

**Comparison of screw versus locking plate fixation via sinus tarsi
approach for displaced intra-articular calcaneal fractures**

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39 **Abstract**

40 **Background:** The optimal treatment of displaced intra-articular
41 calcaneal fractures (DIACF) is controversial. This study compared the
42 fixation stability of screws and locking plates in DIACF treated via the
43 sinus tarsi approach (STA).

44 **Methods:** We retrospectively evaluated 118 DIACF cases treated via
45 STA and extracted data that could affect treatment outcomes. Loss of
46 Böhler's angle after surgery was measured to compare fixation stability.

47 **Results:** The loss of Böhler's angles was significantly smaller in the
48 locking plate group than in the screw group ($2.6 \pm 2.7^\circ$ vs. $5.6 \pm 5.3^\circ$
49 $P < 0.01$). There was no difference in the clinical outcomes between the
50 groups. On multivariate logistic regression analysis, screw fixation was
51 significantly associated with loss of Böhler's angle by $>10^\circ$ (odds ratio,
52 8.63; 95% confidence interval, 1.16-64.4; $P < 0.05$).

53 **Conclusions:** Locking plate fixation is more reliable than screw fixation
54 for preventing correction loss in DIACF treated via STA.

55 **Level of evidence:** III

56

57 **Keywords:** calcaneal fracture, Böhler's angle, sinus tarsi approach,
58 locking plate fixation, screw fixation

59 **1. Introduction**

60 Calcaneal fractures account for almost 1-2% of all fractures, and
61 approximately 75% are intra-articular fractures. Displaced intra-articular
62 calcaneal fractures (DIACF) have an adverse economic impact on
63 society and negatively affect daily activities and quality of life due to the
64 difficulties of returning to preinjury employment or level of activity [1-
65 3].

66 Several studies have shown that anatomical reconstruction of the
67 calcaneus in DIACF decreases malunion and subtalar arthritis [4],
68 resulting in higher functional scores and fewer socioeconomic burdens
69 [5]. In the surgical treatment of DIACFs, the extensile lateral approach
70 (ELA) has long been considered the standard approach [6,7], despite the
71 high rate of wound complications. The thin and weak soft tissue on the
72 lateral side of the calcaneus can be easily damaged by the intraoperative
73 procedure [8]. Consequently, minimally invasive surgical methods have
74 been developed in recent years. In particular, the sinus tarsi approach
75 (STA) is an effective and reliable method with good visualization of the
76 posterior facet and fewer wound complications than ELA [9].

77 Although percutaneous screw fixation for comminuted calcaneal
78 fractures is considered to have lower stability than plate fixation [2],
79 limited studies have compared the stability of screw fixation and plate
80 fixation via STA. This study aimed to compare the stability of screw and
81 locking plate fixation in DIACF treated via STA by evaluating the
82 degree of correction loss after the surgery.

83

84 **2. Materials and methods**

85 **2.1. Study participants**

86 The medical records of patients who had undergone screw or locking
87 plate fixation via STA at our institute for DIACFs between January 2013

88 and June 2020 were retrospectively reviewed. This study included 118
89 consecutive fractures. The exclusion criteria were as follows: (1)
90 patients aged <18 years, (2) patients with open fractures, (3) patients
91 with <12 months follow-up, and (4) patients with pathological fractures.
92 The operative procedures were left to the discretion of the surgeon.
93 Patients were divided into two groups according to the fixation method:
94 screw or locking plate fixation. Patients' demographic data in each group
95 were corrected for age, sex, body mass index (BMI), past medical
96 history, Essex–Lopresti classification, Sanders classification, and
97 waiting time until the surgery. The Institutional Review Board of
98 Okayama University Hospital approved this study.

99

100 **2.2. Radiographic and clinical outcomes**

101 Böhler's angle [10] was measured using plain lateral radiographs of the
102 calcaneus preoperatively, immediately postoperatively, and at the 12-
103 month follow-up. Correction loss was indicated by the difference in
104 Böhler's angle between postoperative and 12-month follow-up.

105 Additionally, we evaluated the quality of joint reduction by measuring
106 the residual intra-articular step-off with an immediately postoperative
107 Brodén view.

108 The Sanders classification [11] was determined based on axial computed
109 tomography (CT) images at the widest point of the posterior facet.

110 Two orthopedic surgeons blinded to patients' radiographic and clinical
111 findings evaluated all radiographs and CT images.

112 Clinical outcomes were evaluated using the American Orthopaedic Foot
113 and Ankle Society (AOFAS) score at the last available follow-up and the
114 incidence of postoperative complications were reviewed from the chart.

115 Postoperative infection was classified as superficial or deep infections
116 according to the criteria of the US Center for Disease Control and

117 Prevention [12].

118

119 **2.3. Operative procedure**

120 All surgical procedures were performed by senior orthopedic surgeons
121 under general or spinal anesthesia in the lateral decubitus position with
122 the affected side up. A tourniquet was routinely applied to the ipsilateral
123 thigh.

124 According to the STA reported by Hospodar [13], a skin incision of
125 approximately 4 cm was made from the tip of the fibula to the
126 calcaneocuboid joint toward the base of the fourth metatarsal bone. After
127 longitudinal and medial traction was applied by pulling down a Kirchner
128 wire or Schanz pin inserted into the calcaneal tuberosity, the posterior
129 facet was elevated and reduced along the talus. Then, transverse
130 compression by Bohler's clamp was applied to reduce the shortening,
131 bulging, and internal rotation of the calcaneal body. Multiple temporary
132 Kirschner wires were used to maintain the reduction. Then, the reduction
133 quality was evaluated by direct visualization of the posterior facet and
134 confirmation of the lateral, Brodén, and Harris views on the C-arm
135 radiograph. When the posterior facet could not be visualized adequately,
136 a Z-shaped incision of the calcaneofibular ligament was added to
137 improve visualization.

138 In the screw group, one or two 4.0 mm cannulated cancellous screws
139 were inserted from the lateral to the sustentaculum tali to stabilize the
140 posterior facet. Another two or three 4.0 mm cannulated cancellous
141 screws were inserted from the calcaneal tuberosity to support the
142 elevated posterior facet.

143 In the locking plate group, a minimally invasive locking plate (MIS LC,
144 Zimmer Biomet, Warsaw, IN, USA or MINI-Calc Plate, Acumed,
145 Hillsboro, OR, USA) was slipped in through the same incision after

146 detaching the soft tissue from the lateral wall. Every fragment was
147 securely fixed by inserting screws in the anterior body, posterior facet,
148 and calcaneal tuberosity. Another small skin incision was required to
149 insert the distal screws.

150 After surgery, the affected limb was non-weight-bearing for 4-6 weeks;
151 partial weight-bearing was started gradually from 4-6 weeks
152 postoperatively, and full weight-bearing was started at 8-10 weeks
153 postoperatively.

154

155 **2.4. Statistical analyses**

156 Descriptive statistics are presented as mean±standard deviation for
157 continuous variables and as numbers and percentages for categorical
158 variables. The normality of each variable was evaluated using the
159 Shapiro–Wilk test. The Mann–Whitney U test was used to assess the
160 difference in continuous variables, and Fisher’s exact test was used to
161 analyze categorical variables. Multiple logistic regression analysis was
162 performed to predict correction loss of Böhler’s angle by >10° [14]
163 based on age, sex, time from injury to surgery, BMI, Sanders
164 classification, and operative procedure. These variables were selected
165 because of their clinically important significance. Values of $P < 0.05$ were
166 considered statistically significant. The Variance Inflation Factor (VIF)
167 was used to check for multicollinearity. Statistical analyses were
168 performed using EZR software (Saitama Medical Center, Jichi Medical
169 University, Tochigi, Japan) [15].

170

171 **3. Results**

172 The demographic and baseline characteristics of the 109 patients and
173 118 feet (male, 80; female, 29) are shown in Table 1. The Mann–
174 Whitney U test and the Fisher’s exact test showed no significant

175 difference in almost all baseline characteristics between the two groups,
176 except the waiting time until surgery, which was shorter in the screw
177 group than in the locking plate group (3.0 days vs. 9.9 days, $P=0.001$).
178 Table 2 shows the average Böhler's angles and postoperative intra-
179 articular step-off in the two groups. Preoperative Böhler's angle in the
180 locking plate group was significantly smaller than in the screw group
181 ($P=0.01$). There was no statistically significant difference in the
182 immediately postoperative and 12-month postoperative Böhler's angle
183 ($P=0.90$ and $P=0.58$ respectively) and intra-articular step-off ($P=0.08$).
184 Loss of Böhler's angle was significantly smaller ($P=0.002$) in the
185 locking plate group than in the screw group (Fig. 1).
186 The AOFAS score was 87.2 ± 9.1 in the locking plate group and 85.0 ± 9.2
187 in the screw group, and the difference was not statistically significant
188 ($p=0.07$). There was no statistically significant difference in the
189 incidence of postoperative complications between the two groups. Deep
190 infection occurred in one case in the locking plate group, which was
191 resolved with plate extraction and antibiotic treatment (Table 3).
192 In the multivariate logistic regression analysis, correction loss of
193 Böhler's angle by $>10^\circ$ was eight-fold more likely to occur with screw
194 fixation compared to that with locking plate fixation (odds ratio, 8.63;
195 95% confidence interval, 1.16-64.4; $P<0.05$) (Table 4). None of the VIF
196 values were >5 , and the mean VIF of the model was <2 , meaning there
197 was no collinearity in the model.

198

199 **4. Discussion**

200 This study aimed to establish whether screw or plate fixation is the
201 preferred technique to stabilize DIACF via STA from the point of view
202 of fixation stability. Stability was evaluated by the degree of correction
203 loss of Böhler's angle. Loss of Böhler angle after surgery was

204 significantly lower in the locking plate group than in the screw group,
205 and multivariate analysis showed that screw fixation had a significantly
206 higher risk of correction loss by $>10^\circ$ than the locking plate fixation.
207 Examples were shown in Figure 2 and 3.

208 In DIACF, the anatomical reduction of the articular surface and the
209 whole shape of the calcaneus is essential [16]. Accordingly, we
210 performed morphological reduction, including posterior facet and
211 Böhler's angle via STA in all cases. Previous studies have reported that
212 the correction loss of Böhler's angle at 12 months postoperatively with
213 non-locking plate fixation was as large as $4\text{--}10^\circ$ [14,17] and that locking
214 plate may be preferable to non-locking plate fixation because the
215 fixation stability of the locking plate was higher [18]. Similarly, in this
216 study, the correction loss of Böhler's angle for DIACF was significantly
217 less in the locking plate fixation group, averaging 5.6° in the screw
218 group and 2.6° in the locking plate group.

219 Percutaneous reduction and screw fixation for comminuted calcaneal
220 fractures are associated with lower quality of reduction [19] and lower
221 fixation stability than plate fixation [2]. In addition, this study suggests
222 that even if articular reduction via STA is performed correctly, screw
223 fixation does not have sufficient fixation stability for maintaining the
224 reduction.

225 Some studies have shown that preoperative and postoperative Böhler's
226 angle does not correlate with postoperative functional outcomes [20,21].
227 In other studies, better restoration of Böhler's angle was associated with
228 better postoperative clinical outcomes [6,22,23]. In our study, the
229 difference in the AOFAS scores was not statistically significant between
230 the two groups; however, it tended to be higher in the locking plate
231 group than in the screw group. Recently, a finite element analysis
232 showed that decreased Böhler's angle increased the possibility of

233 subtalar arthrosis [24], indicating the importance of restoration of
234 Böhler's angle to maintain the function of the subtalar joint. The authors
235 supported the use of a locking plate to maintain reduction and function.
236 Wound complications and infection are common postoperative
237 complications of calcaneal fractures. A study of soft tissue micro-
238 circulation, which is important for adequate wound healing, showed that
239 regions near the STA have higher blood flow than those surrounding the
240 ELA [25]. The rate of postoperative wound complications with STA is 5-
241 6%, significantly less than that with ELA [9,26]. This study's incidence
242 of postoperative complications was similar to that previously reported,
243 with no difference between the screw and locking plate groups.
244 Generally, surgery should be performed after skin blisters have healed
245 and soft tissue swelling has diminished within 1-2 weeks after injury
246 [16]. We delayed surgery via STA for the same duration reported in a
247 previous study [26] until soft tissue swelling decreased, particularly in
248 the locking plate group. Consequently, the time before surgery in the
249 locking plate group was significantly longer than that in the screw group
250 in our study. However, previous studies have reported that plate fixation
251 via STA can be performed with a shorter waiting time until surgery than
252 ELA [26,27]. Furthermore, in our study, soft tissue complications did not
253 increase in the locking plate group. Therefore, locking plate use via STA
254 may not increase soft tissue invasion.

255 This study has several limitations that must be considered. First, this
256 study has a potential selection bias because the selection of fixation
257 methods was not randomized. Second, all radiographs were evaluated by
258 two orthopedic surgeons who were blinded to the patient's radiographic
259 and clinical findings. Nevertheless, interobserver variability and
260 misalignment of the lateral image of the calcaneus on radiographs can
261 cause measurement errors [28]. Further, weight-bearing images were not

262 obtained at follow-up. Third, a previous study showed that six-month
263 radiograph evaluations revealed the collapse of Böhler's angle [17]. The
264 follow-up in this study was ≥ 12 months, but no long-term prognosis was
265 established, and no complications were observed. To overcome these
266 limitations, longer-term randomized controlled studies that include
267 various factors, such as functional outcomes, are needed.

268

269 **5. Conclusion**

270 This study suggests that locking plate fixation via STA is a more
271 effective treatment than screw fixation via STA for DIACF, with less
272 correction loss of Böhler's angle at 12 months postoperatively.

273

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277

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400 **FIGURE LEGENDS**

401 Fig. 1 Correction loss of Böhler's angle in the screw and locking plate
402 groups

403 The mean correction loss of Böhler's angles is $5.6 \pm 5.3^\circ$ in the screw group
404 and $2.6 \pm 2.7^\circ$ in the locking plate group. This difference is statistically
405 significant ($P=0.002$).

406 Data are represented as mean $\pm$ standard deviation. $**P<0.01$.

407

408 Fig. 2

409 Radiograph of lateral view (A) of 39 year-old-male shows joint depression
410 type fracture of left calcaneus sustained after falling from stairs. The
411 fracture was reduced and fixed with a locking plate 6 days after the injury
412 via STA (B). Radiograph at 12-month follow-up shows that reduction is
413 maintained (C). The Böhler's angle in each radiograph is -14, 29, and 28
414 degrees respectively.

415

416 Fig. 3

417 Radiograph of lateral view (A) of 48 year-old-male shows joint depression
418 type fracture of left calcaneus sustained after falling from height. The
419 fracture was reduced and fixed with screws 4 days after the injury via STA
420 (B). Radiograph at 12-month follow-up shows re-displacement (C). The
421 Böhler's angle in each radiograph is 0, 35, and 15 degrees respectively.

422 **Table 1. Baseline and clinical characteristics of patients who**
423 **underwent surgery for intra-articular calcaneus fracture**

424 Data are shown as cases (%) for categorical variables or mean±standard
425 deviation for continuous variables. BMI, body mass index; Time, time
426 elapsed between injury and surgery. Asterisks indicate significant
427 differences. **P<0.01.

428

429 **Table 2. Radiographic evaluation in the two groups**

430 Data are shown as mean±standard deviation.

431 Asterisks indicate significant differences. *P<0.05.

432

433 **Table 3. Clinical outcomes in the study groups**

434 Data are shown as cases (%) for categorical variables or mean±standard
435 deviation for continuous variables. AOFAS, American Orthopaedic Foot
436 and Ankle Society.

437

438 **Table 4. Multivariate logistic regression analysis associated with**
439 **correction loss of Böhler's angle by >10°**

440 CI, confidence interval; BMI, body mass index; Time, time elapsed
441 between injury and surgery. Asterisks indicate significant differences.

442 *P<0.05.

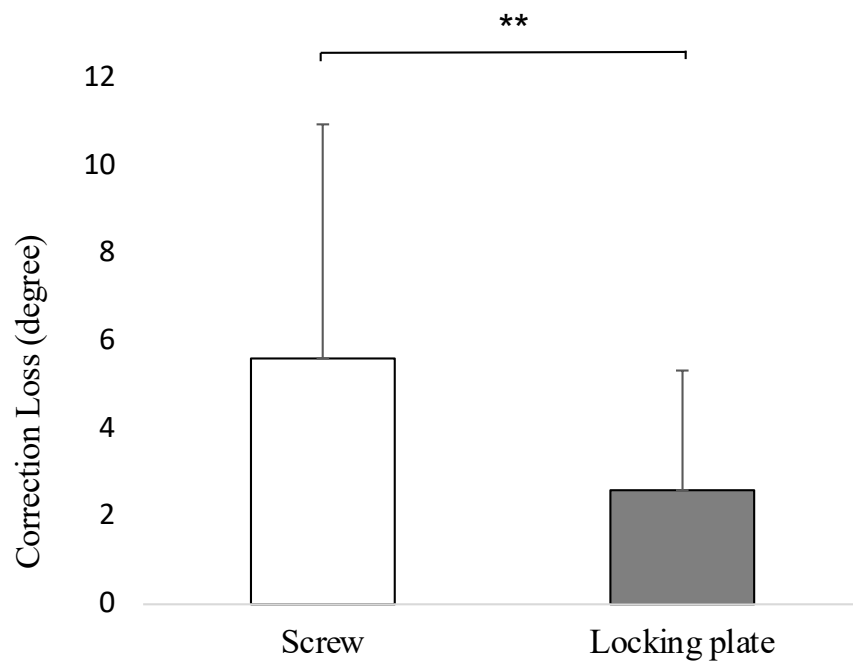


Fig 1

(A)



(B)

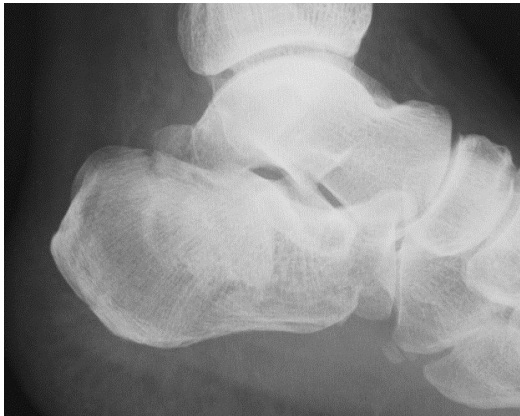


(C)



Fig 2

(A)



(B)



(C)



Fig 3

Variables		Screw (n = 73)	Locking Plate (n = 45)	P-value
Age (years)		53.5±13.7	60.0±17.1	0.19
Sex (cases [%])	Male	51 (69.9)	29 (64.4)	0.39
BMI (kg/m ²)		23.3±3.8	23.0±4.5	0.54
Hypertension (cases [%])		18 (24.7)	11 (24.4)	1.00
Diabetes mellitus (cases [%])		7 (9.6)	4 (8.9)	1.00
Essex–Lopresti type (cases [%])	Tongue	42 (57.5)	30 (66.7)	0.34
	Joint depression	31 (42.5)	15 (33.3)	
Sanders type (cases [%])	Type I or II	31 (42.5)	15 (33.3)	0.09
	Type III or IV	42 (57.5)	30 (66.7)	
Waiting time until the surgery (days)		3.0±3.9	9.9±3.7	< 0.01**

Table 1

Variables		Screw (n=73)	Locking plate (n=45)	P-value
Bohler's angle (°)	Preoperative	10.3±13.5	6.0±10.7	0.01 [*]
	Immediate postoperative	26.9±7.0	26.3±8.9	0.90
	12 months postoperative	21.9±9.3	23.4±9.8	0.58
Intra-articular step-off (mm)	Immediately postoperative	1.5±1.3	1.0±0.7	0.08

Table 2

Variables		Screw (n=73)	Locking plate (n=45)	P-value
Complication (cases [%])	Wound dehiscence	2 (2.7)	2 (4.4)	0.62
	Superficial infection	0 (0.0)	0 (0.0)	
	Deep infection	0 (0.0)	1 (2.2)	0.37
	Sural nerve injury	4 (5.5)	3 (6.7)	0.70
AOFAS score		85.0±9.2	87.2±9.1	0.07

Table 3

Dependent variables	Independent variables	Odds ratio	95% CI	P-value
Correction loss by >10°	Age (years)	1.02	0.97-1.06	0.46
	Sex	0.29	0.05-1.58	0.15
	Time (days)	1.13	0.96-1.34	0.15
	BMI	0.90	0.75-1.07	0.22
	Sanders classification	2.28	0.96-5.42	0.06
	Screw fixation	8.63	1.16-64.4	0.04*

Table 4