The Association of Bohler's Angle with Postoperative Pain and Gender for Displaced Intra-articular Calcaneal Fracture, Multicenter Retrospective Study - TRON Study

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Abstract

A relationship between Böhler angle (BA) before or after surgery and clinical outcomes remains unclear. This retrospective multicenter cohort study aimed to compare pain and functional outcomes between a group in which the reduction angle was preserved and a group in which the reduction angle was lost during follow-up, and to clarify the risk factors leading to loss of last follow-up BA. From 2014 to 2018, 271 cases of calcaneal fractures were surgically treated at ten facilities. We divided patients into Group L (lost reduction of fracture) and Group P (preserved reduction of fracture). We matched subjects between the two groups according to age, sex and BA before surgery and compared American Orthopedic Foot and Ankle Society (AOFAS) score between the groups. We investigated the correlation between the amount of BA loss and postoperative pain, The factors leading to loss of last follow-up BA were examined by logistic regression analysis. Ultimately, 112 patients were eligible. After matching, each group included 38 patients. There was no difference between the two groups in total AOFAS score. However, the pain component of AOFAS score at 6 months and 12 months were worse in group L than in group P (P=.011, P=.031, respectively). We also showed a weak correlation between the amount of BA loss and postoperative pain. Logistic regression analysis revealed that female and BA before surgery independently predicted loss of reduction (odds ratios: 4.66 ,95%CI:1.15-18.9 and odds ratios: 0.90, 95%CI:0.82-0.99, respectively). We clarified that reduction and preservation of BA within its normal range should lead to decrease postoperative pain. Female and lower pre-BA were risk factors leading to loss of reduction of BA in operative treatment of calcaneal fractures.

Level of Clinical Evidence: Level II, retrospective cohort study

Key words: Calcaneus, Reduction, Böhler height, Trauma, Multicenter study

Introduction

Calcaneal fractures are one of the major fractures, accounting for 60% to 65% of all tarsal fractures (1,2). Calcaneal fractures are usually secondary to high-energy injuries such as falling from heights or car accidents. They occur mostly in young, active physical laborers and, therefore, have a high socioeconomic impact (3,4).

The Böhler angle (BA), which is an index of calcaneal height, is one of the evaluations performed in lateral plain radiographs and is widely used as an index for diagnosis and postoperative reduction of calcaneal fractures (5). The normal range of BA is 20 to 40° (6).

Several previous reports showed a relationship between BA before or after surgery and clinical outcomes (3,7,8,9,10). A large-population retrospective study showed a positive correlation between last follow-up BA and the American Orthopedic Foot and Ankle Society (AOFAS) score (10). Another retrospective study found that low BA values before surgery are associated with worsening patient satisfaction and pain by Visual Analog Scale (VAS) (3,7,9). However, a different retrospective study showed no association between last follow-up BA after open reduction internal fixation (ORIF) surgeries (with plates, percutaneous screws, and percutaneous Kirschner wires [K-wires]) and AOFAS scores and pain by VAS (8). It remains unclear whether BA before surgery and last follow-up BA affect pain and functional outcomes after ORIF surgeries for calcaneal fractures.

In this multicenter retrospective study, we hypothesized that appropriate reduction of BA before surgery and preservation of the BA after surgery within the normal range would lead to good clinical results in the operative treatment of calcaneal fractures. This study thus aimed 1) to compare the AOFAS score between a group in which the reduction angle was preserved and a group in which the reduction angle was lost during the follow-up period after matching for age, sex and BA before surgery and 2) to clarify the risk factors leading to loss of BA in a multicenter study.

Patients and Methods

This retrospective multicenter study was conducted according to the principles expressed in the Declaration of Helsinki. The ethics committee of each participating hospital approved this study. We obtained informed consent from all patients. Hospitals of the Trauma Research Group of Nagoya (TRON) have registered orthopedic trauma surgery cases in the TRON database annually since 2014. The participating hospitals in the database are all hospitals associated with the Department of Orthopedic Surgery of our university. Orthopedic surgeons performed the surgery at these hospitals in the Chubu Region of Japan. We collected cases of calcaneal fractures from this database that were treated surgically.

Subjects

From 01/01/2014 to 12/31/2018, 271 cases of calcaneal fractures were surgically treated at ten facilities. We excluded the following patients: patients less than 18 years old or older than 70 years old, patients followed up less than 12 months, patients without intra-articular fractures (beak fractures, fracture of the sustentaculum tali and so on). We also excluded bilateral calcaneal fractures, previous trauma of calcaneum and previous history of arthrodesis. In this study, the patients with BA before surgery more than 20° and with BA immediately after surgery less than 20° were excluded because we considered it important to reduce the lost BA by surgery and preserve the BA after surgery. Finally, 112 patients remained. We divided the patients into the group who lost calcaneal height during the follow-up period (last follow-up BA less than 20°:Group L) and the group who preserved calcaneal height during that period (last follow-up BA of 20° or more: Group P). We matched subjects in Group L with those in Group P according to BMI, age, sex, and BA before surgery at baseline at a 1:1 ratio (Figure 1).

Data Collection

We collected the following data from the patients' medical records: age, sex, body mass index (BMI), type of injury (fall from a high place, traffic accident, and fall on flat ground), multiple fracture (the other site fractures other than calcaneus), smoking status (currently smoking or not), and diabetes mellitus status (during treatment). We obtained the types of implants (only K-wires, cannulated screws [with or without K-wires], plate) as operative information. We also investigated postoperative infections, pulmonary embolus, and fibularis tendon dislocation as postoperative complications. We defined postoperative infection as those that showed redness of the skin and required antibiotics occurring within 3 months after surgery and classified superficial and deep infections according to the presence or absence of operative intervention.

Clinical Evaluation

The AOFAS scores were used to evaluate pain and functional outcome during the follow-up period (11,12). We assessed the AOFAS score at three, six, and twelve months after surgery. This score includes nine components: pain, function, maximum walking distance (in blocks), walking surfaces, gait abnormality, sagittal motion (flexion plus extension), hindfoot motion (inversion plus eversion), ankle hindfoot stability (anteroposterior, varus valgus), and alignment. The maximum score is 100 points, which indicates the best possible outcome.

Radiographical Evaluation

Radiographic data were obtained by reading the radiographic computerized images. The radiographic evaluation comprised the analysis of conventional radiographs, including lateral and axial views in the preoperative, postoperative, and follow-up periods, and preoperative computed tomography (CT) scans (2- to 3-mm slice thickness, multiplanar reconstruction). The fractures were classified according to the Essex-Lopresti classification (tongue type or joint depression type) (13) and Sanders classification (14).

Each measurement was taken twice by one orthopedic surgeon (YK) at intervals of two weeks. We used average of two for analysis.

Surgical Management

All patients were placed in either the supine, lateral, or prone position. We used spinal anesthesia or plexus anesthesia, and sedation was used when necessary. The operative method was decided by the preferences and experience of the surgeons in each hospital involved in the operations and on the basis of fracture type and the soft tissue condition of each case. A thigh tourniquet was always applied only when the ORIF technique was performed.

ORIF surgery was performed only in patients without soft tissue damage after swelling had subsided and skin wrinkles were present. A full-thickness L-shaped lateral incision or sinus tarsi approach was used. The fracture was reduced and temporarily fixed with K-wires under direct view and radiographic guidance. When the reduction was satisfactory, as observed via fluoroscopy and direct view of the joint surface, final stabilization was obtained with a plate (MIS™, Zimmer, Warsaw, ABD; VariAx™, Stryker, Mahwah, NJ; or LCP™, Synthes, Solothurn, Switzerland) and titanium screws or with 4.0 to 6.5-mm diameter titanium cannulated screws (Synthes or MEIRA, Nagoya, Japan). Bone graft or bone graft substitutes were used to fill the bony defect beneath the articular surface in 54 of the cases. The closure was performed in two layers. No suction drains were used. A compression dressing was applied on the operated site for 48 h after the surgery.

To achieve reduction via percutaneous surgery, one or two 2.0 to 3.0-mm K-wires were inserted under fluoroscopic control from the calcaneal tuberosity toward the subtalar joint. Then, during closed reduction, using the K-wires like a joystick via external maneuvers and a leverage technique with axis stress applied onto the pins down the distal side, restoration of BA was attempted. Fluoroscopic images in the lateral and axial radiographic views allowed the evaluation of the anatomical reduction. Final stabilization was obtained with other 2.0 to 3.0-mm K-wires or with 5.0 to 6.5-mm diameter titanium cannulated screws (Synthes or MEIRA) inserted in the same posterior anterior direction. A compression dressing was applied on the operated site for 48 h after surgery. All patients received antibiotic for 1 to 3 days after the surgery according to hospital protocol.

In the postoperative protocol, the surgeons selected postoperative immobilization: cast, splint, or none. Ankle planter flexion and dorsiflexion training was started after the cast or splint was removed. The attending physician allowed the patients to start weightbearing, and the amount was gradually increased to full loading according to each patient’s level of pain. Pins in the patients with pinning were removed around 4 to 8 weeks postoperatively after confirming good callus and bone union on radiographs.

Statistical Analysis

All statistical analyses were performed using the EZR software program (version 1.40, Jichi Medical University, Tochigi, Japan) with the significance level set at $P \leqq 0.05$ (15). The test checked the normality of data distribution for equality of variance. Fisher's exact test was used to detect differences within categorical data.

The Mann-Whitney U test was used to compare the continuous and ordinal variable between Group L and Group P. We examined the risk factors for last follow-up BA loss by logistic regression analysis. The correlations between amount of BA loss and pain component of AOFAS score were analyzed with bivariate correlation (spearman's rank correlation).

We calculated the required sample size to achieve a statistical power (1 to β) of 80%, where alpha is 0.05. We referred to a previous report (3) that suggested a ten-point difference in AOFAS score with a standard deviation of 10 points between two groups. Thus, 19 patients had to be recruited in each group.

Results

In radiographic evaluation, intraobserver reliability was measured using Fleiss' kappa value. Intraobserver reliability was found to be good (Fleiss' kappa: 0.89, 95% confidence interval: 0.84-0.93). The intra-class correlation coefficient of BA evaluated by the orthopedic surgeons was 0.93 (95% confidence interval: 0.85-0.97).

Table 1 shows the background characteristics of the 112 patients. Forty-two patients (37.5%) lost the reduction of calcaneal height during the follow-up period (Figure 1).

Table 2 shows the patient backgrounds of the two groups after matching for age, sex, and BA before surgery (Group L and Group P). There was no significant difference between the two groups in total AOFAS score at three, six and twelve months postoperatively (Table 3). However, the pain component of AOFAS score in Group L was worse than that of Group P at six and twelve months (Table 4).

Table 5 shows the predictors for the loss of reduction as determined by logistic regression analysis. The analysis revealed that female sex and BA before surgery independently predicted loss of reduction.

Table 6 shows the correlations between amount of BA loss and the pain component of AOFAS score. The amount of BA loss was found to correlate with postoperative pain.

Discussion

This study showed that although there was no significant difference between the two groups in the total AOFAS score, the group with appropriate reduction and preservation of BA after surgery had less pain than the group that had lost the reduction of BA. In a prior retrospective study of 274 cases, BA at final follow-up was also found to have a significant correlation with pain ($r = 0.259$, $P = .003$) (10).

Pain might be related to anatomical changes in the calcaneus due to the fracture. Restoration of calcaneal height was reported to improve anterior tibiotalar impingement and decrease the lever arm of the Achilles tendon (16). In calcaneal fractures, the loss of the reduction leads to a reduction of the lever arm of the Achilles tendon and a more dorsiflexed talus that may result in painful anterior tibiotalar impingement (10). Therefore, restoration of BA, which is an index of calcaneal height, reduces pain. The significant correlation between amount of BA loss and pain, shown in Table 6, also reinforces this notion.

This study also revealed that female and lower BA before surgery were significantly related to an increased risk of loss of BA after surgery. There are few reports on the relationship between gender and lost reduction of BA. Bone density of the calcaneus does not change much in men after the age of 40, but in women, it decreases sharply from the 40s to the 60s (17). The mean age of the women in our cohort was 52.6 years, which may have been affected by reduced bone density. Another study showed that lower bone density of the calcaneus correlated significantly with decreased last follow-up BA ($r = 0.348$, $P = .022$) (18). These results suggested that bone density in women might be a factor in the loss of BA because it is lower than that of men.

A lower BA before surgery was also an independent risk factor for loss of the reduction although the odds ratio is low compared to gender. The lower the BA before surgery is, the greater is the amount of collapse. This means that a calcaneal fracture with smaller BA before surgery will require a larger amount of reduction to reach its normal range. Collapse of the cancellous bone results in a bone defect when reducing the lesion in calcaneus fractures. One retrospective study showed that when BA is restored by more than 25° by surgery, a loss in the BA of more than 10° is likely after surgery (19). This may result in larger bone defects and further loss of BA due to the reduced volume.

Most orthopedic surgeons know that correcting the Bohler angle is an important aspect of calcaneal fracture surgery, but it was not clear to what extent correcting and maintaining the Bohler angle actually leads to anything. In this study, we were able to clarify that correcting and maintaining the Bohler angle in the normal range can decrease postoperative pain. As mentioned earlier, the BA before surgery was shown to be an independent factor for loss of the reduction. As shown in the systematic review, it is one of the right surgical techniques for preservation of BA after surgery to use a sufficient amount of bone graft or bone substitutes in the fracture void (20). In the future, a large prospective study with the same surgical technique and postoperative treatment will further clarify the relationship between the Bohler angle and clinical outcomes.

This study has some limitations. First, it is a retrospective study using a clinical database, so selection bias must be considered. Second, the sample size is small and the follow-up period is short. Third, as for the final x-ray, the timing was not exactly the same. Fourth, postoperative CT evaluation, such as of gap and step off of the articular surface, was not performed in all cases. Various radiographic parameters may affect functional outcomes, such as a reduction in the quality of the posterior articular surface or reduced width of the calcaneus (21). It is thus necessary to evaluate the joint surface and width by CT. Fifth, we did not measure the height of the contralateral calcaneus. Sixth, although the possibility of an association with bone density was mentioned, bone density testing could not be performed. Seventh, heterogeneity of postoperative protocol may affect the result of this study. We assessed pain with only four ordinal variables and did not take a VAS. The VRS, which is a similar four-level assessment, has been validated, but the use of subcategories for the AOFAS score has not been validated. Finally, we excluded people over the age of 70 because we targeted active people, and older age may affect the outcome in terms of reduced bone mineral density. In conclusion, we clarified that reduction and preservation of BA within its normal range should lead to decrease postoperative pain. Female and lower pre-BA were risk factors leading to loss of reduction of BA in operative treatment of calcaneal fractures.

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Figure Legend

Figure. Flow diagram of the participants included in the study. Abbreviation: BA, Böhler angle.

Table 1. Patient Characteristics (N=112 patients)

Characteristic	N=112
Age, yrs, mean ±SD	50.59 ±13.78
Sex, male/female n	86/26
BMI, kg/m^2, mean ±SD	23.14±3.52
Current smoking, n (%)	32 (28.57)
Diabetes mellitus, n (%)	4 (3.57)
Open fracture, n (%)	5 (4.5)
Injury mechanism, n (%)	
Tumble	15 (13.16)
Fall from a high place	96 (85.71)
Traffic accident	1 (0.89)
Multiple fracture, n (%)	32 (28.57)
Essex-Lopresti classification, n (%)	
Tongue type	55 (49.11)
Joint depression type	57 (50.89)
Sanders classification, n (%)	
I	14 (12.50)
II	45 (40.18)
III	41 (36.61)
IV	12 (10.71)
Böhler angle before surgery, degrees, mean±SD	5.91±9.89
Date from surgery to weightbearing, days, mean±SD	36.05±15.86

Abbreviations: SD, standard deviation; BMI, body mass index.

Table 2. Patients Characteristics after Matching (N=76 Patients)

Characteristic	Group L (N=38)	Group P (N=38)	P value
Age, yrs, mean±SD (range)	54.89±12.02 (21-69)	50.24±14.21 (21-69)	.13
Sex, male/female, n	27/11	27/11	1.00
BMI, kg/m^2, mean±SD (range)	22.99±3.33 (17.3-30.6)	23.02±3.25 (16.6-30.1)	.97
Diabetes mellitus, n (%)	2 (5.26)	1 (2.63)	1.00
Injury mechanism, n (%)			.52
Tumble	7 (18.42)	4 (10.52)	
Fall from a high place	31 (81.58)	34 (89.47)	
Traffic accident	0 (0.00)	0 (0.00)	
E-L classification, n (%)			.65
Tongue type	16 (42.11)	19 (50.00)	
Joint depression type	22 (57.89)	19 (50.00)	
Sanders classification, n (%)			.83
I	5 (13.16)	3 (7.89)	
II	16 (42.11)	15 (39.47)	
III	14 (36.84)	17 (44.74)	
IV	3 (7.89)	2 (5.26)	
BA before surgery, degrees, mean±SD	4.48±10.02	4.52±11.63	.98
BA immediately after surgery, degrees, mean±SD	23.68±3.32	29.29±5.22	<.001*
Type of implant, n (%)			.53
Kirschner wires	13 (34.21)	13 (34.21)	
Cannulated screws	16 (42.11)	12 (31.58)	
Plate	9 (23.68)	13 (34.21)	
Infection, n (%)			.67
Superficial infection	3 (7.89)	2 (5.26)	
Deep infection	1 (2.63)	0 (0.00)	
Pulmonary embolus	0 (0.00)	0 (0.00)	1.00

Abbreviations: SD, standard deviation; BMI, body mass index; E-L, Essex-Lopresti.

*p <.05

Table 3. AOFAS Scores at 3, 6 and 12 Months

	3 months			6 months			12 months		
	Group L	Group P	P	Group L	Group P	P	Group L	Group P	P
AOFAS, mean±SD	69.59±14.24	71.94±16.90	.54	80.79±11.53	84.70±13.18	.23	84.74±11.03	87.81±12.21	.29

Abbreviations: AOFAS, American Orthopedic Foot and Ankle Society; SD, standard deviation.

Table 4. the pain component of AOFAS score at 3, 6 and 12 Months

Characteristic	Group L (N=38)	Group P (N=38)	P value
3 Months			.27
No pain, n	2	7	
Mild pain, n	23	19	
Moderate pain, n	12	11	
Severe pain, n	1	1	
6 Months			.011*
No pain, n	6	16	
Mild pain, n	25	19	
Moderate pain, n	6	2	.
Severe pain, n	1	1	
12 Months			
No pain, n	9	18	.031*
Mild pain, n	23	17	
Moderate pain, n	6	3	
Severe pain, n	0	0	

Abbreviations: AOFAS, American Orthopedic Foot and Ankle Society.

*p <.05

Table 5. Logistic Regression Analysis for Lost Böhler Angle at Final Follow up

Variable	Odds ratio (95% CI)	P Value
Age	1.03 (0.98-1.08)	.27
Sex		
Male	1.00 (reference)	
Female	4.66 (1.15-18.9)	.03*
BMI	1.06 (0.89-1.26)	.52
Current smoking	0.97 (0.28-3.35)	.97
Diabetes mellitus	0.55 (0.05-6.30)	.63
E-L classification		
Tongue type	1.00 (reference)	
Joint depression type	2.39 (0.58-9.84)	.23
Böhler angle before surgery	0.90 (0.82-0.99)	.02*
Sanders classification, n (%)		
I	1.00 (reference)	
II	0.55 (0.08-3.53)	.53
III	0.14 (0.01-1.40)	.09
IV	0.09 (0.005-2.07)	.14

Abbreviations: CI, confidence Interval; BMI, body mass index; E-L, Essex-Lopresti.

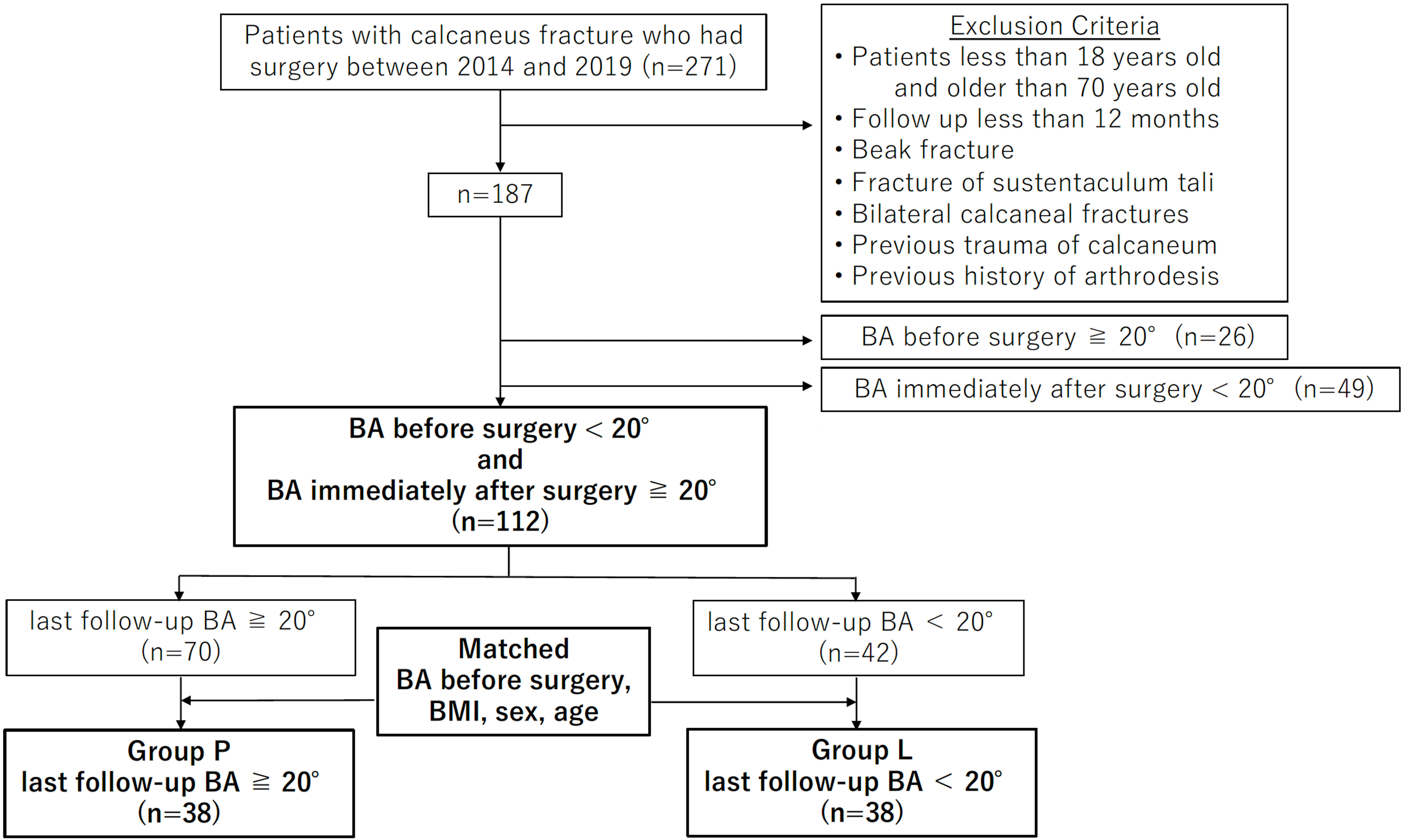
*p <.05

Table 6. The correlation between Böhler's angle and the pain component of AOFAS score

Correlation		rs-value	P value
Amount of Böhler angle loss	AOFAS Pain	0.242	.045*

Abbreviations: AOFAS, American Orthopedic Foot and Ankle Society.

*p <.05


Patients with calcaneus fracture who had surgery between 2014 and 2019 (n=271)
Exclusion Criteria
• Patients less than 18 years old and older than 70 years old
• Follow up less than 12 months
• Beak fracture
• Fracture of sustentaculum tali
• Bilateral calcaneal fractures
• Previous trauma of calcaneum
• Previous history of arthrodesis
n=187
BA before surgery ≧ 20° (n=26)
BA immediately after surgery < 20° (n=49)
BA before surgery < 20° and BA immediately after surgery ≧ 20° (n=112)
last follow-up BA ≧ 20° (n=70)
last follow-up BA < 20° (n=42)
Matched BA before surgery, BMI, sex, age
Group P last follow-up BA ≧ 20° (n=38)
Group L last follow-up BA < 20° (n=38)