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Ultrasound guidance in the surgical removal of internal fixators after complete healing of limb fractures

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Abstract

Purpose The aim of this study was to determine whether ultrasound guidance can reduce the duration, blood loss volume and invasiveness of surgery for internal fixator removal.

Methods The clinical data from 35 adults patients who underwent ultrasound-guided surgical removal of internal fixators after complete healing of limb fractures between June 2019 and April 2023 were retrospectively analysed and compared with those from 34 controls who underwent the procedure without ultrasound guidance. Data concerning the patients' demographic and clinical characteristics and surgical sites were collected. Differences in the patients' demographic and clinical characteristics were compared between the two groups.

Results Sixty-nine patients were enrolled in the study. Thirty-five patients underwent surgical removal of internal fixators with ultrasound guidance, and the average intraoperative blood loss volume was 15.17 ± 18.54 ml, average difference between the incision length and scar length was 4.24 ± 1.38 cm, average operation time was 60.66 ± 24.30 min, and average ultrasound assessment time was 10.00 ± 3.90 min. Thirty-four patients underwent surgical removal of internal fixators without ultrasound guidance, and the average blood loss volume was 46.76 ± 90.74 ml, average difference between the incision length and scar length was 2.68 ± 1.04 cm, and average operation time was 80.15 ± 58.84 min. The difference between the incision length and scar length was significant ($P < 0.01$), as was the difference in the intraoperative blood loss volume ($P < 0.05$) between the two groups.

Conclusion Ultrasound is a convenient, noninvasive, radiation-free technique that allows dynamic scanning of multiple sections regardless of patient position. Ultrasound-assisted removal of internal fixators might reduce bleeding and therefore the invasiveness of the procedure. Physicians can use ultrasound for preoperative patient

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positioning, intraoperative monitoring, and postoperative confirmation of complete removal of internal fixators if necessary.

Keywords Device removal, Ultrasonography, Small incision, Minimally invasive surgical procedures

Introduction

Implants are frequently removed after open reduction and internal fixation. Despite the extra expense, surgical implant removal is associated with few perioperative complications and benefits the patient in terms of improved biomechanics, less pain, increased range of motion, and improved postoperative function; moreover, surgical implant removal is associated with patient satisfaction and a lower risk of fixator breakage and facilitates the ease of secondary surgery in the event that the patient develops post-traumatic osteoarthritis [1–5].

In 2008, orthopaedic surgeons completed a survey to explore their perceptions of the indications for and risks associated with implant removal. 69% of respondents indicated that they would remove an implant if the patient experienced unexplained pain or functional deficits, and 48% reported that removal was riskier than leaving the implant in place [6, 7]. This hesitation is likely influenced by the possibility that numerous complications can occur during and after surgical implant removal [5].

Therefore, methods to safely assist the removal of internal fixators and reduce the incidences of surgical complications and trauma remain unknown.

In recent decades, the development of musculoskeletal ultrasound has led to its widespread use in orthopaedics, particularly in the period following orthopaedic surgery, when metallic hardware may affect the quality of images obtained via other imaging methods [8–10]. Some scholars have focused on the use of ultrasound to observe screws used as internal fixators. Studies have revealed that ultrasound could be used in the detection of postoperative screw penetration [11–13], the evaluation of mechanical tendon impingement or tendon tears caused by metal implants [14, 15], and the localized removal of interlocking femoral and intermedullary nails and screws [16, 17].

Hence, ultrasound guidance is expected to reduce the incidence of complications of surgical internal fixator removal. The aim of this study is to determine whether ultrasound guidance can reduce the duration, blood loss volume, and invasiveness of surgical removal of internal fixators.

Materials and methods

The Ethics Committee of The Seventh Affiliated Hospital of Sun Yat-Sen University approved the study (KY-2024-056-01). All procedures were conducted in accordance with ethical standards, and informed consent was obtained from all patients.

Study design and the inclusion and exclusion criteria

Patients aged 18 to 60 years who underwent open reduction internal fixation (ORIF) were assessed for study eligibility. One hundred twenty-three patients who underwent ORIF between June 2019 and April 2023 at the Department of Orthopaedics of the Seventh Affiliated Hospital of Sun Yat-Sen University were retrospectively enrolled.

The inclusion criteria were as follows: (1) sustained a closed limb fracture in the past 2 years and required ORIF. (2) Experienced symptoms following ORIF and showed complete healing (clinical evaluation and conventional serial radiographs indicate complete healing). (3) Requested removal. (4) Consented to ultrasound guidance before and during surgery.

The exclusion criteria were as follows: (1) Underwent ORIF more than two years before surgery. ($n=13$) (2) Did not consent to surgical removal of internal fixators under ultrasound guidance. ($n=16$) (3) Prior or current infection at the operative site. ($n=5$) (4) Fracture nonunion. ($n=5$) (5) Peripheral neuropathies. ($n=8$) (6) Ongoing litigation surrounding the initial injury or surgery. Moreover, 3 patients were excluded because of multiple operations for which the length of the surgical scar could not be determined.

Finally, sixty-nine patients were enrolled in the study. Patients who underwent ultrasound-guided surgical internal fixator removal were assigned to the experimental group, and those who underwent surgical fixator removal without ultrasound guidance were assigned to the control group. Moreover, 35 patients were in the experimental group, and 34 patients were in the control group (Fig. 1). Patient age, incision length, original incision scar length, difference between the incision length and scar length, intraoperative blood loss volume, operation time, body mass index (BMI), and patient height and weight were compared between the two groups.

Instruments and surgical technique

All patients underwent radiography before the operation to confirm that the fracture had completely healed, the internal fixator type (plate or nail (Dabo Medical Technology Co., Ltd., Shandong Weigao Group Co., Ltd.), and the number and location of K-wires and tension bands. All the manufacturers of the fixators documented before

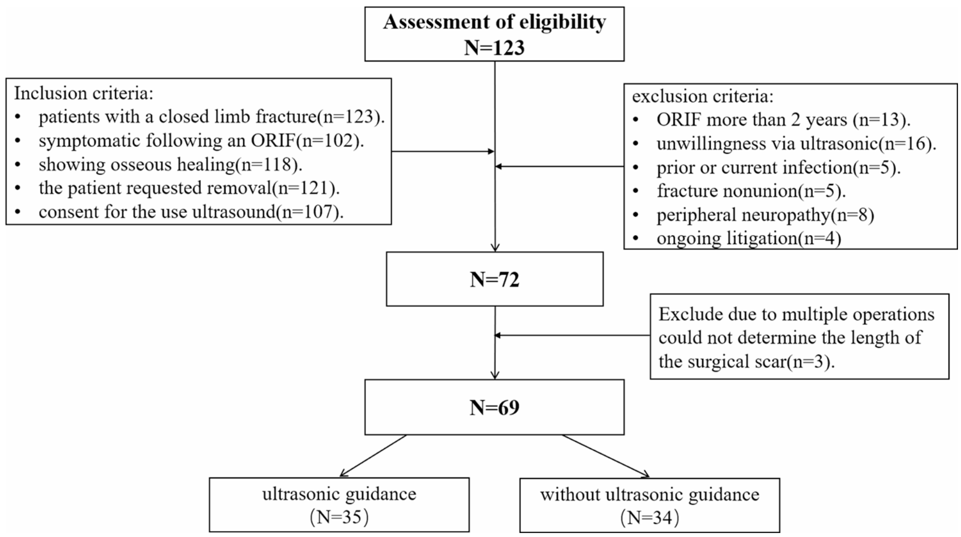

Fig. 1 Flow chart of patient selection for enrolment in the study

surgery, and all the tools were the same at the Seventh Affiliated Hospital of Sun Yat-Sen University.

For the control group, the operation was completed as usual. The patients were in the operative position. The surgical area was routinely palpated before disinfection. The surface of the skin was marked with a marker when the internal fixator was located via palpation. If the fixator was not located via palpation, the incision was made at the site of the original surgical incision.

Ultrasound examination method

All the patients in the experimental group underwent ultrasound-guided positioning by a surgeon before surgery. A sterile ultrasound gel was applied to the surface of the probe (4–12 MHz, M9 Expert; Mindray Medical International Limited, Shenzhen, China/5–12 MHz, BK Falcon 2101, BK Medical, Herlev, Denmark), followed by a sterile sleeve. Finally, the sterile ultrasound gel was reapplied to the surface of the probe to ensure aseptic operation. The position and direction of superficial and easily palpated screws were reconfirmed with a high-frequency probe. The high-frequency probe was used to scan the area near the scar first to locate unpalpable screws; if the screw could not be observed on the image of the scanned area, a low-frequency probe was used for scanning. Multisection dynamic scanning was continued until the screw was displayed.

Preoperative ultrasonography was used for localization and identification. If the internal fixators were not found near the mark intraoperatively, ultrasound was repeated to reduce the duration and trauma of surgery. Ultrasound could also be used postoperatively to confirm complete removal of the internal fixators.

Ultrasound detection of internal fixators

Owing to the capability of ultrasound to detect metallic objects, as evidenced by a strong echo and a comet tail sign, screws can be relatively easily visualized. The two mutually perpendicular sections on the body surface, both of which can show the internal fixators, were marked, and the approximate distance from the skin to the screw was measured (Fig. 2).

The adjacent structure of the screw could be observed on ultrasound images

In addition to observing the position of the screw, the structure around the nail can be visualized; if the screw is close to the vasculature or nerve, the surgical incision should be made as far away as possible. If the screw still cannot be located during the operation for various reasons, ultrasound could be used to identify the screw head, guide the screwdriver to reach it and avoid damaging the surrounding blood vessels and nerves (Fig. 3).

Postoperative ultrasonography

After the operation, when all the nail plates were removed, ultrasound examination was repeated with the aim of confirming whether there was residual implant material locally and the presence or absence of a haematoma or factors preventing healing in the incision area, such as neurovascular injury, which should be corrected immediately.

Attention to aseptic operation

Aseptic operation should be considered during and after the procedure. For example, the probe should be equipped with an aseptic sleeve, and aseptic gel should be used inside and outside the sleeve.

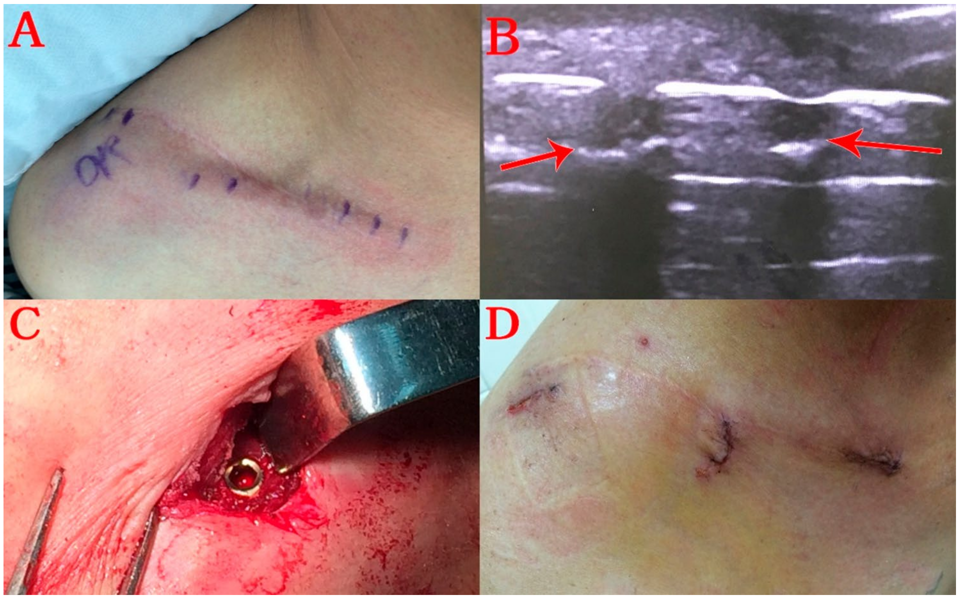

Fig. 2 A 43-year-old female underwent ultrasound-guided percutaneous removal of screws previously placed for fixation of a clavicular fracture via a mini-incision. **A** Preoperative skin markings and old scars. **B** Echo of the plate and screw on ultrasound (red arrow); **C** mini-incision showing the nail tail; **D** Skin incision after surgery

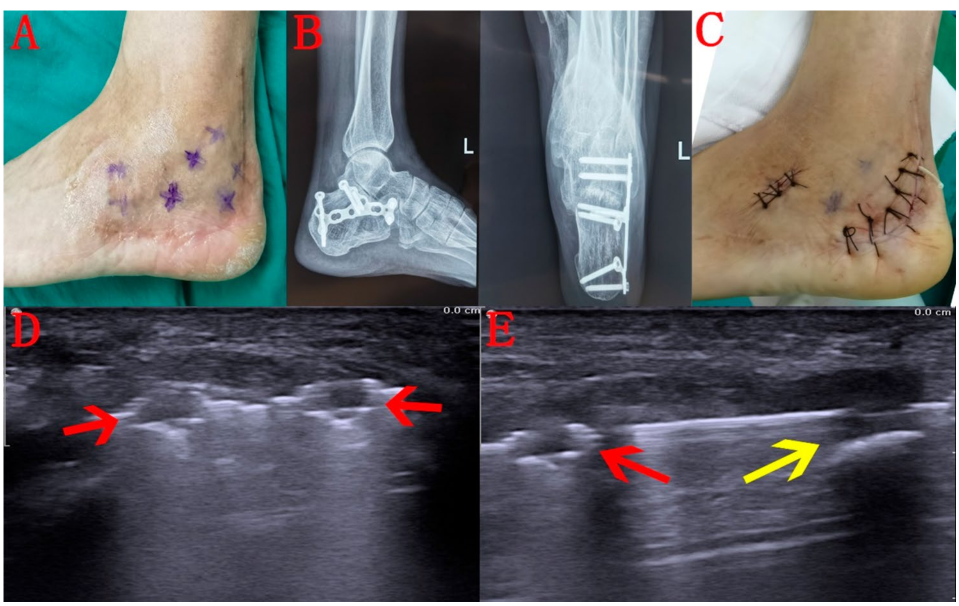

Fig. 3 A 51-year-old male underwent ultrasound-guided percutaneous removal of screws previously placed for the fixation of a calcaneal fracture via a mini-incision. **A** Preoperative skin markings and old scars. **B** Preoperative X-ray of the calcaneal fracture. **C** Skin incision after surgery; **D** and **E** Echo of the plate and screw on ultrasound (the red arrow represents an echo of the nail tail, and the yellow arrow represents an echo of a blank hole in the plate)

Statistical analysis

SPSS version 20 software (SPSS, Chicago, IL, USA) was used for all the statistical analyses. All values are expressed as means ± standard deviations. The power of the study was based on the standard deviation (SD) of the scar length minus the incision length (3.47 cm). On the basis of these differences, a sample size of 12 patients per group was needed, with a power (1-β) of 90% and a type I error (α) of 5%. An independent Student's t test was used to compare the differences in scar length minus incision length, operation time, age at surgery, and BMI between the experimental and control groups. A Mann–Whitney U test was used to compare the differences in incision length, scar length, intraoperative blood loss volume, and patient height and weight between the two groups. A P value < 0.05 indicated statistical significance.

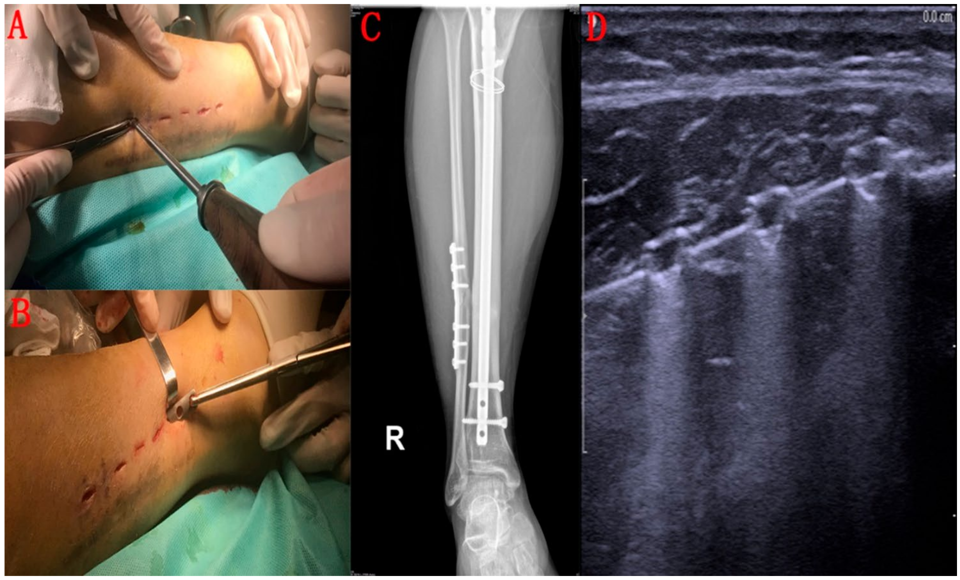

Fig. 4 A 53-year-old male underwent ultrasound-guided percutaneous removal of screws previously placed for the fixation of an ankle fracture via a mini-incision, **A** and **B** The surgeon identified screws and plates with ultrasound and removed them through a small incision. **C** Preoperative X-ray of the fibular fracture. **D** Echo of the plate and screw on ultrasound

Table 1 Demographic information of the two groups

Variable	Ultrasound guidance Group ($n=35$)	Without ultra-sound guidance Group ($n=34$)	*P* value
Sex (male/female)	23/12	22/12	-
Age at surgery, years	46.60 ± 11.52	42.76 ± 10.20	$P=0.148$
BMI (kg/m2)	24.76 ± 4.48	24.64 ± 2.99	$P=0.900$
Height, m	1.65 ± 0.11	1.66 ± 0.83	$P=0.466$
Weight, kg	67.91 ± 15.49	68.12 ± 9.59	$P=0.948$

Notes BMI stands for body mass index

Results

In both the experimental and control groups, the internal fixators were successfully removed by two senior surgeons, and their complete removal was confirmed via postoperative fluoroscopy. There were no postoperative complications, such as wound infection, in either group. In the experimental group, sonography provided good visualization of the screw and plate, so the position and depth of the screw and plate could be precisely determined at the beginning of the surgical procedure. The screw showed a remarkably strong echo with a comet tail sign, and the plate showed a thick linear strong echo (Fig. 4). Postoperative ultrasound examination revealed no residual internal fixator material during any of the operations.

Among the 69 patients, 35 underwent ultrasound-guided surgical removal of internal fixators, and 34 patients underwent surgical removal without ultrasound guidance. There were 45 males and 24 males aged 18 to 68 years. The mean age of the patients was 44.71 ± 10.98 years, the mean body mass index (BMI) was 24.70 ± 3.79 kg/m2, the mean height was 1.76 ± 0.10 m, the mean weight was 68.01 ± 12.83 kg, the mean blood loss volume was 30.74 ± 66.49 ml, the mean length of the incision was 6.88 ± 6.32 cm, the mean length of the original incision scar was 10.35 ± 6.63 cm, and the mean difference between the incision length and scar length was 3.47 ± 1.45 cm. The mean operation time was 70.26 ± 45.52 min.

The experimental group consisted of 23 males and 12 females (Table 1), with an average age of 46.60 ± 11.52 years. The mean BMI was 24.76 ± 4.48 kg/m2; the mean height was 1.65 ± 0.11 m; the mean weight was 67.91 ± 15.49 kg; the mean intraoperative blood loss volume was 15.17 ± 18.54 ml (Table 2); the mean length of the incision was 5.83 ± 3.92 cm; the mean length of the original incision scar was 10.07 ± 4.49 cm; the mean

Table 2 Clinical evaluation of the two groups

Variable	Ultrasound guidance Group ($n=35$)	Without ultrasound guidance Group ($n=34$)	*P* value
The length of the incision, cm	5.83 ± 3.92	7.96 ± 8.00	$P=0.164$
The scar length of the original incision, cm	10.07 ± 4.49	10.63 ± 8.35	$P=0.728$
Scar length minus incision length, cm	4.24 ± 1.38	2.68 ± 1.04	$P<0.001$
Intraoperative blood loss, ml	15.17 ± 18.54	46.76 ± 90.74	$P=0.048$
Operation time, minutes	60.66 ± 24.30	80.15 ± 58.84	$P=0.075$

Table 3 Surgical site details in the two groups

Surgical site	ultrasound guidance	without ultrasound guidance	type of removed implant
Total	35	34	-
Humeral fracture	2	2	plate and nail
Radius and ulna fracture	4	4	plate and nail
fracture of distal radius	2	1	-
Olecranon fracture	2	3	-
Metacarpophalangeal fracture	2	3	plate and nail
Femoral fracture	3	2	plate and nail
Tibial and fibular fractures	12	11	plate and nail
Ankle joint	6	6	-
tibial and fibula shaft fracture	2	2	-
Fracture of tibial plateau	4	3	-
Patella fractures	8	9	K-wires and tension band
Calcaneus fractures	1	1	plate and nail
Clavicle fracture	3	2	plate and nail

difference between the incision length and scar length was 4.24±1.38 cm; and the mean operation time was 60.66±24.30 min. The mean ultrasound assessment time was 10.00±3.90 min.

The control group consisted of 22 males and 12 females (Table 1), with an average age of 42.76±10.20 years. The mean BMI was 24.64±2.99 kg/m2; the mean height was 1.66±0.83 m; the mean weight was 68.12±9.59 kg; the mean blood loss volume was 46.76±90.74 ml (Table 2); the mean length of the incision was 7.96±8.00 cm; the mean length of the original incision scar was 10.63±8.35 cm; and the mean difference between the incision length and scar length was 2.68±1.04 cm. The mean operation time was 80.15±58.84 min. The details of the surgical sites are shown in Table 3.

Statistical analysis revealed that the difference in scar length minus incision length between the experimental group and the control group was statistically significant ($P<0.01$), and the intraoperative blood loss volume between the two groups significantly differed ($P<0.05$). Other factors, such as age at surgery ($P=0.148$), length of the incision ($P=0.164$), scar length of the original incision ($P=0.728$), BMI ($P=0.90$), height ($P=0.466$), weight ($P=0.948$), and operation time ($P=0.075$), were not significantly different between the two groups. However, the operation time in the experimental group was shorter than that in the control group, although the difference was not significant.

All the data are shown in Tables 1 and 2, and Table 3.

Discussion

Compared with other imaging methods, ultrasound can detect metal implants and is noninvasive, nonradiative, convenient, real-time dynamic, and low-cost. On ultrasound, internal fixators present a clear, strong echo followed by the comet tail sign. A simple scan of the target area allows the inspector to easily locate fixation screws [11–13, 16–24].

Although the use of ultrasound to remove femoral and tibial intramedullary nails has been reported, the use of ultrasound to remove metal materials in other parts is rare. Ultrasound is highly useful in different aspects of surgery for internal fixator removal. It can be used to locate internal fixators before the operation [16, 17, 25], monitor the progress of surgery when necessary [26, 27], confirm the complete removal of internal fixators and ascertain the presence or absence of postoperative complications, such as local muscle, vascular, or nerve damage or haematoma [10, 18, 28].

Although ultrasound cannot penetrate the internal fixator, we can slightly adjust the probe direction or patient position to better visualize the area of interest and avoid interference of metal hardware [16]. As in our study, preoperative ultrasound can accurately locate the screw so that a smaller incision is needed. It also helps prevent damaging the critical vascular nerves around the screw.

In this study, the intraoperative blood loss volume was significantly lower in the ultrasound-guided group than in the nonultrasound-guided group, and the difference in scar length minus incision length was significantly greater in the ultrasound-guided group than in the nonultrasound-guided group. The operation time in the ultrasound-guided group was shorter than that in the nonultrasound-guided group; however, there was no significant difference, which might be related to the small sample size of this study. The conclusion that a smaller incision means less bleeding and a shorter operation time [29] was also confirmed in this study. Intraoperative ultrasound-guided removal of internal fixators can reduce injury, and small incisions can minimize bleeding and shorten the operation time. These findings indicate that ultrasound has certain advantages in guiding the removal of internal fixators and can play an essential role in the operation. In particular, ultrasound-guided internal fixator removal has clinical value, especially in the operating rooms of essential hospitals in developing countries, because of the relative lack of radiation equipment.

Finally, since ultrasound also has advantages over X-ray or CT imaging of soft tissue, postoperative ultrasound evaluation is also essential. The application of ultrasound in assessing orthopaedic trauma has often been reported [10, 15, 18]. If there is a vascular nerve or a muscle-tendon injury, it can be treated in time.

In this study, we wanted to show that ultrasound guidance is useful for this type of surgery, especially for junior doctors who are not experienced in surgery and cannot always palpate the implant due to its deep location or patient obesity. Ultrasound has advantages over X-ray in terms of its convenience, noninvasiveness, lack of radiation, and multisection dynamic scanning ability. Moreover, ultrasound is also very advantageous for displaying soft tissue, blood vessels and nerves. Hence, intraoperative exploration of the soft tissue adjacent to the surgical area can be assisted by ultrasound if necessary. Of course, this does not mean that every surgery should be performed under ultrasound guidance; in practical applications, ultrasound is only used to assist the surgeon when necessary. Moreover, we highly recommend the use of aseptic gel and an aseptic sleeve for intraoperative ultrasound to reduce the risk of infection.

The limitations of this study are as follows. First, although the screw tail and plate can be visualized by ultrasound, ultrasound cannot penetrate the bone; thus, it cannot detect the path and direction of the nail, which still needs to be determined by X-ray or CT. Second, this was a retrospective study, and the small number of comparable cases of fractures at the same site limits the reliability of the findings. In the future, multicentre large-sample, randomized controlled studies are needed to further confirm the accuracy of the research results. Third, this study was not focused on postoperative complications or postoperative functional recovery, so further studies are needed to confirm the effects on postoperative pain, postoperative quality of life, and postoperative joint mobility.

Conclusion

Ultrasound is useful in the surgical removal of internal fixators. Ultrasound guidance can reduce bleeding and the invasiveness of surgical removal. Physicians might use ultrasound for preoperative positioning, intraoperative monitoring, and postoperative confirmation of complete internal fixator removal if necessary. The relevant results need to be further confirmed in future multicentre, large-sample, prospective studies.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12893-024-02730-7.

Supplementary Material 1
Supplementary Material 2
Supplementary Material 3
Supplementary Material 4
Supplementary Material 5
Supplementary Material 6
Supplementary Material 7
Supplementary Material 8
Supplementary Material 9
Supplementary Material 10
Supplementary Material 11
Supplementary Material 12
Supplementary Material 13

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Not applicable.

Author contributions

All authors contributed to the study conception and design. Material preparation was performed by [J.L.], [W. L.] and [L. L.], data collection was performed by [J.W.], [T. S.] and [P. C.] and analysis were performed by [S. H.], [Y. H.] and [W. L.]. The first draft of the manuscript was written by [J. L.], [L. L.] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability

The datasets used or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The Seventh Affiliated Hospital Ethics Committee of Sun Yat-sen University approved the study. All procedures were performed in accordance with ethical standards, and informed consent was obtained from all patients.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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