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CLINICAL ARTICLE

Does the Level of Syndesmotic Screw Insertion Affect Clinical Outcome after Ankle Fractures with Syndesmotic Instability?

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Objective: Ankle fractures are often combined with syndesmotic instability, requiring reduction and stabilization. However, the optimal level for syndesmotic screw positioning remains unclear. This study aims to evaluate the effect of different syndesmotic screw insertion levels on postoperative clinical outcomes and determine whether an optimal level exists.

Methods: This retrospective study included data from 43 adult patients with acute closed ankle fractures combined with intraoperative evidence of unstable syndesmotic injuries who underwent open reduction internal fixation from January 1, 2017 to March 1, 2018 according to the inclusion and exclusion criteria. All 43 patients were divided into three groups based on the syndesmotic screw placement level: trans-syndesmotic group: screw level of 2–3 cm; inferior-syndesmotic group: screw level <2 cm; and supra-syndesmotic group: screw level >3 cm. Clinical outcomes were measured at the final follow-up, including the American Orthopedic Foot and Ankle Society (AOFAS) ankle-hindfoot score, Olerud–Molander Ankle Score (OMAS), short-form 36-item questionnaire (SF-36), visual analogue scale (VAS) score and restrictions in ankle range of motion (ROM). The relationships between screw placement level and clinical outcomes were analyzed with the Kruskal–Wallis H-test and Spearman correlation analysis.

Results: The median follow-up duration was 15 months (range, 10–22 months). No patients developed fracture non-union or malunion or experienced hardware failure. The outcome scoring systems showed an overall score for the entire group of 94.91 points for the AOFAS ankle-hindfoot score, 83.14 for the OMAS, 96.65 for the SF-36, 1.77 for the VAS, 9.14° for the restrictions in dorsiflexion, and 1.30° for the restrictions in plantarflexion. There were no significant differences among three groups in clinical outcomes ($P > 0.05$). Neither the AOFAS score nor OMAS had significant correlations with screw insertion level ($P = 0.825$ and $P = 0.585$, respectively). No postoperative arthritis or widening of the tibiofibular space was observed at the final follow-up.

Conclusion: Different syndesmotic screw placement levels appear not to affect the clinical outcomes of ankle fractures with syndesmotic instability. No optimal level was observed in this study. Our findings suggest other clinically acceptable options apart from syndesmotic screw placement 2–3 cm above the ankle.

Key words: Ankle fractures; Correlation of data; Distal tibiofibular syndesmosis joint; Syndesmotic screw

Introduction

Ankle fractures are one of the most common orthopedic injuries. Approximately, 20% of surgically treated ankle fractures are combined with syndesmotic instability.[1,2] According to the mechanism of the injury, a syndesmotic disruption should be considered in Danis–Weber C-type fractures.[3] However, such injuries were also frequently seen in Danis–Weber B-type fractures.[4,5] Failure to detect and repair syndesmosis injuries early may result in poor clinical outcomes and complications affecting ankle function, such as

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long-term residual pain, traumatic arthritis, and ankle impingement syndromes.[6] Therefore, aggressive treatment is important when facing syndesmotic instability.

Most authors recommend surgical placement of a trans-fixation screw after anatomical reduction of the syndesmosis if a disruption is diagnosed to avoid complications.[7] The main aims of treatment for dislocation of the distal tibiofibular syndesmosis are to restore the original anatomy and normal function and to recreate the stability of the ankle joint.[4] The syndesmosis is traditionally fixed with a metallic screw, which is a method that has been used for decades and demonstrates good to excellent outcomes. Current research suggests that syndesmotic screws should be placed at a height of approximately 2 cm above the ankle because the Arbeitsgemeinschaft für Osteosynthesefragen (AO) internal fixation manual suggests that syndesmotic screws should be planted 2–3 cm above the articular surface.[8] However, the syndesmotic screw often cannot be inserted at this height if there is a fracture line or plate in this area. Thus, other appropriate levels are needed. McBryde *et al.*[9] conducted a biomechanical analysis of 17 cadaver legs undergoing knee disarticulation and found less syndesmotic widening with syndesmotic screws inserted 2 cm above the tibiotalar joint than with no screw fixation or screws at 5 cm. In another finite-element analysis, based on computed tomography (CT) data of the ankle joint and a 3-dimensional finite-element model, Verim *et al.*[10] evaluated the stress of syndesmotic screws and syndesmotic widening under load and concluded that fixation at a level of 30 to 40 mm above the ankle joint had advantages in terms of screw stress compared to other levels. Miller *et al.*[11] conducted a cadaver study in which syndesmosis was fixed with a screw and a suture implant at a height of 2 and 5 cm above the tibiotalar joint respectively and the authors found that the 5 cm group had significantly better fixation strength than the 2 cm group. In a retrospective study, the authors evaluated the technical aspects of placing syndesmotic screws in a variety of anatomic breakage locations and observed that the height of syndesmotic screw placement was not significantly associated with the location of screw breakage.[12] Schepers *et al.*[13] evaluated the effects of different levels of screw insertion and other technical aspects of syndesmotic screw placement on clinical outcomes following acute syndesmosis injury, finding no significant difference in clinical outcomes between screw placement levels of 0–20.99 mm and 21–40.99 mm above the ankle. Hence, although syndesmotic screw fixation has been discussed in an abundance of literature, the optimal level of screw insertion has not yet been clearly defined.

The purposes of this study were as follows: (i) to evaluate the effect of different levels of syndesmotic screw insertion on the postoperative clinical outcomes of ankle fractures with syndesmotic instability; and (ii) to test correlations between levels of syndesmotic screw placement and clinical outcomes to detect whether an optimal level of syndesmotic screw insertion exists. We hypothesized that the level of syndesmotic screw insertion would not significantly affect the clinical outcomes and that no optimal level would be observed.

Patients and Methods

Inclusion and Exclusion Criteria

This retrospective study was approved by the institutional review board (number IRB-2021-116) and was performed in compliance with the Declaration of Helsinki. The review board waived the requirement for informed consent because of the retrospective nature of the study and no informed consent was obtained. We included patients with acute closed ankle fractures treated operatively using open reduction and internal fixation (ORIF) from January 1, 2017 to March 1, 2018 based on the inclusion and exclusion criteria. The inclusion criteria were as follows: (i) treatment for acute closed ankle fractures accompanied by syndesmosis injury, which was judged using the Cotton test during the operation; and (ii) placement of only metallic syndesmotic screws. The exclusion criteria were as follows: (i) pathologic fractures; (ii) Maisonneuve fractures; (iii) medical illness or mental disorders affecting the follow-up examination; (iv) incomplete medical record data or radiographic data including pre- and postoperative imaging; (v) no radiographic anatomical reduction of the distal tibiofibular syndesmosis on postoperative CT scans (to eliminate the effect of syndesmotic malreduction on clinical outcomes); and (vi) loss to follow-up. A total of 272 consecutive patients were reviewed, and ultimately, 43 patients were eligible for inclusion in this study.

General Patient Data

We collected the sex, age, and medical comorbidities (diabetes mellitus, hypertension, and smoking habits) of all patients. Moreover, we recorded the injury side, fracture classification, level of screw placement and number of syndesmotic screws. The time from injury to surgery, timing of screw removal and postoperative follow-up time were collected as well. The injury was classified using the Lauge–Hansen (LH) and Danis–Weber classification systems.[14,15] Fracture patterns were determined according to the Danis–Weber classification to be Weber A, Weber B and Weber C fractures and according to the LH classification as supination-external rotation (SER), supination-adduction (SA), pronation-external rotation (PER), and pronation-abduction (PA).

Radiographic Evaluation

The radiographic images of every patient were reviewed, including the mortise and lateral views as well as CT scans of the ankle with 3-dimensional (3D) reconstruction before and after surgery. Preoperative imaging was used to classify the injury pattern, and postoperative radiography was used to measure the level of syndesmotic screw placement and estimate the quality of the syndesmosis reduction and assess fracture union, the presence of arthritis and evidence of hardware failure and screw loosening or breakage at the follow-up visit.

Surgical Techniques

Anesthesia and Positioning

General or combined spinal-epidural-sciatic nerve block anesthesia was given to the patients. The patients were placed in the lateral decubitus position. The lateral malleolar fracture was reduced first, followed by the posterior. Next, the patients were shifted to the supine position to reduce the medial malleolar fracture and finally the distal tibiofibular syndesmosis.

Approach and Reduction

A lateral approach to the lateral malleolus was adopted. After exposing the fractured end, the fibular fracture was fixed with a locking plate. Fixation of the posterior malleolar fracture was mandatory if the posterior fragment involved 25% of the joint surface. In the cases of medial malleolar fractures, fixation was carried out through a standard anteromedial incision using cannulated screws.

After tri-malleolar fixation of the bony anatomy, the Cotton test was conducted during the operation to evaluate the stability of the syndesmosis. To perform this test, a bone hook was placed on the fibula and a distraction force was applied in an attempt to separate the fibula from the tibia. The syndesmosis was deemed unstable if the tibiofibular clear space was 5 mm or greater.[2,16] If the syndesmosis was deemed unstable, a syndesmotic cortical screw was inserted at a 20-to-30-degree oblique angle from the posterolateral fibula to the anteromedial tibia, with the syndesmosis joint held by a large pointed reduction clamp. We chose one or two 3.5 mm diameter syndesmotic screws involving three cortices. Two syndesmotic screws were used in select cases if the surgeon considered it necessary to strengthen the stability of the construct such as in patients with a higher body mass index. There were no additional surgical steps during the intraoperative period.

Postoperative Management

All patients received standardized postoperative management that included non-weight-bearing until the syndesmotic screw was removed and then partial weight-bearing with progression to full weight-bearing. Patients were required to visit the hospital 8–12 weeks after the operation for removal of the syndesmotic screws. All patients were regularly followed up at 6 weeks, 12 weeks, 6 months, and 10 months and until the last follow-up after surgery at outpatient clinics.

Measurement of the Screw Placement Level and Patient Grouping

The level of screw placement was defined as the vertical distance between the center core of the syndesmotic screw and the distal tibial articular surface (Fig. 1). We chose the lower screw for analysis if two syndesmotic screws were implanted. As part of a retrospective study design, all 43 patients in the study were divided into three groups based on the level of syndesmotic screw placement and the AO internal fixation manual: the trans-syndesmotic group, with a screw placement level of 2–3 cm; the inferior-syndesmotic group, with a screw placement level <2 cm; and the supra-syndesmotic group, with a screw placement level >3 cm.

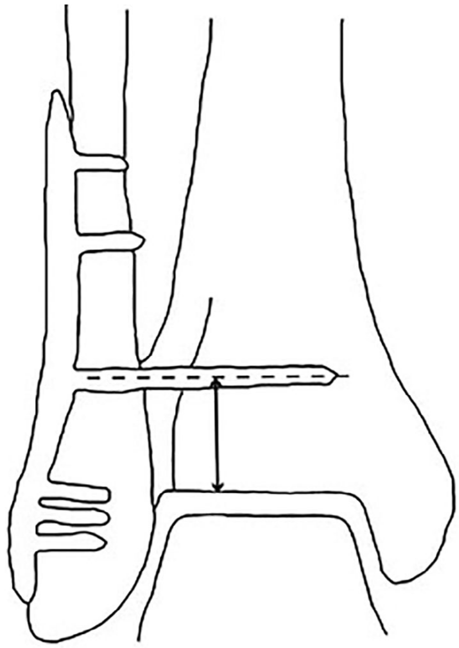

Fig. 1 A sketch of a syndesmosis injury associated with ankle fractures treated with syndesmotic screw fixation. The double arrow indicates the level of screw placement

Clinical Outcomes Assessments

We evaluated the clinical outcomes of all included patients using four validated questionnaires and based on the restriction in range of motion (ROM) of the ankle at the final follow-up. The questionnaires consisted of the American Orthopedic Foot and Ankle Society (AOFAS) ankle-hindfoot score, Olerud–Molander Ankle Score (OMAS), short-form 36-item questionnaire (SF-36) and a visual analogue scale (VAS).

American Orthopedic Foot and Ankle Society Ankle-Hindfoot Score

The AOFAS ankle-hindfoot score is a clinical rating system associated patients-reported outcomes with clinician-measured outcomes to make a 100-point scale that comprises nine questions in approximately three categories: pain (one question; 40 points), function (seven questions; 50 points) and alignment (one question; 10 points). Through this questionnaire, the condition of the ankle could be described in a more comprehensive and simple way.[17]

Olerud–Molander Ankle Score

OMAS is a self-administered patient questionnaire developed by Olerud and Molander.[18] The scoring ranges from 0 (completely impaired) to 100 (totally unimpaired). This scoring system was proven to be effective and scientific and was considered to give a good estimation of the clinical results after ankle fractures.

Visual Analogue Scale

The VAS is a scale to help describe the degree of pain using a visual method. This scale ranges from "no pain" to "pain as bad as it could be" with no pain indicated as 0 points, mild pain indicated as 1–3 points, moderate pain indicated as 4–7 points and severe pain indicated as 8–10 points.[19]

Short-Form 36-Item Questionnaire

SF-36 is a short form health survey published by Ware and Sherbourne in 1992 and consists of 36 items included in long-form measures.[20] A higher SF-36 score indicates a better quality of life. The SF-36 was shown to be highly likely to precisely detect socially and medically relevant differences in health conditions and changes in health over time. Research assistants were allowed to help patients who were unable to complete the SF-36 without help, especially for some aged patients. Moreover, we used the Chinese version of the SF-36 and it has been proven to be reliable and valid with the elderly.

Restriction in Range of Motion

The restriction in ROM was obtained by comparing the treated ankle to the ankle with a normal ROM, including in dorsiflexion and plantarflexion. The difference between these angles was defined as the restriction in ROM. The ROM of the ankle was assessed in the sitting position using a standard goniometric method.

Statistical Analysis

Statistical analysis was conducted with SPSS 21.0 (SPSS, Chicago, IL, USA). Normality was assessed with the Shapiro–Wilk test. Normally distributed continuous variables are presented as the mean with standard deviation and were analyzed using one-way analysis of variance (ANOVA). Continuous variables not following a normal distribution are presented as the median with interquartile range (IQR) and were analyzed using the Kruskal–Wallis H-test. The Levene test was used to evaluate variance homogeneity, and multiple comparisons were conducted using Bonferroni's multiple comparison test. Categorical variables are expressed as frequencies and percentages and were analyzed using the chi-squared test. Correlation analyses of the AOFAS ankle-hindfoot score and OMAS with the level of screw insertion were conducted using the Spearman correlation test. A significance level of $P < 0.05$ was employed.

Results

General Outcomes

Forty-three patients were included in this study. The mean age of all patients was 36.8 ± 14.5 years (range, 15–67 years)

TABLE 1 Baseline characteristics of the included patients

	Trans-syndesmotic (n = 18)	Inferior-syndesmotic (n = 14)	Supra-syndesmotic (n = 11)	Statistic value	*P* value
Age (year)[†]	32.0 ± 12.0	34.6 ± 13.1	47.4 ± 15.6[§]	4.804[¶]	0.013*
Male, *n* (%)[‡]	13 (72.2%)	9 (64.3%)	6 (54.5%)	0.946[‖]	0.623
Diabetes mellitus, *n* (%)[‡]	2 (11.1%)	0 (0.0%)	3 (27.3%)	4.467[‖]	0.107
Hypertension, *n* (%)[‡]	3 (16.7%)	3 (21.4%)	3 (27.3%)	0.467[‖]	0.792
Smoking, *n* (%)[‡]	7 (38.9%)	1 (7.1%)	5 (45.5%)	5.386[‖]	0.068
Danis–Weber class, *n* (%)[‡]					
Weber B	9 (50.0%)	7 (50.0%)	8 (72.7%)	1.715[‖]	0.424
Weber C	9 (50.0%)	7 (50.0%)	3 (27.3%)		
Lauge-Hansen class, *n* (%)[‡]					
SER	9 (50.0%)	7 (50.0%)	8 (72.7%)	2.956[‖]	0.565
PER	8 (44.4%)	7 (50.0%)	3 (27.3%)		
PA	1 (5.6%)	0 (0.0%)	0 (0.0%)		
Number of screws, *n* (%)[‡]					
1 screw	18 (100.0%)	12 (85.7%)	11 (100.0%)	4.345[‖]	0.114
2 screws	0 (0.0%)	2 (14.3%)	0 (0.0%)		
Timing of screw removal (w)[†]	11.9 ± 2.3	10.3 ± 2.1	11.9 ± 1.6	2.857[¶]	0.069
Side of injury, left, *n* (%)[‡]	7 (38.9%)	8 (57.1%)	4 (36.4%)	1.431[‖]	0.489

Notes: We used mean ± standard deviation if the continuous variables were normally distributed and median (interquartile range, or IQR) if the continuous variables were not normally distributed. The categorical variables were expressed as frequencies and percentages. Because there was no patient suffering from Weber A or supination-adduction (SA) injury in this study, the Weber A and SA injuries were not shown in the table. One-way analyses of variance[†] was used for continuous variables and the chi-square test[‡] was used for categorical variables. §, statistically significant difference compared with trans-syndesmotic group using Bonferroni's multiple comparison test ($P = 0.014$). The statistic value included *F* value[¶] and chi-square value[‖]; Abbreviations: PA, pronation-abduction; PER, pronation-external rotation; SER, supination-external rotation; * $p < 0.05$.

with 28 males (65.1%) and 15 females (34.9%) and all patients had unilateral ankle fractures with 19 (44.2%) left ankle fractures and 24 (55.8%) right ankle fractures (Table 1). In the present study, 18 (41.8%) patients were assigned to the trans-syndesmotic group (Fig. 2), 14 (32.6%) to the inferior-syndesmotic group (Fig. 3) and 11 (25.6%) to the supra-syndesmotic group (Fig. 4). Their baseline characteristics are shown in Table 1. There was no significant difference in terms of sex, diabetes mellitus, hypertension, or smoking in the three groups, but age differed between the trans-syndesmotic and supra-syndesmotic groups (32.0 ± 12.0 years *vs.* 47.4 ± 15.6 years, $P < 0.05$).

The median level of screw insertion was 2.4 cm, with a range from 1.2 to 3.9 cm. Using the Danis–Weber classification, all included patients were classified as having Weber B or Weber C fractures, with no patients experiencing a Weber A pattern. Regarding the LH classification, most fractures were classified as SER injuries (55.8%). Moreover, no SA injuries were present in the 43 patients. (Table 1).

In this study, the fractures of all patients were fixed with one 3.5 mm diameter metallic syndesmotic screw involving three cortices except for two patients who underwent fixation with two screws. The average time from injury to surgery was 6.3 ± 2.7 days. CT scans were obtained before and after surgery for all patients (Fig. 5). None of the patients in this study developed fracture nonunion or malunion. Syndesmotic screw removal was performed in all

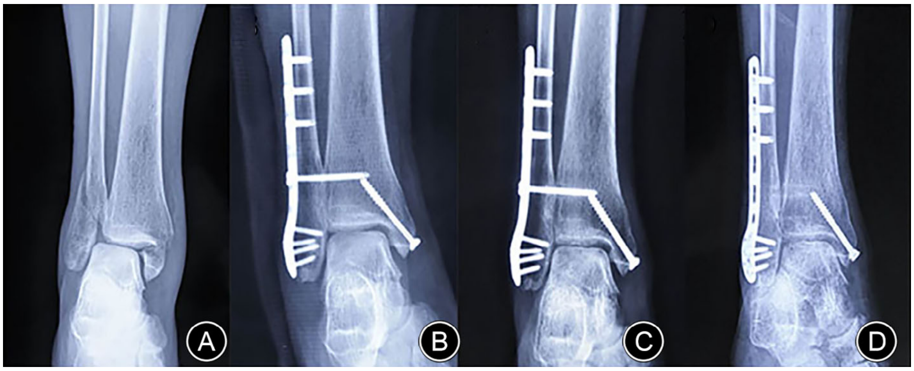

Fig. 2 Radiographic images of a patient with the syndesmotic screw placed at 2.4 cm (2–3 cm). (A) Radiographic image taken before surgery. (B) Radiographic image taken after surgery. (C) Radiographic image taken before the removal of syndesmotic screw. (D) Radiographic image taken after the removal of syndesmotic screw

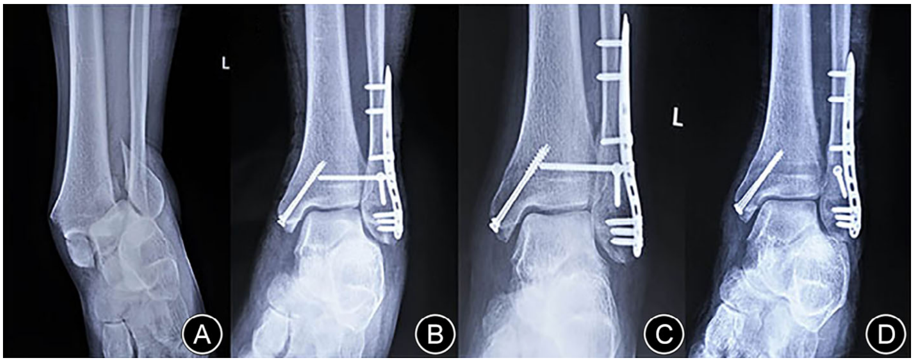

Fig. 3 Radiographic images of a patient with the syndesmotic screw placed at the level of 1.6 cm (<2 cm). (A) Radiographic image taken before surgery. (B) Radiographic image taken after surgery. (C) Radiographic image taken before the removal of syndesmotic screw. (D) Radiographic image taken after the removal of syndesmotic screw

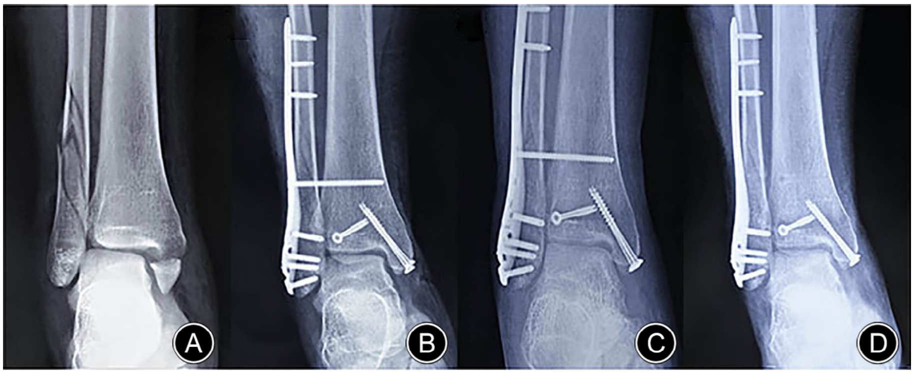

Fig. 4 Radiographic images of a patient with the syndesmotic screw placed at the level of at 3.6 cm (>3 cm). (A) Radiographic image taken before surgery. (B) Radiographic image taken after surgery. (C) Radiographic image taken before the removal of syndesmotic screw. (D) Radiographic image taken after the removal of syndesmotic screw

patients and there was no significant difference the timing of screw removal among the three groups (Table 1).

Implant Evaluation

There was no evidence of hardware failure in any of the included patients. Two cases of syndesmotic screw breakage were observed because of the poor compliance of the two patients who started weight-bearing prior to screw removal. The levels of the broken screws were 1.7 and 2.4 cm. These two patients had AOFAS ankle-hindfoot scores of 100 and 100 and OMAS scores of 90 and 85, respectively.

Follow-Up

All 43 patients were followed up regularly for 10–22 months during the study period, with a median time of 15 months. At the last follow-up visit, clinical outcome data were collected including the four questionnaire scores and degrees of ROM restriction. Postoperative imaging data were obtained in all patients at the final follow-up visit.

Functional Outcomes

At the final follow-up, the AOFAS ankle-hindfoot score, the OMAS, the SF-36 score and the VAS score were 100.00 (IQR, 90.00 to 100.00), 85.28 ± 11.56, 95.00 (IQR, 94.00 to 100.00) and 1.00 (IQR, 0.00 to 3.00) in the trans-syndesmotic group; 98.00 (IQR, 88.00 to 100.00), 82.50 (IQR, 70.00 to 90.00), 95.79 ± 4.81 and 1.50 (IQR, 0.00 to 4.25) in the inferior-syndesmotic group; and 98.00 (IQR, 88.00 to 100.00), 82.73 ± 10.57, 97.36 ± 3.85 and 1.00 (IQR, 0.00 to 3.00) in the supra-syndesmotic group, respectively. No significant difference was observed among the three groups ($P > 0.05$). The relevant results are shown in Table 2.

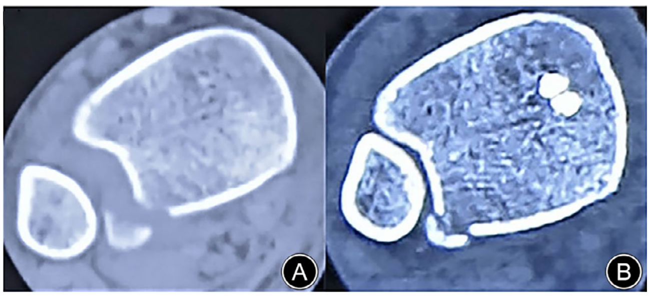

Fig. 5 The Figure shows the axial computed tomography (CT) scans of a 37-year-old male who suffered a Weber C fracture. (A) The axial CT scan before surgery. (B) The axial CT scan after surgery

Restrictions in Range of Motion

There were 10 (23.3%) patients with restricted plantarflexion and 37 (86.0%) patients with restricted dorsiflexion. In the trans-syndesmotic group, at the final follow-up, the mean restriction in ROM for dorsiflexion was 9.83 ± 7.74° and the median for plantarflexion was 0.00° (IQR, 0.00° to 1.00°). In the inferior-syndesmotic group, the median restrictions in dorsiflexion and plantarflexion were 7.50° (IQR, 5.00° to 15.00°) and 0.00° (IQR, 0.00° to 4.25°) at the final follow-up, respectively. In the supra-syndesmotic group, the corresponding values were 7.45 ± 4.55° and 0.00° (IQR, 0.00° to 0.00°) at the final follow-up. No significant differences were found among the three groups based on the Kruskal–Wallis H-test ($P > 0.05$). The relevant results are shown in Table 2.

Correlation Analyses

The results of the correlation analyses are shown in Fig. 6. No significant correlation was noted between the AOFAS ankle-hindfoot score and level of screw insertion ($P = 0.825$), nor was there a significant correlation between the OMAS and level of screw insertion ($P = 0.585$).

Complications

Postoperative radiographic images showed that no patient developed postoperative arthritis or widening of the tibiofibular space at the final follow-up visit. None of the patients in this study developed deep infections, compartment syndrome or peroneal tendonitis after surgery.

TABLE 2 Questionnaires scores and restriction of ROM in three groups

	Trans-syndesmotic ($n = 18$)	Inferior-syndesmotic ($n = 14$)	Supra-syndesmotic ($n = 11$)	H value	P value
AOFAS[†]	100.00 (90.00–100.00)	98.00 (88.00–100.00)	98.00 (88.00–100.00)	1.329	0.514
OMAS[†]	85.28 ± 11.56	82.50 (70.00–90.00)	82.73 ± 10.57	1.356	0.508
SF-36 score[†]	95.00 (94.00–100.00)	95.79 ± 4.81	97.36 ± 3.85	0.351	0.839
VAS score[†]	1.00 (0.00–3.00)	1.50 (0.00–4.25)	1.00 (0.00–3.00)	0.450	0.798
Restriction of ROM (°) [†]					
RDF	9.83 ± 7.74	7.50 (5.00–15.00)	7.45 ± 4.55	1.244	0.537
RPF	0.00 (0.00–1.00)	0.00 (0.00–4.25)	0.00 (0.00–0.00)	0.618	0.734

Notes: We used mean ± standard deviation if the continuous variables were normally distributed and median (interquartile range, or IQR) if the continuous variables were not normally distributed. Kruskal–Wallis *H*-test[†] was used for continuous variables; Abbreviations: AOFAS, American Orthopedic Foot Ankle Society hindfoot score; OMAS, Olerud-Molander Ankle Score; RDF, restriction of dorsiflexion; ROM, range of motion; RPF, restriction of plantarflexion; SF-36, short-form 36-item questionnaire; VAS, visual analogue scale.

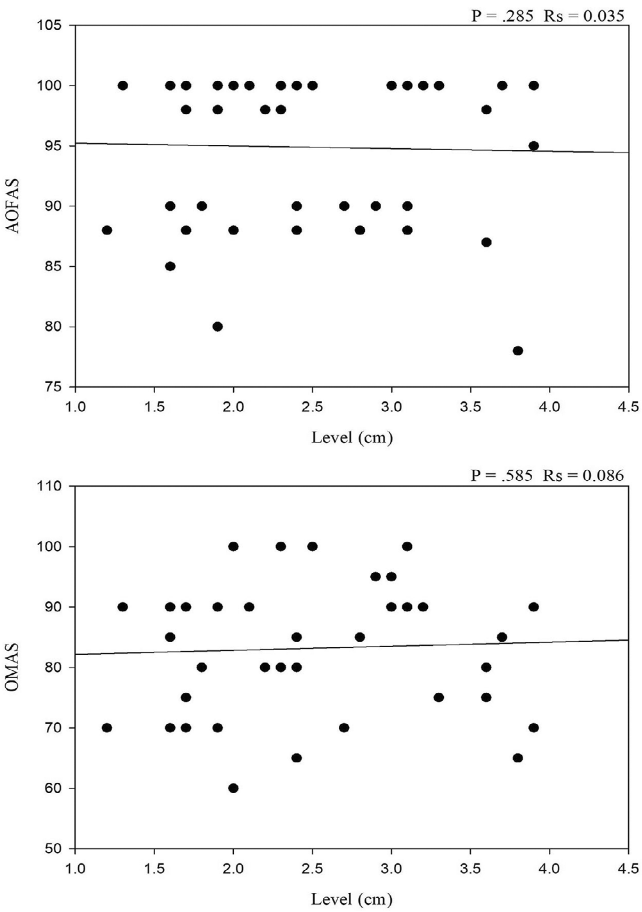

Fig. 6 Correlation analyses between the AOFAS ankle-hindfoot score and the level of screw insertion and between OMAS and the level of screw insertion. Data was analyzed using the Spearman correlation test. Rs denotes the correlation coefficient. No significant correlation was noted between the AOFAS ankle-hindfoot score and the level of screw insertion ($P = 0.825$ and $Rs = 0.035$), nor was there a significant correlation between the OMAS and the level ($P = 0.585$ and $Rs = 0.086$)

Discussion

The present study compared the postoperative clinical outcomes of different levels of syndesmotic screw placement following ankle fractures with syndesmotic instability. Our findings revealed no significant differences in questionnaire scores and degrees of ROM restriction among different levels of screw positions. Furthermore, we evaluated the correlations between clinical outcomes and the levels of screw insertion. Similarly, we found no statistically significant correlations. Herein, we discuss some interesting observations.

Level of Syndesmotic Screw Placement

Similar observations have been reported by other investigators. Kukreti *et al.*[21] found no significant difference regarding radiological and clinical outcomes between groups with screws placed at 2 cm or 2–5 cm above the ankle. In another clinical study, researchers evaluated the difference in clinical outcomes among different levels of syndesmotic screw position and found no significant difference between screws placed from 0 to 20.99 mm and those placed from 21 to 40.99 mm above the ankle.[13] However, a significantly worse outcome was also found among patients with screws placed at 41–60 mm in their study. Cornu *et al.*[4] recently reviewed the relevant literature and concluded that the syndesmotic screw should be inserted 1.5–3 cm above the ankle and never more than 4 cm above the ankle. Thus, the current consensus seems to be that when the screw is inserted <4 cm above the ankle, the level of the screw does not affect the clinical outcomes. However, there seems to be no agreement on the "lower limit" of screw height. In the present study, we obtained similar results to the previous studies. No significant differences in clinical outcomes were observed when the syndesmotic screws were placed <2, 2–3 and >3 cm above the ankle joint. The overall clinical outcomes were satisfactory. This could be because patients with syndesmosis malreduction were excluded from the current study, and no screws were inserted above 4 cm (range, 1.2–3.9 cm). Based on some other studies, the fibular incisura provides intrinsic bony security for syndesmosis stabilization, and maintaining the normal anatomical position of the fibula in the fibular notch is essential for achieving stability of the syndesmosis.[22,23] Thus, we have reason to speculate that no matter the level of screw insertion, the clinical outcome would be satisfactory if the syndesmotic screw is not inserted higher than the height of the fibular incisura. However, this remains an issue that needs further study.

Correlation Analyses

We performed Spearman correlation analyses to evaluate the association of the AOFAS ankle-hindfoot score and OMAS with the level of screw insertion, and we did not observe any significant correlations between the questionnaire scores and levels of screw positioning. A similar study was performed by *Schepers et al.*, who obtained different results through multivariable linear regression analysis.[13] The AOFAS ankle-hindfoot score and VAS score decreased with a higher placement of the syndesmotic screw. This was probably because their research had a large sample size, and they found that the VAS score significantly decreased with a screw placement level higher than 41 mm. However, no patients in the present study had screws implanted higher than 41 mm, and we had a relatively small sample size. Our findings further support the view that different levels of screw placement do not appear to influence clinical outcomes. Therefore, it seems that there is no optimal level of screw insertion from the perspective of clinical outcomes. There was only one patient with an OMAS of 60 points, although the overall AOFAS and OMAS scores were relatively desirable. We noted that the AOFAS ankle-hindfoot score of this patient was 88 points, but the VAS score was 3, indicating that he might have subjectively painful symptoms. This probably explains the comparatively low OMAS score for this patient.

Restrictions in Range of Motion

In the present study, we also observed that there were 10 patients with restricted plantarflexion and 37 patients with restricted dorsiflexion. An explanation may be that in our clinical practice, the ankle joint is placed in plantarflexion during insertion of the syndesmotic screw. According to a previous classic study, plantarflexion of the ankle during syndesmotic screw placement leads to a decrease in dorsiflexion capacity.[24] However, other authors argued that there was no need to keep the ankle in maximal dorsiflexion when inserting the screw because they observed no significant relationship between the change in maximal dorsiflexion and ankle position.[25] van Zuuren *et al.*[2] concluded that the most important aspect of syndesmotic fixation was the anatomical reduction of the syndesmosis and the ankle's position during fixation was ultimately not important. Therefore, further research is required to examine this question.

Limitations and Advantages

There are some limitations in the present study. First, this study is retrospective, and thus carries the biases inherent to this type of research. Second, in this study, we only analyzed whether the level of syndesmotic screw placement affected clinical outcomes after ankle fractures with syndesmotic instability and might have ignored the effect of other surgery-related factors on outcomes, such as the number of screws, number of cortices engaged, and diameter of the screw. However, we controlled for these factors at baseline, thereby decreasing their impact on the results. Third, the sample size was small, which may lead to less convincing results. Fourth, the follow-up period was short, and long-term follow-up is needed to investigate the long-term clinical outcomes.

This study also has some advantages. First, we conducted correlation analyses between the clinical outcomes and levels of screw positioning to detect possible associations and to determine if an optimal level of screw placement existed. Second, we used restrictions in ROM and four validated questionnaires to evaluate the clinical outcomes. These questionnaires covered the subjective outcomes of patients and clinician-measured outcomes to assess patient health and quality of life, allowing for a more comprehensive and integrated assessment of patient clinical outcomes.

Conclusion

In conclusion, different syndesmotic screw placement levels do not appear to have a significant effect on clinical outcomes following ankle fractures combined with syndesmotic instability. No correlation was found between the levels of syndesmotic screw placement and clinical outcomes. Therefore, there does not appear to be an optimal level of syndesmotic screw insertion. The AO internal fixation manual recommends that syndesmotic screws should be placed 2 –3 cm above the ankle joint, but there are some specific clinical situations in which the syndesmotic screws cannot be inserted at this height, such as in the presence of fracture lines or plates in the area. Our results indicate that the clinical outcomes do not differ according to whether screws are placed at levels of 2–3, >3 or <2 cm. Therefore, our findings may provide some other options for orthopedic surgeons when a placement level of 2–3 cm is not suitable.

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Author Contributions

All authors had full access to the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Conceptualization, Jia-Guo Zhao, Xian-Tie Zeng; Methodology, Xian-Tie Zeng, Ying-Hua Wu, and Jia Wang; Investigation, Jin-Kun Li, Yi Yu, and Jia Wang; Formal Analysis, Jia-Guo Zhao, Ying-Hua Wu; Resources, Jia-Guo Zhao, Xian-Tie Zeng; Writing - Original Draft, Jin-Kun Li, Yi Yu; Writing - Review & Editing, Jia-Guo Zhao, Xian-Tie Zeng; Visualization, Jin-Kun Li, Yi Yu; Supervision, Jia-Guo Zhao, Xian-Tie Zeng. Jin-Kun Li and Yi Yu contributed equally to this work as first authors. Jia-Guo Zhao and Xian-Tie Zeng contributed equally to this work as corresponding authors.

References

1. Haller JM, Githens M, Rothberg D, Higgins T, Barei D, Nork S. Syndesmosis and syndesmotic equivalent injuries in tibial plafond fractures. J Orthop Trauma. 2019;33(3):e74–e8.
2. van Zuuren WJ, Schepers T, Beumer A, Sierevelt I, van Noort A, van den Bekerom MPJ. Acute syndesmotic instability in ankle fractures: a review. Foot Ankle Surg. 2017;23(3):135–41.
3. Ogilvie-Harris DJ, Reed SC, Hedman TP. Disruption of the ankle syndesmosis: biomechanical study of the ligamentous restraints. Art Ther. 1994;10(5):558–60.
4. Cornu O, Manon J, Tribak K, Putineanu D. Traumatic injuries of the distal tibiofibular syndesmosis. Orthop Traumatol Surg Res. 2021;107(1S):102778.
5. Huber T, Schmoelz W, Bölderl A. Motion of the fibula relative to the tibia and its alterations with syndesmosis screws: a cadaver study. Foot Ankle Surg. 2012; 18(3):203–9.
6. Corte-Real N, Caetano J. Ankle and syndesmosis instability: consensus and controversies. EFORT Open Rev. 2021;6(6):420–31.
7. Wake J, Martin KD. Syndesmosis injury from diagnosis to repair: physical examination, diagnosis, and arthroscopic-assisted reduction. J Am Acad Orthop Surg. 2020;28(13):517–27.
8. Yuce A, Misir A, Yerli M, et al. The effect of syndesmotic screw level on postoperative syndesmosis Malreduction. J Foot Ankle Surg. 2022;61(3):482–5.
9. McBryde A, Chiasson B, Wilhelm A, Donovan F, Ray T, Bacilla P. Syndesmotic screw placement: a biomechanical analysis. Foot Ankle Int. 1997;18(5):262–6.
10. Verim O, Er MS, Altinel L, Tasgetiren S. Biomechanical evaluation of syndesmotic screw position: a finite-element analysis. J Orthop Trauma. 2014; 28(4):210–5.
11. Miller RS, Weinhold PS, Dahners LE. Comparison of tricortical screw fixation versus a modified suture construct for fixation of ankle syndesmosis injury: a biomechanical study. J Orthop Trauma. 1999;13(1):39–42.
12. Vander Maten JW, McCracken M, Liu J, Ebraheim NA. Syndesmosis screw breakage: an analysis of multiple breakage locations. J Orthop. 2022;29:38–43.

13. Schepers T, van der Linden H, van Lieshout EM, Niesten DD, van der Elst M. Technical aspects of the syndesmotic screw and their effect on functional outcome following acute distal tibiofibular syndesmosis injury. Injury. 2014;45(4):775–9.
14. Michelson J, Solocoff D, Waldman B, Kendell K, Ahn U. Ankle fractures. The Lauge-Hansen classification revisited. Clin Orthop Relat Res. 1997;345:198–205.
15. Müller ME. Injuries of the upper ankle joint. Aktuelle Probl Chir. 1972;3: 1–241.
16. Chun DI, Kim J, Kim YS, et al. Relationship between fracture morphology of lateral malleolus and syndesmotic stability after supination-external rotation type ankle fractures. Injury. 2019;50(7):1382–7.
17. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. Foot Ankle Int. 1994;15(7):349–53.
18. Olerud C, Molander H. A scoring scale for symptom evaluation after ankle fracture. Arch Orthop Trauma Surg (1978). 1984;103(3):190–4.
19. Huskisson EC. Measurement of pain. Lancet. 1974;2(7889):1127–31.
20. Ware JE Jr, Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care. 1992;30(6):473–83.
21. Kukreti S, Faraj A, Miles JN. Does position of syndesmotic screw affect functional and radiological outcome in ankle fractures? Injury. 2005;36(9): 1121–4.
22. Fojtík P, Kostlivý K, Bartoníček J, Naňka O. The fibular notch: an anatomical study. Surg Radiol Anat. 2020;42(10):1161–6.
23. Huysse W, Burssens A, Peiffer M, et al. Morphometric analysis of the incisura fibularis in patients with unstable high ankle sprains. Skelet Radiol. 2021;50(6):1141–50.
24. Olerud C. The effect of the syndesmotic screw on the extension capacity of the ankle joint. Arch Orthop Trauma Surg (1978). 1985;104(5): 299–302.
25. Pallis MP, Pressman DN, Heida K, Nicholson T, Ishikawa S. Effect of ankle position on Tibiotalar motion with screw fixation of the distal tibiofibular syndesmosis in a fracture model. Foot Ankle Int. 2018;39(6):746–50.