern included 12 type II, 10 type III and 8 type IV fractures. According to American Orthopaedic Foot and Ankle Society hindfoot scoring system, the excellent, good, fair and poor results were achieved in 10, 8, 4 and 2 patients, respectively. The preoperative Bohler's angle, difference value of Bohler's angle between bilateral calcaneus and change in Bohler's angle by ratio each has a significant relationship with Sanders classification ($P=0.003$; $P=0.004$; $P=0.005$, respectively), however, is not correlated with functional outcome individually. However, these relationships were all weak to low.

CONCLUSION

A strong connection between preoperative Bohler's angle and the injury severity of displaced intra-articular calcaneal fractures, but only postoperative Bohler's angle factors were major relationship with the functional recovery.

KEYWORDS

Calcaneum, Bohler's Angle, Intra-Articular.

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BACKGROUND

Displaced intra-articular calcaneal fractures constitute 70% of all calcaneus fractures in adults.¹⁻⁴ Bohler's angle is frequently assessed when evaluating this type of fractures on lateral plain x-ray films.⁵ A number of studies have examined the relationship between Bohler's angle and the functional outcome of displaced intra-articular calcaneal fractures, but produced varied outcomes.⁶⁻¹⁴ Certain studies recommend that surgical repair of Bohler's angle improves

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Corresponding Author:

Dr. Dev Padia,

Third Year Postgraduate Student,

Department of Orthopaedics,

SAIMS Campus, Indore,

Ujjaini, Highway, Indore.

E-mail: devpadia@live.com

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the outcome and has a prognosis value of postoperative success as well as predictive value for subtalar joint fusion.⁶⁻¹² Some indicate the initial Bohler's angle is highly prognostic regardless of treatment modality.¹³ However, Ibrahim et al reported no relationship at all between Bohler's angle and functional outcome based upon the assessment of their 15-year follow up of a randomised controlled trial of displaced calcaneal fractures treated conservatively against surgical.¹⁴ The controversy maybe partially due to the limitations of original study design and the comparatively small sample size. Bohler's angle varies little between left and right foot of an individual,¹³ but considerably among individuals from 25 to 40 degrees. Given the variability of Bohler's angle between different individuals, we think it is an objective way to obtain the Bohler's angle of uninjured foot as the patient's own normal control to assess the relationship between Bohler's angle and the functional outcome. Accordingly, we advised a new technique to describe Bohler's angle with the undamaged foot. This study will address the following



questions- (1) Whether there is a relationship between Bohler's angle and the injury severity of displaced intra-articular calcaneal fractures; (2) Whether surgical improvement of Bohler's angle is related to the functional outcome; and (3) To what degree Bohler's angle need to be improved to achieve a satisfactory outcome if such correlation exists.

MATERIALS AND METHODS

Between May 2014 and October 2016, 30 with displaced intra-articular calcaneal fractures were treated operatively in our department were identified through the trauma registration system. The inclusion criteria were aged 18 years and above; closed unilateral fractures; treated with surgical technique; Computed Tomography (CT) scans performed on the injured calcaneus; and absence of severe medical disorders.¹⁵

Surgical Technique and Postoperative Management

In the Orthopaedic Department of our hospital, the L-appearing extended lateral approach with fractures fixed by plating surgical methods were applied to treat displaced intra-articular calcaneal fractures during the study period.¹⁶ Operation was performed on an average of 5.7 days (range, 3-13 days) after injury when swelling subsided and positive wrinkle appeared on the hindfoot. The surgery aimed to regain respective anatomy, Bohler's angle.

Open Reduction and Internal Fixation Technique

The L-shaped extended lateral approach was made. The peroneal tendons and calcaneofibular ligament were retracted to expose the fracture. The K wires were used for fixation followed by definitive fixation with a plate and screws. In case of significant bone defect, the iliac bone graft was used to fill up the defect.

Postoperative Management

All patients completed the same standardised postoperative rehabilitation protocol. Patients were encouraged to start non-weightbearing exercise including extension and plantar flexion of toes, ankle and subtalar joints as soon as pain can be tolerated. Crutch-assisted walking was allowed two or three days postoperatively. The amount of time for non-weightbearing was 8 weeks after operation as recommended by Schepers et al.¹⁷ Partial weightbearing was started after 8 weeks and advanced to full weightbearing, which was allowed with radiographic evidence of fracture union generally at three months postoperatively. Functional outcomes were assessed based upon American Orthopaedic Foot and Ankle Society hind foot score at the final follow-up.

Data Collection and Statistical Analysis

The severity of calcaneal fractures were assessed according to Sanders classification determined by CT scans. The Bohler's angles of both calcaneus were measured (Figure 1) with MB-ruler on the PACS workstation. Twice, two trained residents took each measurement and the final measurement was the average of the two. Any discrepancy

was settled by consensus. The difference value between Bohler's angle were checked before and after surgery on the injured foot and that of the contralateral unaffected calcaneus was calculated, respectively. The preoperative change in Bohler's angle by ratio was calculated by dividing preoperative difference value of Bohler's angle between bilateral calcaneus by Bohler's angle of its normal control.

The data were analysed with SPSS 13.0 for Windows. Various parameters were recorded as numbers and percentiles with frequency tables. Continuous variables were expressed as mean±standard deviation (SD). The relationships between Bohler's angle and American Orthopaedic Foot and Ankle Society hindfoot scores, Bohler's angle and Sanders classification, American Orthopaedic Foot and Ankle Society hindfoot scores and Sanders classification were analysed with bivariate relationship (Spearman's rank relationship). To interpret Spearman value of r_s of 0.9 to 1 indicates very strong relationship between 0.7 and 0.89; strong relationship between 0.5 and 0.69; moderate between 0.3 and 0.49; moderate-to-low between 0.16 and 0.29; weak to low and below 0.16, relationship is too low to be meaningful.¹⁸ A P value less than 0.05 were regarded as statistically significant. The review board of the Sri Aurobindo Institute of Medical Science, Indore has approved the study. Signed informed consents have been obtained from all patients.

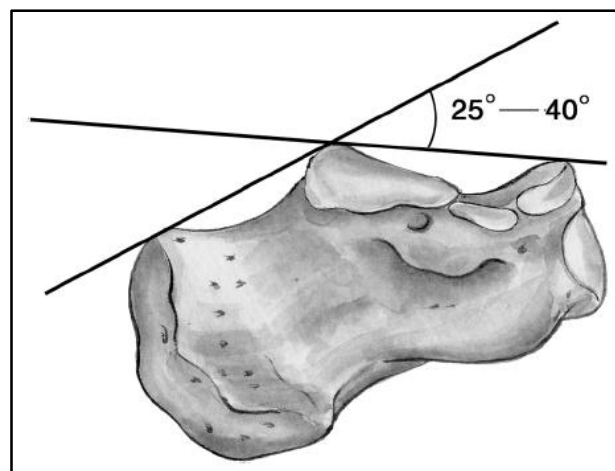


Figure 1. The Schematic Drawing of the Modality of Measurement of Bohler's Angle

Bohler's angle can be measured with the use of two intersecting lines- one drawn from anterior process of the calcaneus to the highest part of posterior articular surface and a second drawn for the same point of posterior articular surface to the most superior point of tuberosity.

RESULTS

30 patients with displaced intra-articular calcaneal fractures met the inclusion criteria. Among them, 274 patients were available for follow up with a mean duration of 30 months. There were 22 males and 8 females with an average age of 38.5 years (range, 18-69 years). The injury mechanisms included a fall from a height in 145 patients, a traffic injury in 62, a crush injury in 51 and a sprain in 16. According to

Sanders classification, the fracture pattern included 12 type II, 10 type III and 8 type IV fractures. According to American Orthopaedic Foot and Ankle Society hindfoot score, the functional outcomes were excellent in 10 patients (37.96%), good in 8 (48.18%), fair in 4 (9.85%) and poor in 1 (1.01%) (Table 1). Soft tissue complications were reported in 2 patients including 4 patients with superficial infection, 2 wound edge necrosis, 2 deep infection, 1 sural nerve injury. Superficial infection and wound edge necrosis were resolved by dressing changes. Deep infection extended to the level of hardware in both patients and mandated a removal of hardware. Implant removal and freeing of the sural nerve carried out on 2 patients with sural nerve injury at 12 weeks after operation and marked symptom relieve was achieved postoperatively. 2 out of the four patients with restricted movement of flexor hallucis longus tendons had pain and tenderness due to the compression bolts passing above the tendons. Hardware was removed and the symptoms were alleviated significantly.

The pre- and postoperative lateral x-ray films of the injured feet were collected in all 274 patients. The x-ray films of the uninjured feet were taken in 96 patients preoperatively and in 156 patients at follow-ups. The average values of the three preoperative measurements (Bohler's angle, difference value of Bohler's angle between bilateral calcaneus and change in Bohler's angle by ratio) was 8.24 degrees (range, -30-32 degrees), -25.42 degrees (range, -62-0 degrees) and -0.80 (range, -1.65-0), respectively. The average values of the three postoperative measurements (Bohler's angle, difference value of Bohler's angle between bilateral calcaneus and change in Bohler's angle by ratio) were 34.45 degrees (range, 0-60 degrees), -3.62 degrees (range, -23-32 degrees) and -0.10 (range, -1-0.58), respectively. For patients who achieved excellent or good results based on American Orthopaedic Foot and Ankle Society hindfoot score, the three postoperative measurements were 28.89 ± 7.24 degrees (range, 9-46 degrees), accordingly.

The three preoperative measurements were all found to have a significant relationship with Sanders classification (Table 2). No preoperative measurements were correlated with American Orthopaedic Foot and Ankle Society hindfoot score ($P=0.156$; $P=0.161$; $P=0.101$, respectively). The three postoperative measurements were all found to have a significant relationship with American Orthopaedic Foot and Ankle Society hindfoot score ($P < 0.001$; $P < 0.001$; $P < 0.001$, respectively) (Table 2). Of the four subjective evaluation categories in American Orthopaedic Foot and Ankle Society hindfoot scores, postoperative Bohler's angle were found to correlate with pain, walking distance and walking surface ($P=0.003$; $P=0.045$; $P=0.027$, respectively), but not correlate with the category of activity limitation. No relationship was found between any of the four subjective variables and the difference value of Bohler's angle between bilateral calcaneus or the change in Bohler's angle by ratio (Table 3).

DISCUSSION

According to the data obtained from 321 patients, we found that the preoperative Bohler's angle, difference value of Bohler's angle between bilateral calcaneus and change in Bohler's angle by ratio each has a strong positive relationship with Sanders classification while the three postoperative measurements each also has a significant positive relationship with American Orthopaedic Foot and Ankle Society hindfoot score. To some extent, the preoperative Bohler's angle can indicate the injury severity of displaced intra-articular calcaneal fractures while the postoperative angle can provide prognostic information with regard to the functional outcomes. Various radiographic parameters have been used to describe calcaneal fractures. Bohler's angle is an accepted method of quantifying fracture displacement and has a prognostic value in predicting morbidity associated with calcaneal fractures.^{5,13} Mitchell et al reported that there was a strong association between Bohler's angle and Sanders classification based upon the analysis of the data obtained from 80 patients.¹⁹ However, we identified a weak to low relationship between preoperative Bohler's angle and Sanders classification after analysing the data obtained from 30 patients. Similarly, the preoperative difference value of Bohler's angle between bilateral calcaneus and the change in Bohler's angle by ratio were also found to significantly correlate with Sanders classification. Our findings indicated that there was no relationship between functional outcomes and preoperative Bohler's angle, difference value of Bohler's angle between bilateral calcaneus or change in Bohler's angle by ratio. That is to say, the greater the energy absorbed by the calcaneus, more severe the fractures. The extreme diminution of preoperative Bohler's angle indicated more severe injury of displaced calcaneal fractures.²⁰

Technically, it is more difficult to restore Bohler's angle of severely displaced calcaneal fractures to normal range than those with less severe injuries. Therefore, theoretically, those severely injured cases would be more likely to suffer poor outcome. Our findings that there was a significant negative relationship between American Orthopaedic Foot and Ankle Society hindfoot scores and Sanders classification ($P < 0.001$) also support this hypothesis. Although, the optimal treatment of displaced intra-articular calcaneal fractures continue to elude investigators.^{21,22} Open or closed reduction and internal fixation has achieved its fame for the ability to re-establish morphology of the calcaneus and articular congruity. Therefore, only surgically treated patients were included into this study. Pozo et al reported that although two-thirds of patients with calcaneal fractures reached a point of maximal functional recovery at two to three years, 24% continued to improve for six years.²³ We enrolled patients treated operatively from May 2014 to October 2016 into this study who were followed up with a duration of 30 months.

The Bohler's angle can be used to guide the fracture reduction intraoperatively. Restoring the Bohler's angle back to normal range of 25-40 degrees is one of the surgical goals in clinical practice,¹⁵ which is one of the important factors to obtain satisfactory results.^{24,25} However, study findings over

whether restoration of Bohler’s angle correlates with an improved clinical outcome have been mixed. There are two opposing viewpoints among the published literature (Table 4). Some authors think that surgical restoration of Bohler’s angle can improve the functional outcome of the injured feet⁶⁻¹⁰ and that Bohler’s angle is of prognostic relevance.²⁶⁻²⁹ In a review of 70 cases with displaced intra-articular calcaneal fractures, Paul et al reported that patients were found to have a good outcome following operative treatment when Bohler’s angle was optimally restored >10 degrees.²⁵ Slightly different from Paul’s study, Buckley et al reported a markedly good functional outcome at a long-term follow ups in patients with restored Bohler’s angle >15 degrees in both operative and conservative group.²⁰ In Makki’s study, restoration of Bohler’s angle ≥30 degrees was associated with a better outcome based upon the data of 47 patients²⁴ and vice versa. Poor functional outcome can be seen in patients without restoration of Bohler’s angle. Janzen et al reported that a loss of Bohler’s angle measured at follow ups was associated with a poor clinical outcome.³⁰ Paley and Hall³¹ found that the ratio of Bohler’s angle of the injured side to the normal side was significantly lower in patients with unsatisfactory outcomes and concluded that a decrease in this ratio was a negative prognostic factor. However, Hutchinson, Kundel, Ibrahim and Mauffrey held the opposite opinion that there was no relationship at all between Bohler’s angle measured at follow-ups and the final functional outcomes in neither operative nor conservative group.^{14,22,26,32} More interestingly, Loucks et al reported that although Bohler’s angle increased after open reduction and internal fixation, the clinical outcome diminished.¹³ In their study, a statistically significant negative relationship (p<0.05) was found between the change in angle (angle measured at 3-month follow-up minus angle at the time of injury) and the SF-36 score at two-year follow up in a surgical treatment group. Our findings support the former viewpoint that postoperative Bohler’s angle can be used to predict the clinical outcomes.

We found a significant positive relationship between postoperative Bohler’s angles and American Orthopaedic Foot and Ankle Society hindfoot scores. Bohler’s angle is defined by two imaginary lines- one drawn from anterior process of the calcaneus to the highest part of posterior articular surface and a second drawn from the same point of posterior articular surface to the most superior point of tuberosity. Bohler’s angle measures the height of posterior articular facet.³³ Anatomical reduction of posterior articular surfaces of the calcaneus is an important goal for the treatment of displaced intra-articular calcaneal fractures, which can help restore Bohler’s angle predicting a promising prognosis. We found out that restoration of Bohler’s angles ≥11 degrees was associated with good to excellent results

similar to the findings reported by Paul et al.²⁵ To investigate the most correlated pattern of Bohler’s angles with functional outcomes, we introduced the Bohler’s angle of uninjured foot as its normal control. The relationship between American Orthopaedic Foot and Ankle Society hindfoot scores and the postoperative difference value of Bohler’s angle between bilateral calcaneus and the change in Bohler’s angle by ratio was also analysed, respectively. Varying from our previous assumption, the postsurgical dimensions were not better to Bohler’s angle in predicting functional outcomes. In addition, postoperative Bohler’s angle was found to correlate with three out of the four subjective variables of American Orthopaedic Foot and Ankle Society hindfoot scores. However, no significant relationship was found between any of the four variables and postoperative difference value of Bohler’s angle between bilateral calcaneus or the change in Bohler’s angle by ratio. In the current study, although significant relationships were identified both between postoperative Bohler’s angles and American Orthopaedic Foot and Ankle Society hindfoot scores and between preoperative angle and Sanders classification.¹⁸ Researches with lesser patient sizes are more prone to errors or bias in patient selection and data collection than those with large sample sizes, which is more likely to compromise the results and lead to the mixed findings as summarised in Table 4. This research included the largest patient sample size among the published studies to detect the role of Bohler’s angle in predicting the injury severity and functional recovery and the comprehensive analysis of a large pool of data should be very helpful to settle this disputes. The study has some limitations. It is limited by the retrospective nature of the study design. Various parameters may influence the functional outcomes of displaced intra-articular calcaneal fractures such as the reduction quality of posterior articular surface and the reduced width and height of the calcaneus. As part of the study design, we did not include those factors. Another limitation is that taking the lateral radiographs of the contralateral unaffected feet increased the burden of radiation exposure for all patients.

CONCLUSION

In displaced calcaneum fractures, the presurgical Bohler’s angle has a strong relationship to the severity of the calcaneum fractures. The postoperative Bohler’s angle has a significant positive role in predicting the efficient outcome. Achieving a significant and normal Bohler’s angle is a vital index during surgical treatment of displaced intra-articular calcaneal fractures and of ≥9 degrees is essential to achieve satisfactory functional outcomes.

Sander’s Classification	American Orthopaedic Foot and Ankle Society Score			
	Excellent	Good	Fair	Poor
Type 2 (12)	5	4	1	1
Type 3 (10)	4	3	2	1
Type 4 (8)	1	1	3	3
Total (30)	10 (33.33%)	8 (26.66%)	4 (13.33%)	2 (6.66%)

Table 1. The American Orthopaedic Foot and Ankle Society Scores and Sander’s Classification

Status	Relationship	Parameter	p-value
Preoperative	Bohler's angle between bilateral calcaneum	Sander's classification	0.003
Preoperative	Bohler's angle between bilateral calcaneum	Functional outcome	0.008
Postoperative	Bohler's angle between bilateral calcaneum	Sander's classification	0.102
Postoperative	Bohler's angle between bilateral calcaneum	Functional outcome	0.105

Table 2. The Relationship between Bohler's Angle, the Difference Value of Bohler's Angle between Bilateral Calcaneus or the Change in Bohler's Angle by the Injury Severity or Functional Outcomes

Relationship	Mode	p-value
Pain	The difference value of Bohler's angle between bilateral calcaneus	0.08
Activity Limitation	The difference value of Bohler's angle between bilateral calcaneus	0.013
Walking Distance	The difference value of Bohler's angle between bilateral calcaneus	0.084
Walking Surface	The difference value of Bohler's angle between bilateral calcaneus	0.061

Table 3. The Relationship between Four Subjective Variables of American Orthopaedic Foot and Ankle Society Scores and the Postoperative Bohler's Angle, Difference Value of Bohler's Angle between Bilateral Calcaneus or Change in Bohler's Angle by Ratio

No.	Cases	Surgeries	Follow up (Years)	Relationship
1.	45	33	4.5	A loss of Bohler's angle measured at follow ups was associated with a poor clinical outcome. ²⁷
2.	44	47	4-14	The ratio of Bohler's angle of the fractured side to that of the normal side was significantly lower in patients with unsatisfactory outcomes at final follow up evaluation. ²⁸
3.	43	47	1	Bohler's angle measured at the final follow-up did not correlate with the clinical result. ²⁰
4.	63	30	5.1	No relationship between Bohler's angle and final functional outcomes. ²³
5.	88	44	2	There was a significant negative relationship between change in Bohler's angle (angle measured at 3-month minus angle at the time of injury) and SF-36 score in surgical group. ¹³
6.	70	29	6.5	Patients with displaced fractures had a good outcome following operative treatment with restored Bohler's angle >10 degrees. ²²
7.	26	15	15	No relationship between Bohler's angle and functional outcome. ¹⁴
8.	16	16	2	No relationship between good restoration of Bohler's angle and high functional score. ²⁹
9.	47	47	10	Restoration of Bohler's angle ≥30 degrees was associated with a better outcome. ²¹
10.	30	30	2.7	The preoperative Bohler's angle has a significant relationship with Sanders classification. The postoperative Bohler's angle has a significant relationship with the final functional outcome (the current study).

Table 4. Summarisation of the Various Articles and its Comparison to this Study in Assessing the Bohler's Angle, the Injury and Functional Outcome for Displaced Intra-Articular Calcaneal Fracture

CLINICAL IMAGES

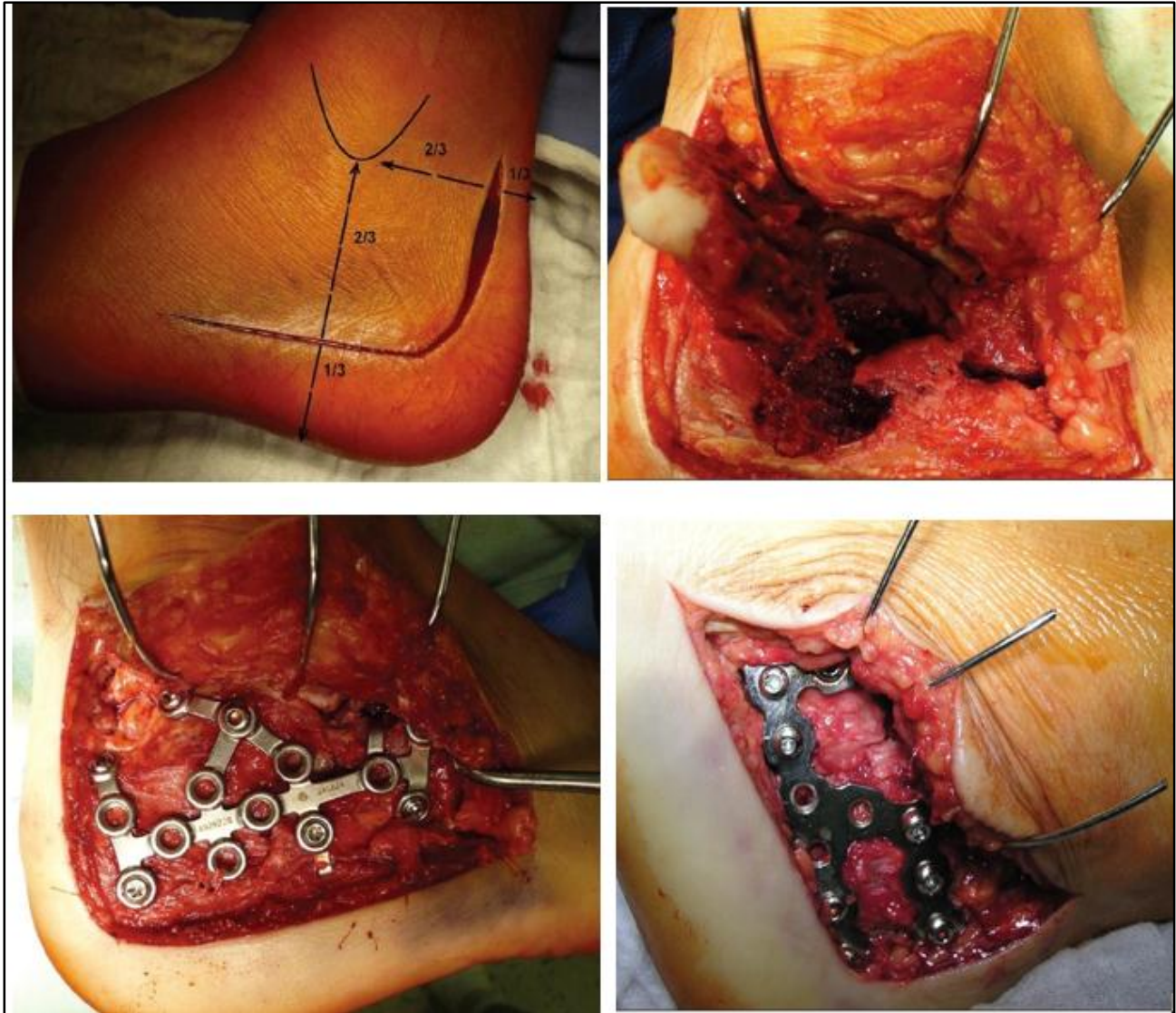


Figure 2. Showing the L-Shaped Incision over the Lateral Aspect of Calcaneus



Figure 3. The Preoperative X-Ray Showing Bohler's Angle of Zero Degree

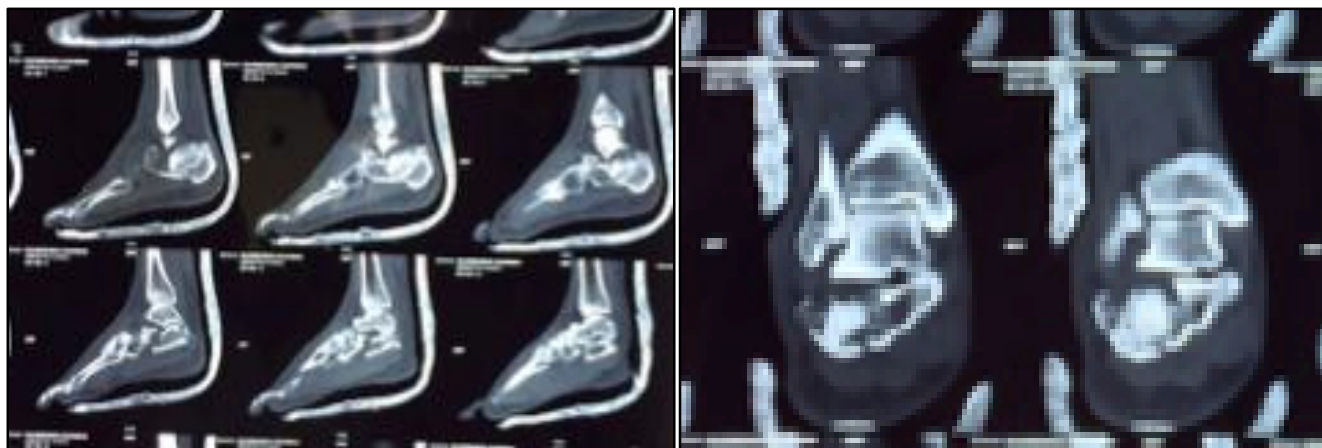


Figure 4. CT Scan Showing the Collapse of the Calcaneum with the Reduction of Bohler's Angle to Zero Degree



Figure 5. Postoperative X-Ray Showing the Achievement of Bohler's Angle to 30 Degree

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