

Locking Compression Plate Distal Ulna Hook Plates as Alternative Fixation for Avulsion Fractures of the Tip of the Lateral Malleolus

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Technical advance

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Abstract

Background: Because of the fragment size and inferior location of the fracture lines, options are lacking for internal fixation to treat avulsion fractures of the tip of the lateral malleolus. Because the anatomical architecture of the distal malleolus is similar to that of the distal ulna metaphysis, the purpose of this study was to assess the effectiveness of 2.0-mm locking compression plate distal ulna hook plates in treating avulsion fractures of the tip of the lateral malleolus.

Methods: Given the characteristics of the 2.0-mm locking compression plate distal ulna hook plate, cases in which the distance between the fracture lines and the distal end of the tip of the lateral malleolus was less than 6 mm were excluded. Seventeen patients (AO Foundation/Orthopaedic Trauma Association (AO/OTA) 44A fractures, 13 males, 4 females, median age 41 years range 18-73 years) with avulsion fractures of the tip of the lateral malleolus were included. All patients were treated with fixation of the fragment to the fibula using a 2.0-mm locking compression plate distal ulna hook plate. Clinical and radiological follow-up visits were conducted at 6 weeks and 3, 6, 12 and 24 months after the operation.

Results: The mean American Orthopedic Foot and Ankle Society Ankle-Hindfoot score of the patients was 97.06 ± 1.92 (range 94 to 100) at the 12-month postoperative follow-up and 97.71 ± 1.54 (range 96 to 100) at the 24-month postoperative follow-up. The mean Karlsson score was 94.18 ± 3.88 (range 90 to 100) at the 12-month postoperative follow-up and 96.43 ± 2.34 (range 95 to 100) at the 24-month postoperative follow-up. Nonunion was not noted; 6 patients complained of lateral malleolar discomfort and foreign body sensation, and 3 of these patients underwent a hardware removal operation at 12 months postoperatively. All patients were clinically and radiographically stable.

Conclusion: A 2.0-mm locking compression plate distal ulna hook plate achieved stable and anatomically suitable fixation and should be considered as an alternative treatment for avulsion fractures of the tip of the lateral malleolus.

Background

If lateral malleolar fractures involve more than rupture of the lateral collateral ligaments, AO Foundation/Orthopaedic Trauma Association (AO/OTA) 44A ankle injuries are classified into the following groups: 44A1.2, 44A1.3, 44A2.2, 44A2.3, 44A3.2, and 44A3.3 [1]. The common features of these groups are fracture of the tip of the lateral malleolus and a distal lateral malleolar fragment connected by the anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL). Among these fractures, there are operative indications for type 44A2 and 44A3, while nonoperative treatment is widely accepted on type 44A1, an isolated lateral malleolar injury [2, 3], which has a higher prevalence than 44A2 or A3 [4, 5].

However, as some articles have reported, conservative treatment for ankle injuries with avulsion fracture of the lateral malleolus results in a high complication rate. Haraguchi et al. [6] found that 35% of conservatively treated lateral malleolar avulsion fractures failed to heal, despite 3 to 7 weeks of strict cast immobilization. The distal fragment of the infrasyndesmotic lateral malleolus fracture resulting from foot

inversion injury is always connected by the ATFL and CFL. Because of the retracting force of the ligaments, the avulsed bony fragment may not be in contact with the distal fibula, making bone-to-bone healing difficult [7]. Therefore, many scholars believe that active surgical intervention, with reduction and fixation of the fracture, is an effective method to promote fracture healing and restore the stability and function of the ankle [7–9].

In these studies, the fragment was fixed in place with 1 or 2 cannulated screws [7–9]. However, in screw fixation, it is often difficult to achieve accurate reduction and rigid fixation when the distal fragment is too small or when the bone is osteoporotic [10]. For patients whose growth plates are not closed yet, threaded screws pose a risk of injury to the growth plate [11]. Furthermore, the commonly used distal fibula anatomical locking compression plate (LCP), which is relatively large and must be positioned relatively superior according to the instruction manual, is also not appropriate for these fractures because sometimes the screws are not sufficient to secure the distal fibular fragment [12]. Therefore, sufficient internal fixation options with which to treat avulsion fractures of the tip of the lateral malleolus are lacking.

There exists a 2.0-mm miniature hook LCP (DePuy Synthes, Oberdorf, Switzerland) designed for the treatment of distal ulna fractures. The advantages of using this plate are stable angular fixation of the fragments, regardless of the bone quality, and a relatively low risk of primary or secondary loss of reduction. Because the anatomical architecture of the distal lateral malleolus is similar to that of the distal ulna metaphysis, we proposed that this miniature hook LCP might be a suitable fixation device for the treatment of avulsion fractures of the tip of the lateral malleolus.

The purpose of this study was to evaluate the clinical outcomes and suitability of treating avulsion fractures of the tip of the lateral malleolus with a 2.0-mm LCP distal ulna hook plate.

Methods

The LCP distal ulna hook plate used in this study was made of titanium, with a groove for shaping. There were pointed hooks in the distal end and 7 proximal screw holes that accepted both 2.0-mm locking and cortex screws. The plate was 46 mm long, 5 mm wide and 2 mm thick (Fig. 1). The distance between the most distal screw hole and the distal end of the plate was 6 mm. Therefore, we excluded cases in which the distance between the fracture lines and the distal end of the tip of the lateral malleolus was less than 6 mm.

From June 2014 to January 2018, a total of 17 patients were included in the present retrospective study and were treated surgically with 2.0-mm LCP distal ulna hook plates. The inclusion criteria for patients were as follows: 1. imaging confirmed the presence of an avulsion fracture of the lateral malleolus; 2. the distance between the fracture lines and the distal end of the tip of the lateral malleolus was more than 6 mm. The exclusion criteria were open fracture, diabetes, prolonged steroid treatment, surgery for previous lateral ankle ligament reconstruction or a previous ankle fracture. All procedures were performed by the same surgeon. The 17 patients had an average age of 41 (range, 18-73) years and comprised 13 males

and 4 females. There were 14 fresh fracture cases and 3 old fracture cases. According to the AO/OTA classification system, there were 8 44A1.2 cases, 6 44A1.3 cases, 2 44A2.2 cases and 1 44A2.3 case. Eight patients had multiple fractures, including 3 cases with distal tibia fractures, 1 case with patellar and talar fractures, 1 case with a pelvic fracture, 1 case with a calcaneal fracture, 1 case with a fracture at the base of the fifth metatarsal, and 1 case with a fresh 44C1.3 fracture at the base of an old 44A1.2 fracture (Table 1). Regarding laterality, there were 9 patients with fractures on the left side and 8 patients with fractures on the right side. The study was approved by the ethics committee of the local hospital, and informed consent was obtained from all patients.

Table 1. Patient information

NO	S	A	AO	FD	AF
1	M	38	44A1.3	F	Y
2	M	61	44A1.2	F	Y
3	F	29	44A1.3	F	-
4	M	33	44A2.2	F	Y
5	F	53	44A1.2	F	Y
6	M	59	44A1.2	F	-
7	M	36	44A1.2	F	-
8	M	21	44A1.3	F	-
9	M	46	44A1.3	F	Y
10	M	73	44A1.3	F	Y
11	F	60	44A2.3	F	-
12	M	29	44A1.2	F	-
13	M	26	44A1.3	F	Y
14	M	24	44A1.2	O	-
15	M	18	44A1.2	O	-
16	M	26	44A1.2	O	Y
17	F	65	44A2.2	F	-

Abbreviations: sex (S), age (A), AO/OTA classification (AO), fracture description (FD), fresh (F)/old (O), associated fracture (AF).

Note: Case No. 2, 6, and 10 were lost to the 24-month follow-up.

Preoperative assessment

An X-ray and a three-dimensional reconstruction of a CT scan of the fracture site for each patient were obtained preoperatively to assess the size of the fragment and the distance between the fracture line and the distal end of the tip of the lateral malleolus. Careful examination of the skin and soft tissue at the surgical site was also carried out in accordance with basic surgical protocols. Antibiotics were administered 30 min prior to surgery to prevent infection.

Operative technique

The operation was performed under general anesthesia or epidural anesthesia and in either the supine or the lateral position. An approximately 7 to 9 cm long incision was made from the distal fibula to the sinus tarsi to expose the fracture site and to determine the size of the distal fracture fragment and its relation with the origin of the fibula. The distance between the fracture line and the distal tip of the lateral malleolus should be no less than 6 mm. Next, the ATFL and CFL were probed, and their integrity was assessed. Varus and anterior drawer tests were performed to evaluate the degree of ankle instability.

The fracture site was debrided before reduction. The assistant pronated the foot to reduce the tension of the ATFL and CFL on the distal fracture fragment. The surgeon used a small periosteal detacher to push outward and upward to move the distal fragment and reduce the fracture. If necessary, the joystick technique was used with 1.0-mm Kirschner wires to assist the reduction. A towel clip was used to maintain the reduction effect. Two 1.0-mm Kirschner wires were used for temporary fixation. The entry points were located on both sides of the tip of the lateral malleolus. The tip of the lateral malleolus between the two wires was reserved as a place for the plate (Fig. 2c). The Kirschner wires were positioned perpendicular to the fracture line. The reduction effect was evaluated by direct vision and X-ray fluoroscopy.

The 2.0-mm LCP distal ulna hook plate was shaped according to the anatomic architecture of the lateral malleolar surface. The plate was positioned to grasp the tip of the lateral malleolus with 2 pointed hooks through the CFL attachment site. A hole was drilled near the sliding screw hole. The grasping force of the pointed hooks was adjusted accordingly. The fracture site was compressed as appropriate, but excessive compression was not applied in patients with severe osteoporosis or comminuted fracture sites. A 2.0-mm locking head screw was inserted from the most distal screw hole, which was nearest to the pointed hook, to secure the distal fracture fragment. If the fracture fragment was large or broken into more than 2 pieces, another independent 2.4- or 3.0-mm headless cannulated screw or 2.0-mm cortex screw could be added. The Kirschner wires used for temporary fixation were removed. Varus and anterior drawer tests were performed to examine the stability of the fracture fragment and ankle. X-ray fluoroscopy was used to determine whether the fracture reduction was satisfactory and whether the length and position of the plate and screws were suitable.

Postoperative care

At 2 or 3 days after the surgery, range-of-motion exercises were initiated, and the ankle was immobilized in a removable cast for 1 or 2 weeks. Thereafter, patients were allowed to bear weight with a walker boot for 6 weeks to the extent that they could tolerate it. An individual and comprehensive rehabilitation program was developed for each patient with multiple fractures. Clinical and radiological follow-up visits were conducted at 6 weeks, 3 months, 6 months, 12 months and 24 months after the operation. If the patients complained of lateral malleolar discomfort or foreign body sensation, a hardware removal operation was performed after 12 months at the patients' request. The functional outcomes were graded using the American Orthopedic Foot & Ankle Society (AOFAS) Ankle-Hindfoot Scale and Karlsson scoring system at 12 and 24 months.

Results

Intraoperative probes of all patients found that the ATFL and CFL were connected with the distal fracture fragment and were integrated. The mean distance between the fracture line and the distal tip of the lateral malleolus was 9.4 mm (range 7–15 mm). At least one 2.0-mm locking head screw was used to secure the distal fracture fragment in each patient. Two or three 2.0-mm cortex or locking head screws were inserted into the proximal screw holes of the plate (Figs. 2 and 3). The stability was tested, with satisfactory results. A 3.0-mm cannulated screw or 2.0-mm cortex screw was added in 7 patients as associated fixation (Fig. 3). Three of the 17 patients were followed up for 12 months after the operation; the other patients were followed up for 24 months after the operation. No infection, breakage of internal fixation or loss of fracture reduction occurred in any of the patients who were followed up. Nonunion was not noted in any of the 17 patients. The functional outcomes were evaluated according to the AOFAS Ankle-Hindfoot Scale and Karlsson score system after the operation. The mean AOFAS score was 97.06 ± 1.92 (range 94 to 100) points at the 12-month follow-up and 97.71 ± 1.54 (range 96 to 100) points at the 24-month follow-up. The mean Karlsson score was 94.18 ± 3.88 (range 90 to 100) points at the 12-month postoperative follow-up and 96.43 ± 2.34 (range 95 to 100) points at the 24-month postoperative follow-up (Table 2). Six patients complained of lateral malleolar discomfort and foreign body sensation. The internal fixations were removed 12 months after the operation at the request of 3 patients.

Table 2
Outcome at the 12-month and 24-month follow-up visits

Follow-up (mo)	AOFAS (p)	Karlsson (p)
12	97.06 ± 1.92	94.18 ± 3.88
24	97.71 ± 1.54	96.43 ± 2.34

Abbreviation: AOFAS ankle-hindfoot score (points) (AOFAS(p)), Karlsson score (points) (Karlsson(p)).

Discussion

Avulsion fractures of the tip of the lateral malleolus, which are classified by the AO/OTA as type 44A, occur when the foot is supinated and an adduction force is applied to the talus, causing the lateral

structures to fail in tension, which corresponds to the supination-adduction type in the Lauge-Hansen classification. Approximately 60%-70% of ankle fractures are monomalleolar fractures, 15%-20% are bimalleolar fractures and 7%-12% are trimalleolar fractures [4, 5]. Most of the cases (n = 14) in this study were monomalleolar fractures of AO/OTA types 44A1.2 and 44A1.3. Only 3 cases were bimalleolar fractures of AO/OTA types 44A2.2 and 44A2.3. This was consistent with the incidence of ankle fracture.

Conservative treatment is quite effective in treating acute ankle sprain. Nonsurgical treatment is widely accepted even by young athletes [2, 3]. However, some articles have reported the incidence of complications with conservative treatment in ankle injuries with avulsion fracture of the lateral malleolus. Haraguchi et al. [6] found in 44 patients with avulsion fracture of the lateral malleolus that, even after 3 to 7 weeks of strict cast immobilization, 35% of the fractures failed to heal. El Ashry et al. [8] reported that in 2 cases of ankle sprain, the avulsion fracture fragment of the distal fibula did not heal after conservative treatment and had clinical symptoms, making secondary operation necessary. The reason for this is that the ATFL and CFL are attached to the fracture fragment of the distal fibula, and the retracting force of the ligament makes it difficult for the fracture site to contact; meanwhile, in the case of insufficient stability of external fixation, even mild foot movements may cause fracture fragments to move, thus causing fracture nonunion [7]. Diallo et al. [7] reported that the displacement of the fragment from the insertion site on the fibula was larger than suspected radiographically; therefore, spontaneous bone-to-bone healing would have been unlikely. In the cases included in this study, it was found intraoperatively that all distal fragments were connected to the ATFL and CFL.

Osseous union is the strongest. Therefore, some scholars tend to adopt operative treatment of fresh and old avulsion fractures of the distal lateral malleolus to reduce and fix the fracture [7–9, 13]. As observed in this study, these therapies have been shown to restore the anatomical position of the ligaments and have achieved good stability of the ankle intraoperatively and postoperatively. The patients regained their previous exercise ability and did not experience repeated ankle sprains. In these articles, most researchers used 1 or 2 2.5- to 3.0-mm cannulated screws for fixation. However, in screw fixation, it will often be difficult to achieve accurate reduction and rigid fixation when the distal fragment is too small or when the bone is osteoporotic [10]. Meanwhile, the fixation of avulsion fractures with screws causes other complications, including irritation by the screw head, injury of the peripheral nerve, bone nonunion because of small diameter, and secondary fractures because of large diameter [14]. In addition, any screw with threads causes further complications in patients whose distal fibula growth plate has not been closed [11]. A Kirschner wire tension band is another alternative fixation method, but complications such as skin and soft tissue irritation, loosening and hardware breakage are likely to occur [15]. Moreover, these fracture fragments are often not large enough to be suitable for a distal fibula anatomical LCP. Since the common distal fibula anatomical LCP is placed in a superior position, not enough screws can be inserted into the distal fracture fragment.

The anatomical contouring, low profile, obtuse edge and polished surface of the 2.0-mm LCP distal ulna hook plate help reduce the irritation of soft tissue. Between the two most distal screw holes, there is a groove to assist shaping, which can allow the plate to attach to the contour of the outer surface of the

distal fibula (Fig. 1). The 2 pointed hooks at the distal end of the plate can be embedded in the tip of the lateral malleolus through the CFL attachment site to form an embrace-like grip and exert multidirectional stress. The operative fixation of intra-articular fracture may be more challenging if the fragment is connected to tendons and ligaments. Nevertheless, the pointed hooks fixed in the attachment site of the lateral collateral ligament of the ankle can effectively resist its tension, restore the rotational displacement, eliminate dynamic factors that cause fracture redisplacement, and create conditions for early functional training without damaging ligament connections. These are unique advantages of hook plates. Based on confidence in the stability, all patients in this study began passive and active ankle functional exercise just 2 or 3 days after the operation. No fracture displacement was observed. A 2.0-mm miniature angle stabilization screw system can secure a small fragment of the tip of the lateral malleolus. The combination of the proximal sliding compression hole and the locking hole facilitates the fixation of osteoporotic fractures and avoids bone loss due to the insertion of cannulated screws. The sustained pressure exerted by the elastic recovery of pointed hooks and the design of the proximal sliding compression holes constitute advantages compared with the other internal fixations. For some cases fixed with screws, if a technical secondary fracture occurs at the distal fragment during the operation, the plate can also be used as a remedy. According to the above thinking, many scholars have used this plate for the fixation of fractures at the base of the fifth metatarsal [10, 16, 17], but its application to the lateral malleolus has not been reported.

We compared this plate with two commonly used types of distal fibula anatomical plates that are manufactured by DePuy Synthes and Zimmer (Fig. 4). As measured, the penultimate distal screw hole of the DePuy Synthes anatomical plate is 10 mm from the distal end of the plate, while that of the Zimmer anatomical plate is 13 mm. According to the instruction manual, they were placed 5 mm proximal to the tip of the lateral malleolus. Therefore, theoretically, the two kinds of plates can be used only when the fracture line is at least 15 mm ($10 + 5$) and 18 mm ($13 + 5$) from the tip of the lateral malleolus, such that at least two 2.7-mm screws can be inserted into the distal fracture fragment to obtain sufficient purchase. The distance between the most distal screw hole of the 2.0-mm LCP distal ulna hook plate and the distal end of the plate is 6 mm. Therefore, a 2.0-mm screw can be inserted as long as the fracture line is not less than 6 mm from the tip of the lateral malleolus, securing the distal fragment together with the pointed hooks. For this reason, we suggest that the use of this plate is indicated if the fracture line is 6 to 15 mm from the distal end of the tip of the lateral malleolus. Such a design also provides the possibility of safe internal fixation for some patients with fractures of the distal fibula when the growth plate is not closed.

Although the hook plate provides rigid fixation, as with other techniques, it is not always possible to obtain accurate fracture fragments and anatomical consistency. In particular, when the fragment is wide or large, to achieve better reduction and fixation effects, independent 2.4- or 3.0-mm cannulated screws or 2.0-mm cortex screws may be added as appropriate. In addition, as mentioned above, the best indication for the use of this plate is the fracture line 6–15 mm from the distal end of tip of the lateral malleolus, which also limits its range of application to a certain extent. If the fracture line is greater than 15 mm, some distal fibula anatomical LCP may be used; if the fracture line is less than 6 mm, other fusion

methods, such as cannulated screws [7], the Broström operation, or other ligament reconstruction methods [18, 19], should be considered.

The lack of a control group to compare the outcomes is another limitation of this study. However, the main objective of this study was to introduce a new feasible fixation rather than compare 2 treatment methods.

Conclusions

A 2.0-mm LCP distal ulna hook plate was used to perform open reduction and internal fixation for avulsion fracture of the lateral malleolus with a fracture line 6–15 mm from the distal end of the tip of the lateral malleolus. The plate is rigidly fixed, ensuring satisfactory stability and easy operation. Although it is controversial whether an isolated avulsion fracture of the tip of the lateral malleolus requires active surgical treatment, fixation with a 2.0-mm LCP distal ulnar hook plate is an acceptable and alternative operative method that can provide good results, especially for patients with non-isolated avulsion fracture of the lateral malleolus with clear operative indications.

List Of Abbreviations

AO/OTA AO Foundation/Orthopaedic Trauma Association

ATFL anterior talofibular ligament

CFL calcaneofibular ligament

LCP: locking compression plate

AOFAS: American Orthopedic Foot & Ankle Society

Declarations

Ethics approval and consent to participate

This study was approved by the Ethics Committee of The First Affiliated Hospital of Chongqing Medical University, (Approval Number 20140506). We obtained written informed consent from all the participants before publishing this information.

Consent for publication

Not applicable.

Availability of data and materials

The datasets concerning this study are available from the corresponding author on reasonable request

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Wei Shui: Chief surgeon, Writing the manuscript ,Collecting the data, Statistical analysis.

Gang Luo: Collecting the data, Reviewing the literature.

Youyin Yang: Collecting the data.

Bo Qiao: Reviewing the literature.

Weidong Ni: Supervising the study, Editing the manuscript.

Shuquan Guo: Designing the study, Reviewing the literature.

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Figures



Figure 1

Photographs of the 2.0-mm locking compression plate distal ulna hook plate.

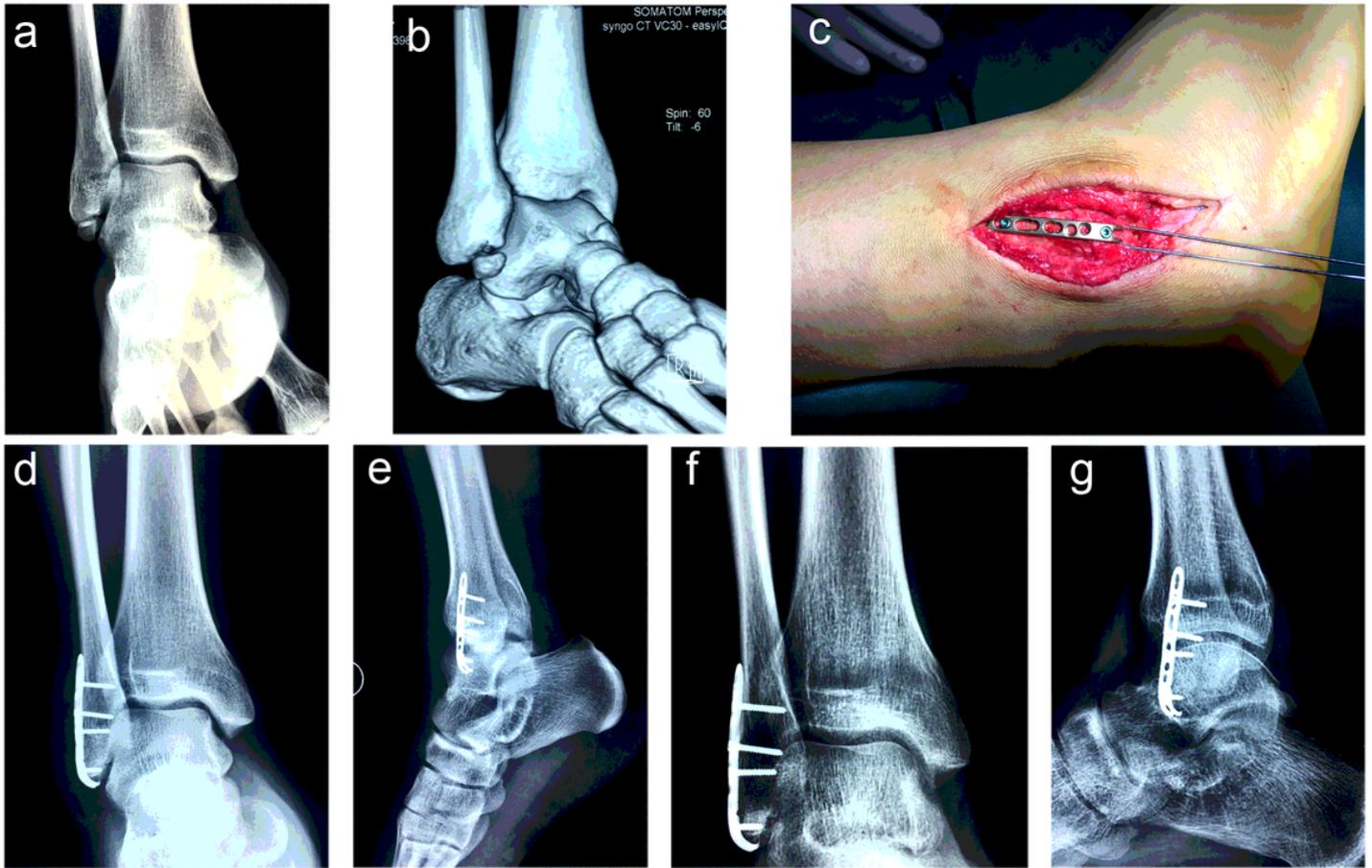


Figure 2

View of an 18-year-old male with a 44A1.2 fracture. (a) Preoperative radiograph showing an avulsion of the tip of the lateral malleolus. (b) Three-dimensional CT reconstruction showing the avulsion of the tip of the lateral malleolus. (c) Intraoperative picture after reduction and fixation of the fracture fragment with a 2.0-mm locking compression plate distal ulna hook plate and Kirschner wires for temporary fixation. (d) Anterior-posterior and (e) lateral X-rays 3 months postoperatively. (f) Anterior-posterior and (g) lateral X-rays 12 months postoperatively.

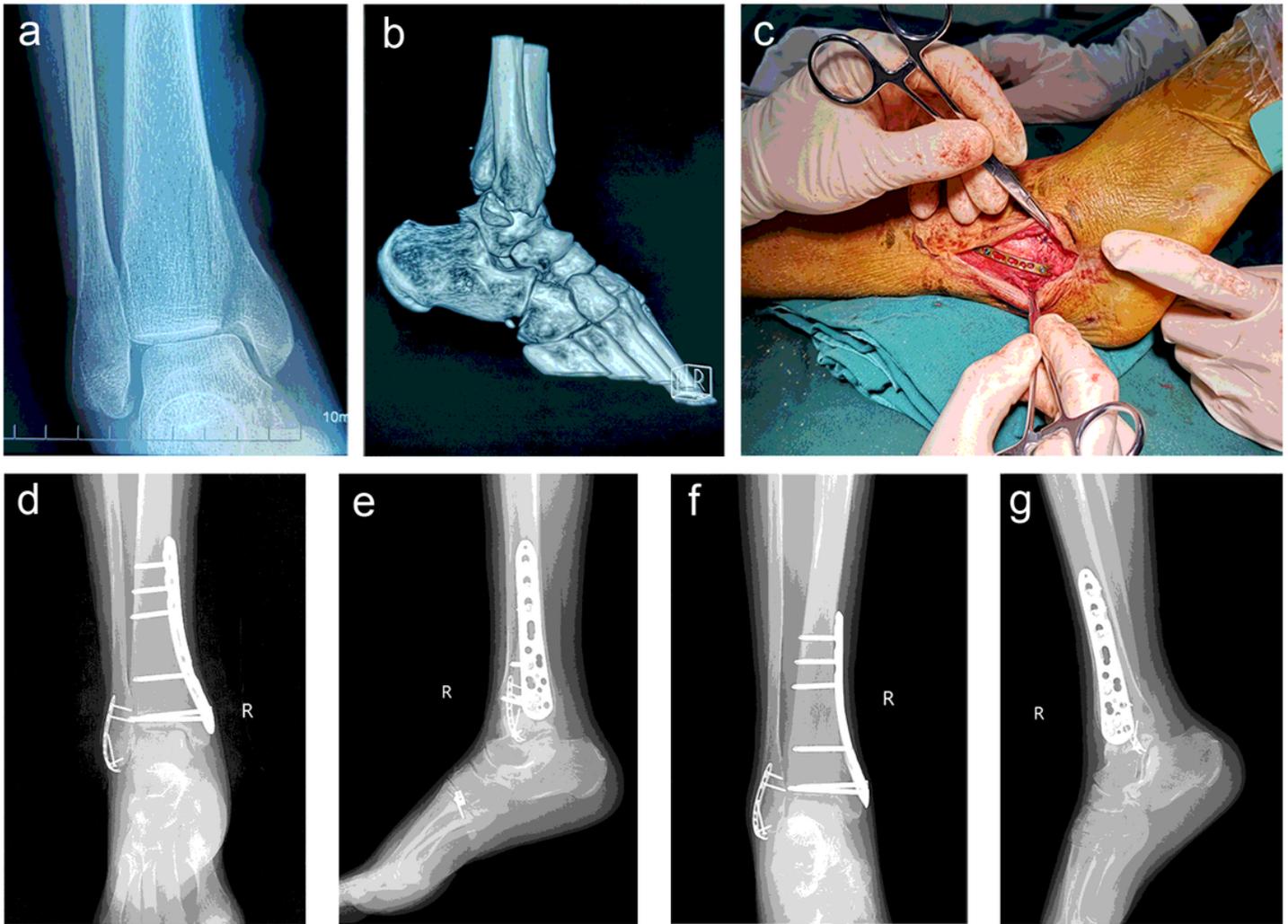


Figure 3

View of a 65-year-old female with a 44A2.2 fracture. (a) Preoperative radiograph showing avulsion of the tip of the lateral malleolus and vertical medial malleolar fractures. (b) Three-dimensional CT reconstruction showing the avulsion of the tip of the lateral malleolus. (c) Intraoperative picture after reduction and fixation of the lateral malleolar fracture fragment with a 2.0-mm locking compression plate distal ulna hook plate. (d) Anterior-posterior and (e) lateral X-rays 1 month postoperatively. (f) Anterior-posterior and (g) lateral X-rays 12 months postoperatively.

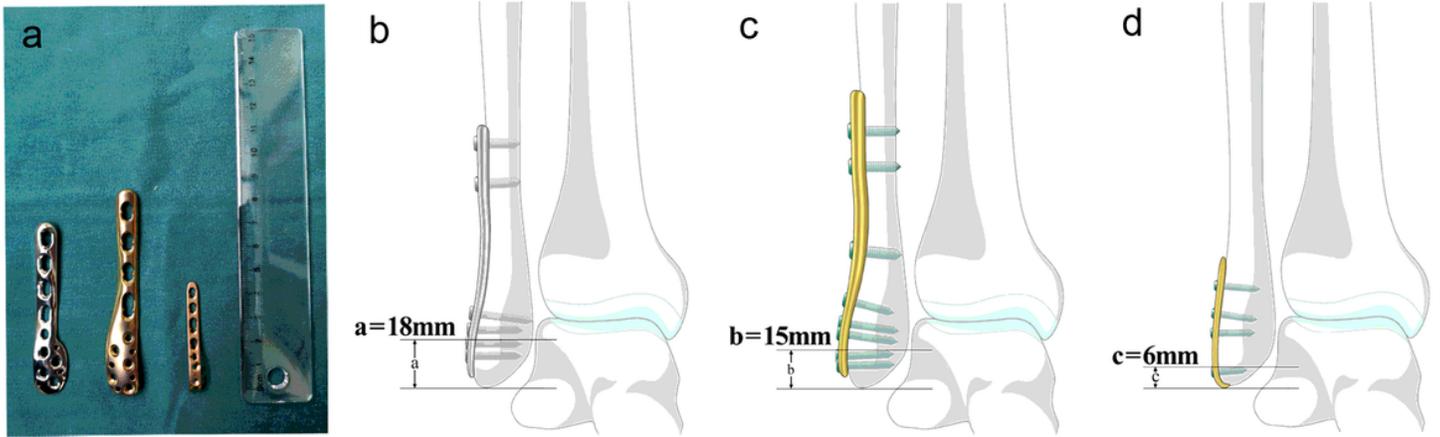


Figure 4

(a) Photograph of the distal fibula anatomical plate (Zimmer and DePuy Synthes) and 2.0-mm LCP distal ulna hook plate. (b) Computer graphics showing the penultimate screw at the distal end of the plate (Zimmer) is 18 mm from the tip of the lateral malleolus. (c) Computer graphics showing the penultimate screw at the distal end of the plate (DePuy Synthes) is 15 mm from the tip of the lateral malleolus. (d) Computer graphics showing the most distal screw of the 2.0-mm LCP distal ulna hook plate is 6 mm from the tip of the lateral malleolus.