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CLINICAL ARTICLE

Should Diastatic Syndesmosis be Stabilized in Advanced Pronation-External Rotation Ankle Injuries? A Retrospective Cohort Comparison

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Abstract

Objective: With or without screw stabilization for diastatic syndesmosis in advanced pronation-external rotation (PE) ankle injuries has not yet been well-determined. Both techniques were retrospectively compared to investigate the superiority of either of the two.

Methods: A retrospective cohort study was carried out. From January 1, 2008, to December 31, 2017, 81 consecutive adult patients (average, 42 years; range, 18–78 years; 44 men and 37 women) with advanced PE ankle injuries (stage 3 or 4 PE type) were treated. After malleolar fractures were internally stabilized with screws and plates, the syndesmotic stability was rechecked by external rotation and hook tests. The necessity of cortical screw insertion to stabilize diastatic syndesmosis was decided by the individual orthopaedic surgeon. Postoperatively, a short leg splint was used for 6 weeks. The syndesmotic screw was removed based on the surgeon's policy. The removal of internal fixation for malleolar fractures was required after 1 year. The outcomes of both approaches were compared clinically, and ankle function was compared using the American Orthopaedic Foot and Ankle Society (AOFAS) score. For statistical comparison, the chi-square test was used for categorical data and the Mann–Whitney U test was used for numerical data.

Results: Seventy-one patients (average, 40 years; range, 18–78 years; 40 men and 31 women) were followed for at least 1 year (87.7%; average, 2 years; range, 1–11 years). Group 1 (with syndesmotic stabilization) had 22 patients and Group 2 (without syndesmotic stabilization), 49 patients. The union rate in Group 1 patients was 100% (22/22), and in Group 2 patients, 91.8% (45/49; $p = 0.17$). One deep wound infection occurred in Group 1 patients and two in Group 2 patients. Syndesmosis re-diastasis occurred in 13.6% (3/22) of Group 1 patients and 30.6% (15/49) of Group 2 patients ($p = 0.13$). One syndesmotic screw broke at 6 months. Satisfactory ankle function according to the AOFAS score was noted in 86.4% (19/22) of Group 1 patients and 65.3% (32/49) of Group 2 patients ($p = 0.07$).

Conclusion: Insertion of syndesmotic screws to promote ligament healing after internal fixation of malleolar fractures in advanced PE ankle injuries may be reasonable.

Key words: ankle injury; external rotation; pronation; screw stabilization; syndesmotic diastasis

Introduction

Ankle injuries are common in daily activity. Clinically, most ankle injuries are not severe and treatment with various nonsurgical techniques can usually achieve success[1,2]. However, some ankle injuries that are normally associated with malleolar fractures and syndesmotic diastasis (SD) generally require surgical treatment[3,4]. Because the markedly unsymmetrical bony structures (the huge distal tibia and the

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small lateral malleolus) are unfavorable for load transfer, ankle injuries are often caused by stress from various directions[5]. The complex injured modes usually introduce the difficulties of comprehensive classification. Until now, no classification is convincingly acknowledged that is applicable for all ankle injuries. Clinically, the combined Weber and Lauge-Hansen classifications had been widely used to treat complex ankle injuries[4,6,7]. It is believed that these classifications comprise most common ankle injuries that should not be ignored.

Pronation-external rotation (PE) injuries according to the Lauge-Hansen classification are often considered to be associated with various degrees of ligamentous injuries[6,8,9]. The characteristics of this type of injury are a medial malleolar fracture or deltoid ligament tear and associated with a spiral fibular fracture several centimeters proximal to the plafond[6,10]. In advanced stages of PE injury (stage 3 or 4), syndesmotic ligaments and interosseous membrane are thought to be extensively compromised. The syndesmotic stability may be lost immediately or insidiously. Without effective stabilization for ligament healing, ankle function will never be restored. However, in the literature, some orthopaedists still advocate that damage to the interosseous membrane happens only to a small extent based on magnetic resonance imaging (MRI) studies and does not require much attention[11].

Clinically, the incidence of PE injuries is evidently lower than supination-external rotation injuries of the ankle (15% *vs* 60%)[6,12,13]. However, it generally requires surgical treatment to restore ankle stability. The most controversial problem is whether the syndesmosis requires stabilization concomitantly after internal fixation of associated malleolar fractures[13,14]. Although on the spot stabilization of the syndesmosis is simple, removal of the stabilizing screw may require another surgery[15]. Clinically, either approach has been implemented widely, but to our knowledge, only few studies have been published. This retrospective study aimed to (i) compare the relative superiority of the two approaches in treating advanced PE injuries and (ii) explain the pathomechanism of advanced PE ankle injuries. Consequently, treatment of this relatively complex injury might become more reasonable.

Materials and Methods

Participants

Inclusion criteria in the present study were all adult patients with (i) advanced PE ankle injuries, (ii) having accepted surgical treatment, and (iii) at least 1-year follow-up. The exclusion criteria were patients having old evident surrounding injuries or associating with congenital or developmental deformities.

From January 1, 2008, to December 31, 2017, 822 consecutive adult patients who sustained malleolar fractures with or without SD and had been surgically treated were followed for this study. All ankle injuries were classified based on the combined Weber and Lauge-Hansen classifications[4,6,7]. Ninety-nine cases were grouped as advanced pronation injuries (PE or pronation-abduction injuries), and 81 patients (average, 42 years; range, 18–78 years; 44 men and 37 women) with advanced PE injuries were enrolled in the present study. This study has been approved by the Institutional Review Board of the authors' institution (IRB: 201900950B0).

Definition

We defined advanced injuries as the stage of injury being beyond half of the full stages[6,16]. Cases with stage 3 or 4 advanced PE injuries were considered and enrolled in this study. The inclusion criteria were all adult patients with stage 3 or 4 PE injuries. The exclusion criteria were association with tibial fractures, old ankle deformities or healed fractures, and congenital or developmental anomalies. The causes of the 81 injuries included motorcycle accidents (29 cases), slide (16 cases), various sports injuries (10 cases), working injuries (six cases), fall from stairs (five cases), car accidents (five cases), and others (10 cases).

At the emergency service or outpatient department (OPD), patients' general conditions were stabilized first. The clinical and radiological manifestations of the ankle were checked carefully. Anteroposterior and lateral views of the ankle were taken[4]. Computed tomography (CT) scans with three-dimensional (3D) reconstruction were arranged whenever necessary. The surgery was performed as early as possible (average, 3.5 days; range, 0.5–14 days).

Intervention

Surgical Procedure

Anesthesia and position. With the general anesthesia and endotracheal intubation, the patient was placed on the operating table in the supine position. A pneumatic tourniquet was routinely used, and an image intensifier was prepared for all surgeries.

Approach. The lateral view of the contralateral uninjured ankle was taken with the fluoroscope and stored in the picture archiving and communication system software (PACS; GE Healthcare, Waukesha, WI, USA) of our institution immediately (Figure 1(A),(B))[17]. The relative position of the lateral malleolus to the distal tibia was measured[18].

After the concomitant malleolar fractures of the injured ankle were openly reduced and internally fixed with screws or plates, the syndesmotic stability was rechecked by external rotational stress and hook tests[11,19]. Whether the syndesmosis had to be stabilized with screws relied on the surgeon's decision. Because these patients were treated by several surgeons on duty, the different decision with screw stabilization was not uncommon.

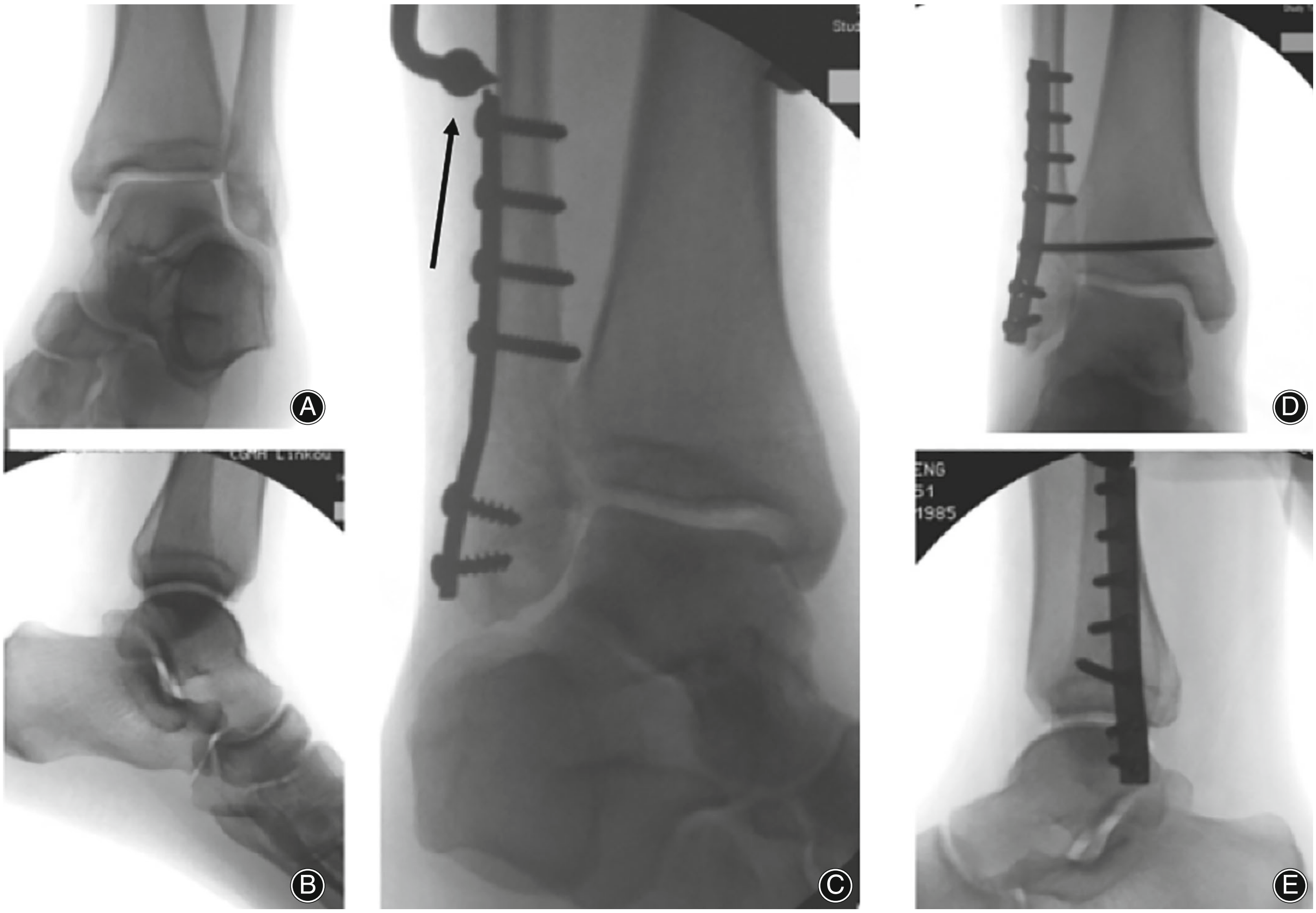

Fig. 1 The sequence of intraoperative procedure is shown: (A, B) The anteroposterior and lateral views of the contralateral uninjured ankle is taken with the fluoroscope and stored in the picture archiving and communication system software (PACS) for anatomic reference. (C) After the fractures of the injured ankle were openly reduced and stabilized with internal fixation, the diastatic syndesmosis was closely reduced and temporarily immobilized with a pointed holding clamp (arrow). (D, E) One or two cortical screws are inserted to stabilize the diastatic syndesmosis

Syndesmotic stabilization. In cases with screw stabilization, the fibula was temporarily immobilized with a pointed holding clamp on the distal tibia (Figure 1(C))[20]. The relative position of the lateral malleolus to the distal tibia was adjusted to match the images of the contralateral ankle. One or two 4.5-mm cortical screws (Synthes, Bettlach, Switzerland) were inserted under image intensifier guidance (Figure 1(D),(E)). After the wound was closed, a short leg splint was applied to all surgical patients.

Comparison of Outcome

Postoperatively, the patients were encouraged to ambulate with protected weight bearing as early as possible. They were followed up at the OPD at 4- to 6-week intervals.

Clinical and radiological healing processes were recorded. The splint was discontinued at 6 weeks. The syndesmotic screw was removed based on the surgeon's policy. Removal of the internal fixation for malleolar fractures was required after 1 year.

Clinical Outcome

The fracture was considered to be in union clinically, with no pain or tenderness locally, and the fracture gap being vanished or connected with a solid callus radiographically[21]. Nonunion was defined as a fracture that was yet to be united beyond 9 months. Complications were closely monitored and were treated whenever necessary, which included infection, nonunion, re-diastasis of the syndesmosis, and ankle osteoarthritis. For patients with syndesmotic re-diastasis, ligament reconstruction with the fascia lata and screw stabilization would be suggested.

Functional outcome

The ankle function was assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) score[22]. The total scores were 100 points and included three categories (pain,

TABLE 1 Comparison between with or without using syndesmotic screws (SC) for advanced pronation-external rotation ankle injuries (n = 71)

Items	With SC (n = 22)	Without SC (n = 49)	*p* value
Union rate	100% (22/22)	91.8% (45/49)	$p = 0.17$; $X^2 = 1.90$
Wound infection	4.5% (1/22)	4.1% (2/49)	$p = 0.93$; $X^2 = 0.01$
Re-diastasis	13.6% (3/22)	30.6% (15/49)	$p = 0.13$; $X^2 = 2.31$
Osteoarthritis	0% (0/22)	8.2% (4/49)	$p = 0.17$; $X^2 = 1.90$
AOFAS score (points)	82 ± 3	80 ± 5	$p = 0.22$; $U = 440$
Satisfactory rate	86.4% (19/22)	65.3% (32/49)	$p = 0.07$; $X^2 = 3.33$

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; *U*-value, Mann–Whitney U test; X^2, chi-square value.

function, and alignment). An excellent result was no less than 90 points, and a good result, no less than 80 points. A satisfactory outcome comprised an excellent or good result.

Statistical Analysis

An SPSS version 20 software (SPSS Inc., Chicago, IL, USA) was used for statistical comparison. $p < 0.05$ was considered

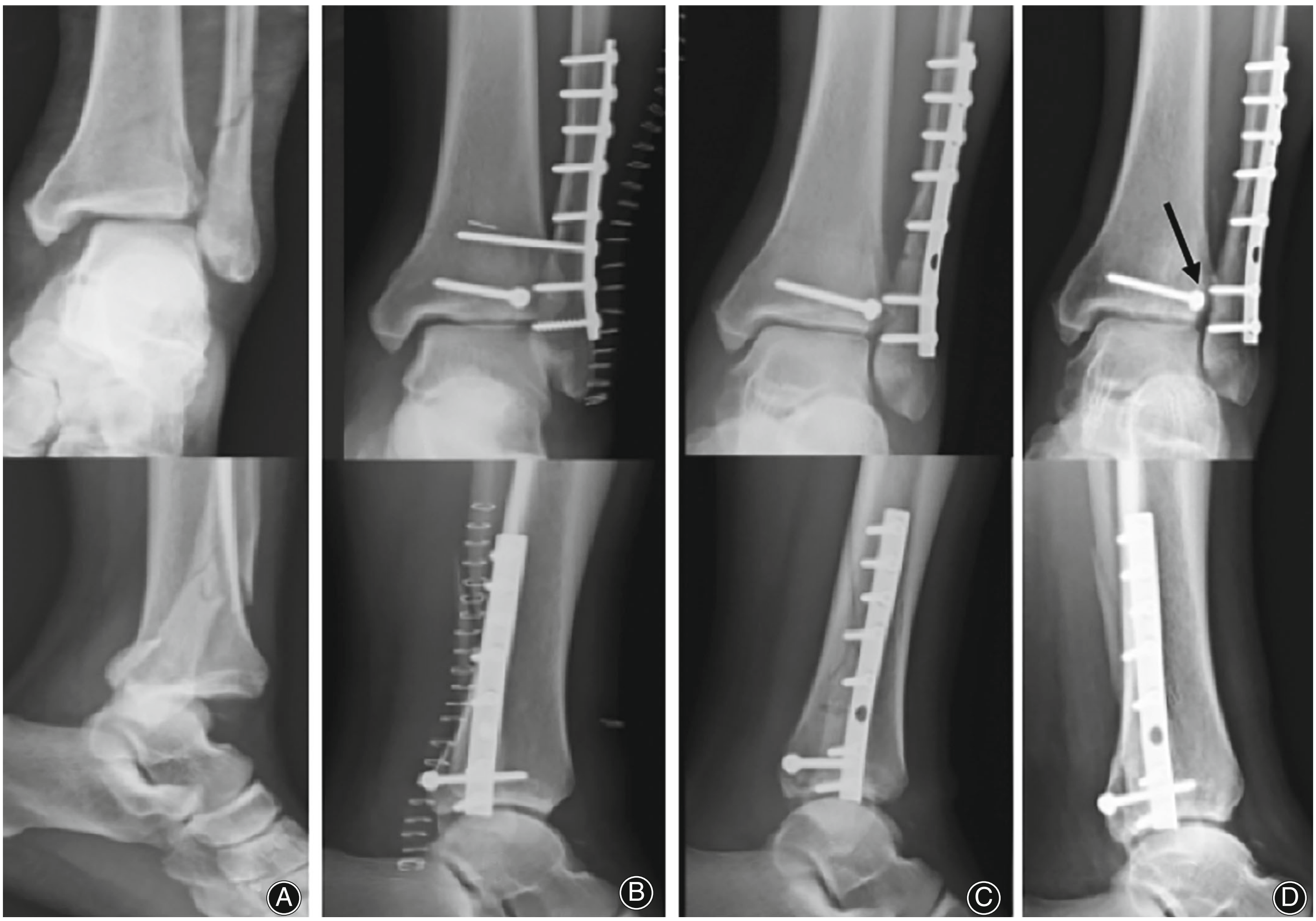

Fig. 2 (A) A 52-year-old man sustained a left stage 4 pronation-external rotation ankle injury due to fall from stairs. (B) Bimalleolar fractures were treated with screws and plates. Diastatic syndesmosis was stabilized with a cortical screw. (C) The syndesmotic screw was removed at 1.5 months. (D) Re-diastasis (arrow) occurred, and the patient had a fair ankle function at 6-year follow-up

statistically significant. The chi-square test was used for categorical data (e.g. union rates) and the Mann–Whitney U test was used for numerical data (e.g. functional scores).

Results

Follow-up

For over 10 years, 71 patients (average, 40 years; range, 18–78 years; 40 men and 31 women) were followed up at the OPD for at least 1 year (average, 2.0 years; range, 1–11 years) with clinical and radiological features. Ten patients were lost despite all possible efforts to contact them. The follow-up rate was (87.7%, 71/81).

A total of 71 patients were divided into two groups: Group 1 (22 patients with syndesmotic screw stabilization) and Group 2 (49 patients without syndesmotic screw stabilization). The follow-up rate of Group 1 was 84.6% (22/26) and Group 2, 89.1% (49/55).

Group 1 included 17 men and five women (average, 36 years; range, 18–77 years). The syndesmotic screws were removed in 20 patients (average, 2.5 months; range, 1.5–5 months). Group 2 included 23 men and 26 women (average, 42 years; range, 18–78 years).

General Results

Because all surgeries were performed with a pneumatic tourniquet, the bleeding amount was small (usually less than 10 ml). No blood drains were inserted. The operating time in Group 1 was an average of 130 ± 20 min (range, 110–170 min), and in Group 2, an average of 110 ± 15 min (range, 90–150 min; $p = 0.11$). No adverse effects occurred throughout the surgery.

Clinical Improvement

Fracture union was achieved in all 22 patients in Group 1 (100% of union rate; Table 1). The union time was an average of 2.8 months (range, 2.5–4.0 months). Two patients in Group 2 had medial malleolar nonunions, and two other

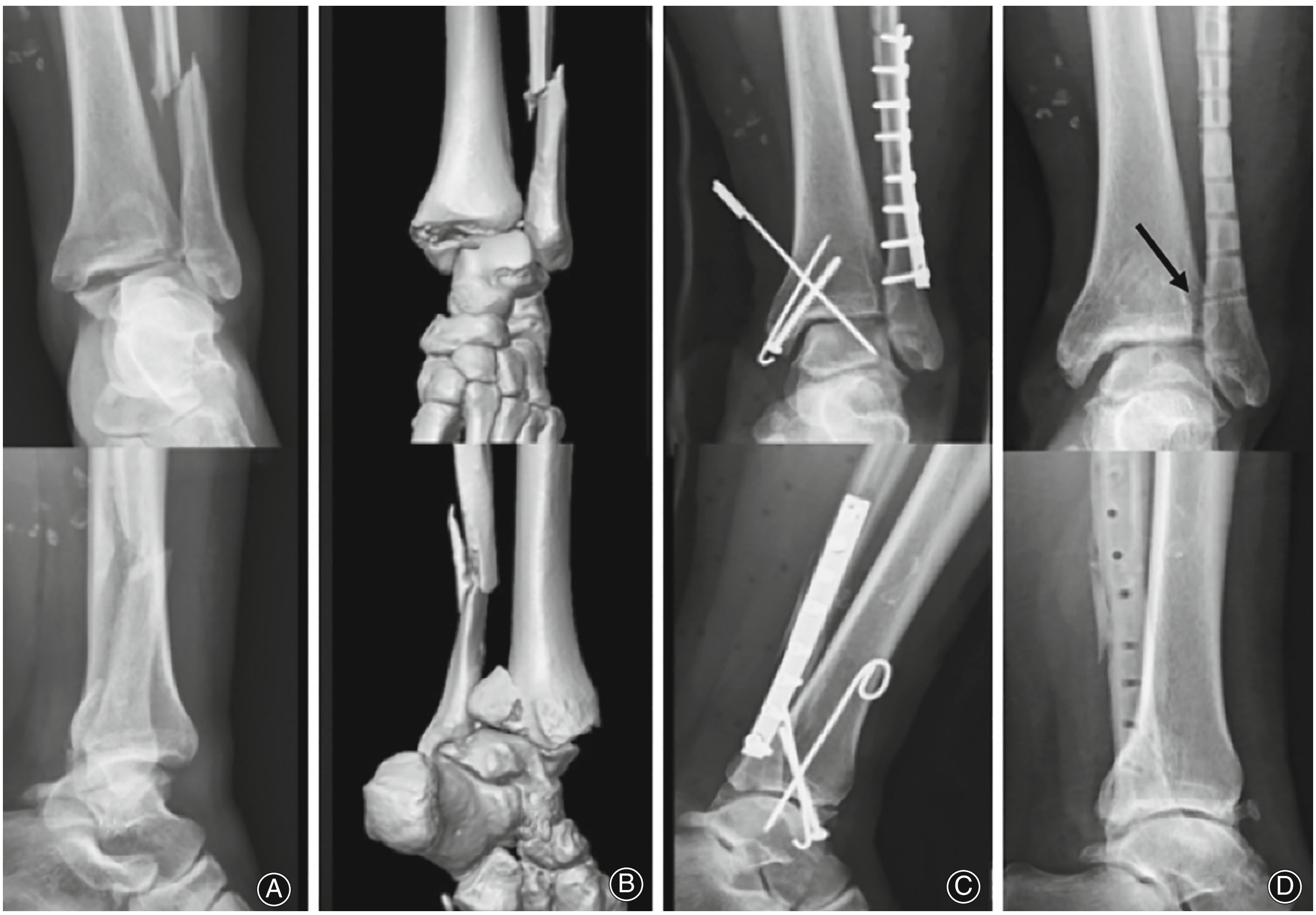

Fig. 3 (A) A 42-year-old woman sustained a left stage 4 pronation-external rotation ankle injury due to slide. (B) Reconstructive computed tomography (CT) scans confirmed the lesions. (C) Bimalleolar fractures were treated with screws, Kirschner wires, and plates. Diastatic syndesmosis was not stabilized. (D) Re-diastasis (arrow) with lateral shift of the talus occurred and the patient had a fair ankle function at 2.5-year follow-up

Fig. 4 (A) A 60-year-old woman sustained a right stage 4 pronation-external rotation ankle injury due to motorcycle accident. (B) Bimalleolar fractures were treated with screws and plates. Diastatic syndesmosis was not stabilized. (C) The malleolar implants were removed at 1.5 years. (D) Re-diastasis (arrow) with ankle osteoarthritis occurred and the ankle function was poor at 11-year follow-up

patients had fibular nonunions (91.8% of the union rate, $p = 0.17$). The union time in Group 2 patients was an average of 3.2 months (range, 2.5–5.5 months).

Functional Evaluation

Ankle function was assessed by AOFAS scores. Group 1 had an average score of 82 ± 3 points (range, 74–88 points) and Group 2, an average of 80 ± 5 points (range, 66–86 points; $p = 0.06$).

A satisfactory ankle function occurred in 86.4% (19/22) of Group 1 patients and 65.3% (32/49) of Group 2 patients ($p = 0.07$; post-hoc power $= 0.44$; Figures 5 and 6).

Complications

One deep wound infection occurred in Group 1 patients and two in Group 2 patients. All recovered after debridement and local care ($p = 0.93$).

One syndesmotic screw broke at 6 months, which occurred in one of the two cases without early removal of the screw.

SD recurred in 13.6% (3/22) of Group 1 patients and 30.6% (15/49) of Group 2 patients ($p = 0.13$; post-hoc power $= 0.31$; Figures 2 and 3). Syndesmotic re-diastasis was defined as the tibiofibular clear space further separated by more than 2 mm based on immediate postoperative radiographs and the latest comparison of anteroposterior radiographs of the ankle[19,21]. Although ligament reconstruction with the fascia lata and screw stabilization were suggested for these patients, none had accepted the revision surgeries during the follow-up period.

Ankle osteoarthritis occurred in four Group 2 patients (8.6%, 4/49) and none in Group 1 patients ($p = 0.58$; Figure 4).

Discussion

In normal human gait, when one foot touches the ground, the body's center of gravity moves to the contralateral side

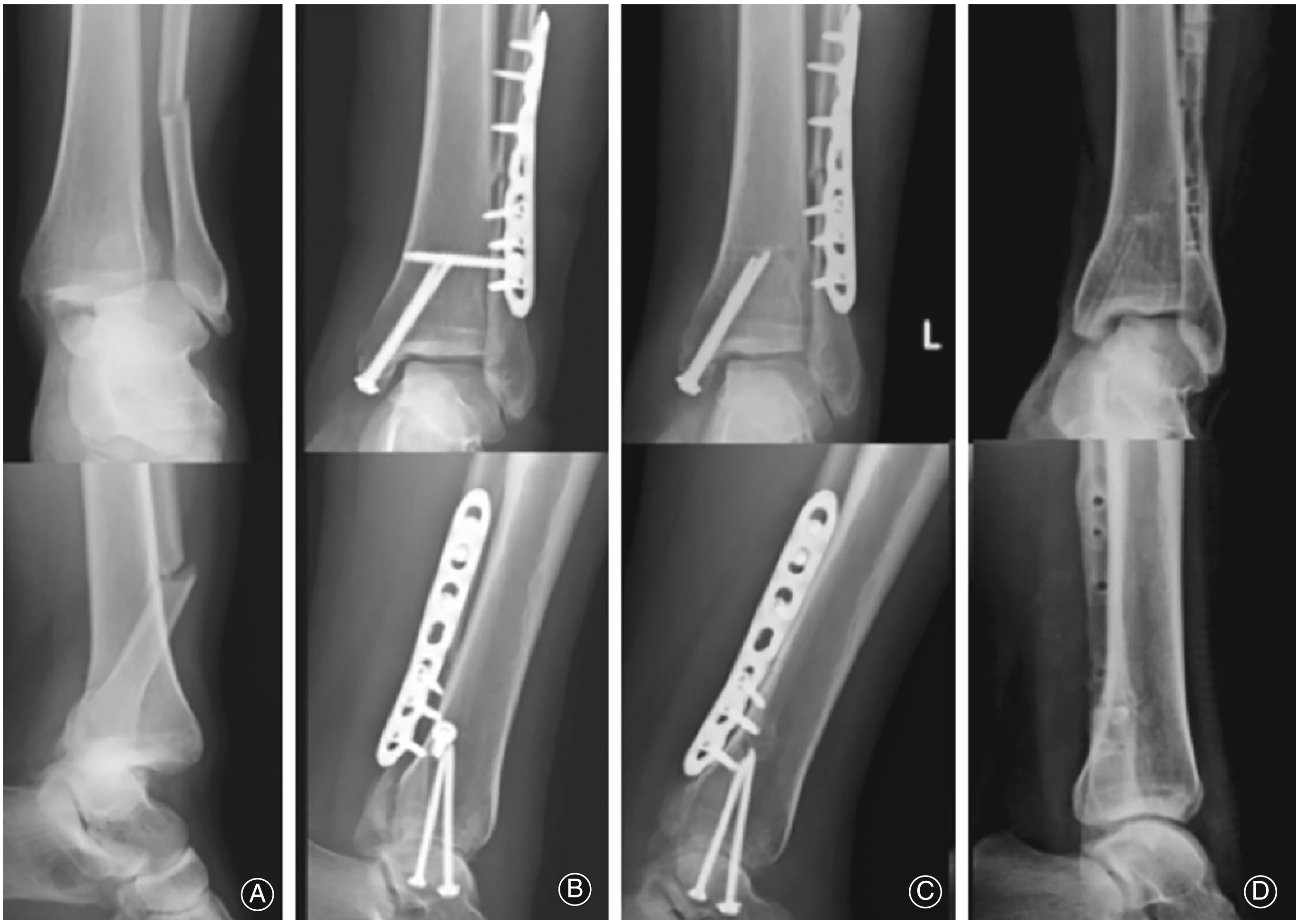

Fig. 5 (A) A 26-year-old man sustained a left stage 4 pronation-external rotation ankle injury due to motorcycle accident. (B) Bimalleolar fractures were treated with screws and plates. Diastatic syndesmosis was stabilized with a cortical screw. (C) The syndesmotic screw was removed at 4 months. (D) The patient had a good ankle function at 2.4-year follow-up

and introduces bending and rotational moments[23]. Because of the marked size disparity between the distal tibia and the lateral malleolus, the ankle contour becomes very unsymmetrical. Not only is the load transfer unsmooth, but the movement of the talus is also greatly restricted[24]. Once stress from various directions affects the ankle, various complex injuries occur. Clinically, among various ankle injuries requiring treatment, supination-external rotation injuries are reportedly the most common (around 60%), followed by PE injuries, around 15%. However, the severity of the latter is much higher and generally requires surgical intervention[6,10,12–14].

Patho-Mechanism of Advanced PE Ankle Injuries

In advanced PE injuries (stage 3 or 4), the stability of the medial aspect of the tibia is lost first because of medial malleolar fractures or deltoid ligament tear. Consequently, the anterior inferior tibiofibular ligament tear follows. Then, the fibular shaft, found several centimeters proximal to the plafond (commonly >6 cm), fractures spirally, and the interosseous membrane is disrupted from the syndesmosis upward to the fractured fibula. This is the standard patho-mechanism of stage 3 PE injuries. If the damage continuously extends, the posterior malleolus will fracture, or the posterior inferior tibiofibular ligament is disrupted. So far, a stage 4 PE injury is developed[6,13,14,25]. In the literature, either injury is regarded as frankly or potentially unstable, and surgical treatment is normally necessary[7,8].

Surgical techniques for the treatment of advanced PE injuries are controversial. Some orthopaedic surgeons declare that once the medial malleolar fracture is stabilized with screws and the fibular fracture is immobilized with a splint with or without plate fixation, the syndesmotic stability may be sufficient. Therefore, syndesmotic screw stabilization may be unnecessary[10,26]. However, more orthopaedic surgeons object to this concept, believing that extensive destruction of the ligaments and interosseous membrane is a potential risk for syndesmotic re-diastasis after walking. The talus will continuously push the lateral malleolus posterolaterally. A

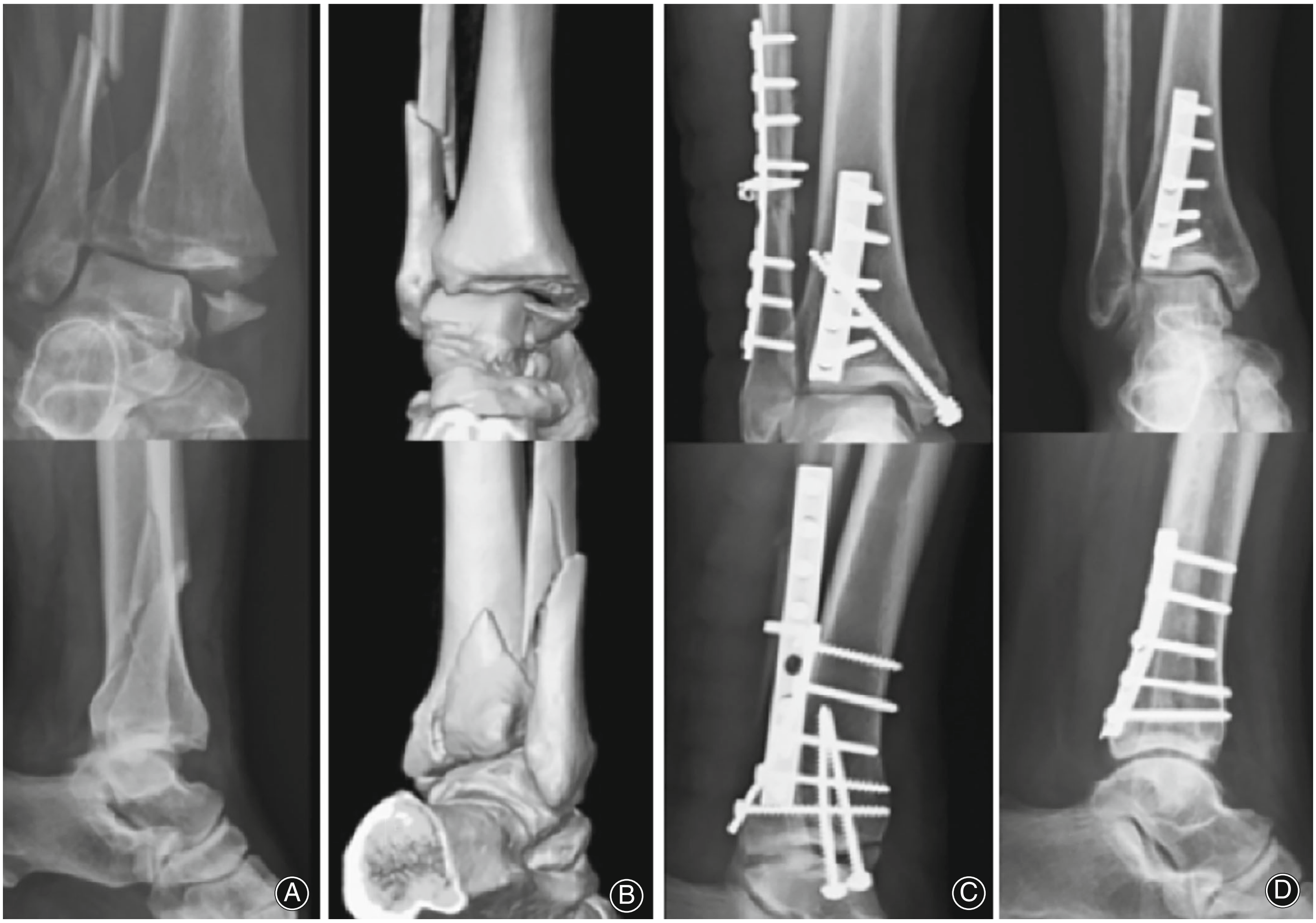

Fig. 6 (A) A 56-year-old woman sustained a right stage 4 pronation-external rotation ankle injury due to slide. (B) Reconstructive computed tomography (CT) scans confirmed the lesions. (C) Trimalleolar fractures were treated with screws and plates. Diastatic syndesmosis was not stabilized. (D) The patient had a good ankle function at 4.3-year follow-up

1.5-month splint immobilization is insufficient for the healing of ligaments and interosseous membrane[8,11]. Despite the lack of statistical significance in the present study, the ratio of re-diastasis (30.6% *vs* 13.6%) may remind of the potential danger of ignorance for syndesmotic re-diastasis. The statistical insignificance may be due to insufficient sample sizes (post-hoc power = 0.31). Re-diastasis of syndesmosis had been reported to cause progressive osteoarthritis in the literature[1,8,11,27,28].

Reasons to Favor Syndesmotic Stabilization from Biomechanical Viewpoints

In the stance phase of gait, the talus will be pushed with 3°–5° of external rotation and 1.5 mm of lateral shift[29]. Consequently, the anteromedial aspect of the lateral malleolus will bear intermittent stresses toward the posterolateral direction during daily activity. A non-stabilized syndesmosis should be very difficult to withstand this load when all surrounding ligaments and interosseous membrane are without resistant function. Theoretically, a stabilizing screw should be inserted[8,30].

The outcomes of syndesmotic re-diastasis may require long-term observation. It is dissimilar to an acute SD, which is always combined with malleolar fractures. Patients are generally unable to bear weight[31]. However, syndesmotic re-diastasis is the only remaining sequela, and the side effects will deteriorate insidiously. It may, therefore, cause ankle function without statistical difference (86.4% *vs* 65.2% of satisfactory rate, $p = 0.07$; post-hoc power = 0.44) between the two groups in the present study. Increased sample sizes and longer follow-up may reflect the true clinical features (Figures 5 and 6).

Reasons to Favor Syndesmotic Stabilization from Biological Viewpoints

The vascularity of syndesmosis has been enthusiastically studied. The perforating branch of the peroneal artery mainly supplies the surrounding ligaments[24,32]. In advanced PE injuries, the interosseous membrane tears from the upper edge of the syndesmosis upward to the fractured fibula[6,13,14,26,33]. There is a great possibility that the blood supply will be severely compromised and hinder ligament healing. Immobilization with a short leg splint for 6 weeks carries a high risk of re-diastasis. In the present study, 30.6% of the re-diastatic rate is found. Insertion of a stabilizing screw lowers the rate to 13.6% ($p = 0.31$).

Syndesmotic stabilization may be done *via* a screw insertion or suture-button technique[31,34]. Although the latter is gradually being supported by some surgeons recently, the former still has merits of technical simplicity and a high success rate as long as screw removal is delayed beyond 3 months[7,15].

Limitations

Some limitations exist in the present study. First, sample sizes are insufficient, and follow-up periods are not long enough (average of 2 years). Therefore, although the ratios of re-diastasis and satisfactory ankle function are evidently different between the two groups, statistical comparison is still insignificant. After all, advanced PE injuries are not so common that enlarging case numbers may require much longer time. Clinically, comparison *via* a cohort study may be less possible. The sample sizes required for the study of re-diastasis are 92 for each group, and for satisfactory ankle function, 63 for each group in the present study. Second, the optimal time for removal or non-removal of a syndesmotic screw cannot be guaranteed. Screw breakage or re-diastasis may cause surgeons to hesitate inserting a stabilizing screw. Recently, keeping syndesmotic screws seems to achieve more support[3,15,35].

Conclusion

Although clinical comparison cannot demonstrate statistical difference, screw stabilization of diastatic syndesmosis may guarantee safer results. The statistical insignificance may be due to insufficient sample sizes. Clinically and theoretically, insertion of syndesmotic screws to promote ligament healing in advanced PE ankle injuries may be reasonable.

Author Contribution

The first author (C.-C. W.) designed study, collected data, analyzed data, and wrote the draft. The other five coauthors provided data and helped to analyze data.

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