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TRAUMA SURGERY

Staged internal plate fixation of severe lower extremity fractures that use a temporary external fixator for the initial treatment as an intraoperative retention tool: a technical note

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Abstract
Staged treatment for severe lower extremity fractures is coming into widespread use, and some reports have described internal fixation (IF) using a temporary external fixator for primary care as an intraoperative retention tool. However, the infection risk with this procedure has not been examined sufficiently. To our knowledge, this article is the first report focusing exclusively on this specific surgical technique. A key point of our developed protocol for internal plate fixation with this technique to avoid postoperative infection is a precisely structured sterilization procedure, which required multiple changes of sterile surgical gloves. In all 19 fractures treated with our set protocol, postoperative infection did not occur. In this regard, however, a goal of definitive IF at the time of initial treatment is essential for this specific procedure. This technique could help orthopaedic trauma surgeons to import a temporary external fixator into the operative field for definitive IF, with less concern regarding risk of infection.

Keywords Lower extremity fracture · Open fracture · Staged treatment · External fixation · Infection · Sterilization

Introduction

A staged approach for polytraumatized or high-energy lower extremity fractures is becoming more common [1–3]. Specifically, this approach involves the initial temporary external fixation (EF) as primary care, followed by definitive fixation when the patient's general condition and soft-tissue status allow. A major problem with this staged approach using a temporary EF is superficial pin tract infections [4, 5]. Shah et al. reported that definitive plate fixation overlapping the previous EF pin sites significantly increased the infection risk in the staged approach for lower leg fractures [6].

On the other hand, some surgeons have performed internal fixation (IF) that uses a temporary external fixator for primary care as an intraoperative retention tool, to maintain reduced alignment and protect the soft tissues [7, 8]. In these reports, not only EF pins but also rods and clamps applied during the primary treatment were diverted directly to the operative field for definitive IF. However, the infection risk associated with using all the components of the temporary external fixator for primary care in the definitive operative field has not been clarified. We hypothesized that the infection risk of this technique is acceptable, and we administered a treatment protocol on a trial basis. Here, we report a completely meticulous sterilization procedure in our departments and demonstrate the possible safety of this specific strategy in terms of avoiding postoperative infection.

Surgical technique

Between 2012 and 2017, we performed staged internal plate fixation using a temporary external fixator for the initial treatment as an intraoperative retention tool for 19 lower extremity fractures in 17 consecutive patients (12 men, 5 women; mean age at injury, 52.5 ± 16.1 years; age range,

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17–81 years) who were treated with a treatment protocol established by two hospitals. Three were femoral fractures and sixteen were lower leg fractures. This study was approved by the institutional review board of the authors' institutions. Informed consent was obtained from the patients in the orthopaedics departments of both participating hospitals.

Treatment protocol was as follows. Temporary EF with the Hoffmann II (Stryker Trauma AG, Selzach, Switzerland) was initially performed for polytraumatized or high-energy lower extremity fractures. When good alignment (length, axis, and rotation) was achieved with the temporary EF and no clinical sign of infection was seen at the EF pin insertion site or the open wound, we planned to perform definitive plate fixation maintaining the reduced alignment with the primary external fixator. Fractures that were ideal indications for intramedullary nailing, those needing multiple internal fixations, or patients with severe immunocompromise were excluded from undergoing this procedure. For internal plate fixation that was performed several days after the initial treatment, we preliminary sterilized the EF components using ethanol-containing antiseptic (0.5% chlorhexidine alcohol or 0.2% benzalkonium chloride). We then sterilized the operative field using povidone iodine applied with a brush while wearing sterile surgical gloves (Fig. 1). After the scrub and changing into new sterile gloves, we put on a sterile gown and repeated sterilization using povidone iodine and covered the EF components with a sterile plastic wrap, followed by applying pieces of tape to the plastic wrap. We then changed to a new set of sterile gloves again, and plate fixation was performed. Basically, the EF components were removed immediately after IF. We again changed our gloves, and performed debridement of the EF pin insertion sites and surgical wound closure. However, we occasionally continued spanning EF for a few days after plate fixation to protect the soft tissue.

Surgical outcomes of 19 severe lower extremity fractures treated with this careful sterilization procedure are listed in Table 1, and representative cases are shown in Figs. 2, 3, and 4. In all 19 fractures, postoperative infection did not occur clinically during follow-up for the medium term (mean follow-up period, 44.3 ± 21.0 months).

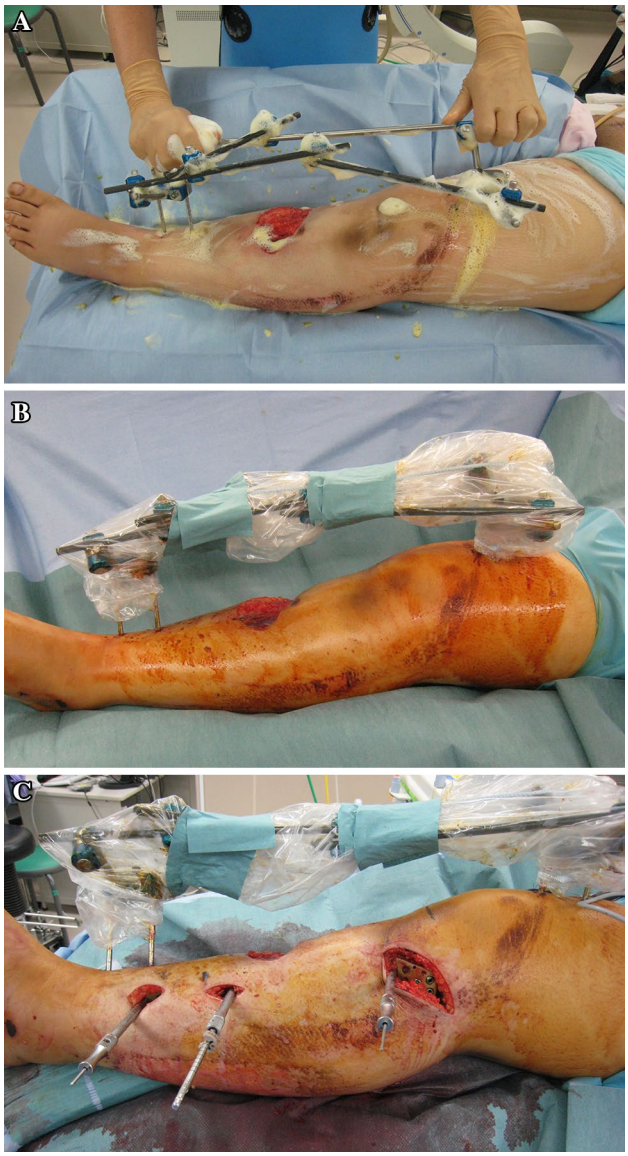

Fig. 1 Surgical technique. **a** Operative field is sterilized using ethanol-containing antiseptic and povidone iodine with a brush. **b** After the scrub, sterilization is repeated using povidone iodine and the external fixation components are covered with a sterile plastic wrap, applying tape to the plastic wrap. **c** Internal plate fixation is performed using the external fixator as an intraoperative retention tool

Discussion

In relation to the decontaminating effect of povidone iodine on EF components, it was reported that the bacterial content in clamps was higher than that in pins or rods and was significantly increased by loosening the clamps [9, 10]. For this reason, when using the specific procedure described here, it is recommended to not loosen the clamps after beginning asepsis (Fig. 5). In some cases which needed the alignment to be fine-tuned immediately before sterilization, we basically complied with covering the EF components with a sterile wrap and never loosening the clamps until the completion of internal plate fixation. Although chlorhexidine–alcohol is superior to povidone iodine in the prevention of surgical site infection [11], its presence ($\geq 0.5\%$) in the open wound may cause anaphylactic shock [12, 13]. Therefore, when performing staged plate fixation using this new method, it is vital to ensure that the clamps not be loosened after sterilization and that the chlorhexidine–alcohol not be let into the open wound, including at the EF pin insertion site.

Table 1 Surgical outcomes

Case no.	Age (years)	Sex	ISS	Fracture (*n*)	Side of fracture	AO/OTA classification	Gustilo classification	Tissue graft	Overlap of EF pin and plate	Waiting period (days)	Follow-up period (months)	Postoperative infection
1	33	M	34	1	L	33-C1	I	–	−	7	72	–
2	64	F	9	2	L	41-C2	IIIa	–	−	10	71	–
3	81	M	9	3	L	41-C2	IIIa	STSG	−	15	68	–
4	47	M	14	4	R	43-A3	IIIb	LD-free flap + STSG	−	11	63	–
5	62	M	13	5	L	41-C3	–	–	−	17	63	–
6	73	F	41	6	R	44-B2	IIIa	–	−	2	58	–
7	38	M	9	7	R	32-A3	–	–	+	6	55	–
				8	R	42-A3	–	–	+	6	55	–
8	50	M	9	9	L	33-C2	IIIa	FTSG	−	7	48	–
				10	L	41-A3	IIIa	–	+	7	48	–
9	45	M	10	11	L	43-A2	I	–	−	10	46	–
10	41	M	22	12	R	41-C2	IIIa	–	−	7	50	–
11	57	M	19	13	L	41-C2	–	–	−	15	49	–
12	40	F	45	14	L	41-A3	IIIb	Soleus muscle flap + STSG	+	8	24	–
13	77	F	9	15	L	41-A2	IIIa	–	−	7	25	–
14	60	M	9	16	R	43-C3	II	–	−	9	13	–
15	17	F	9	17	R	41-C2	IIIa	–	+	7	12	–
16	57	M	9	18	L	43-C3	IIIb	ALT-free flap	−	11	12	–
17	50	M	10	19	R	44-B1	–	–	−	10	9	–
mean	52.5 ± 16.1		15.7 ± 11.3							9.1 ± 3.5	44.3 ± 21.0	

ALT anterolateral thigh, *EF* external fixation, *FTSG* full-thickness skin grafting, *ISS* injury severity score, *LD* latissimus dorsi, *STSG* split-thickness skin grafting; waiting period, days from initial EF to definitive plate fixation

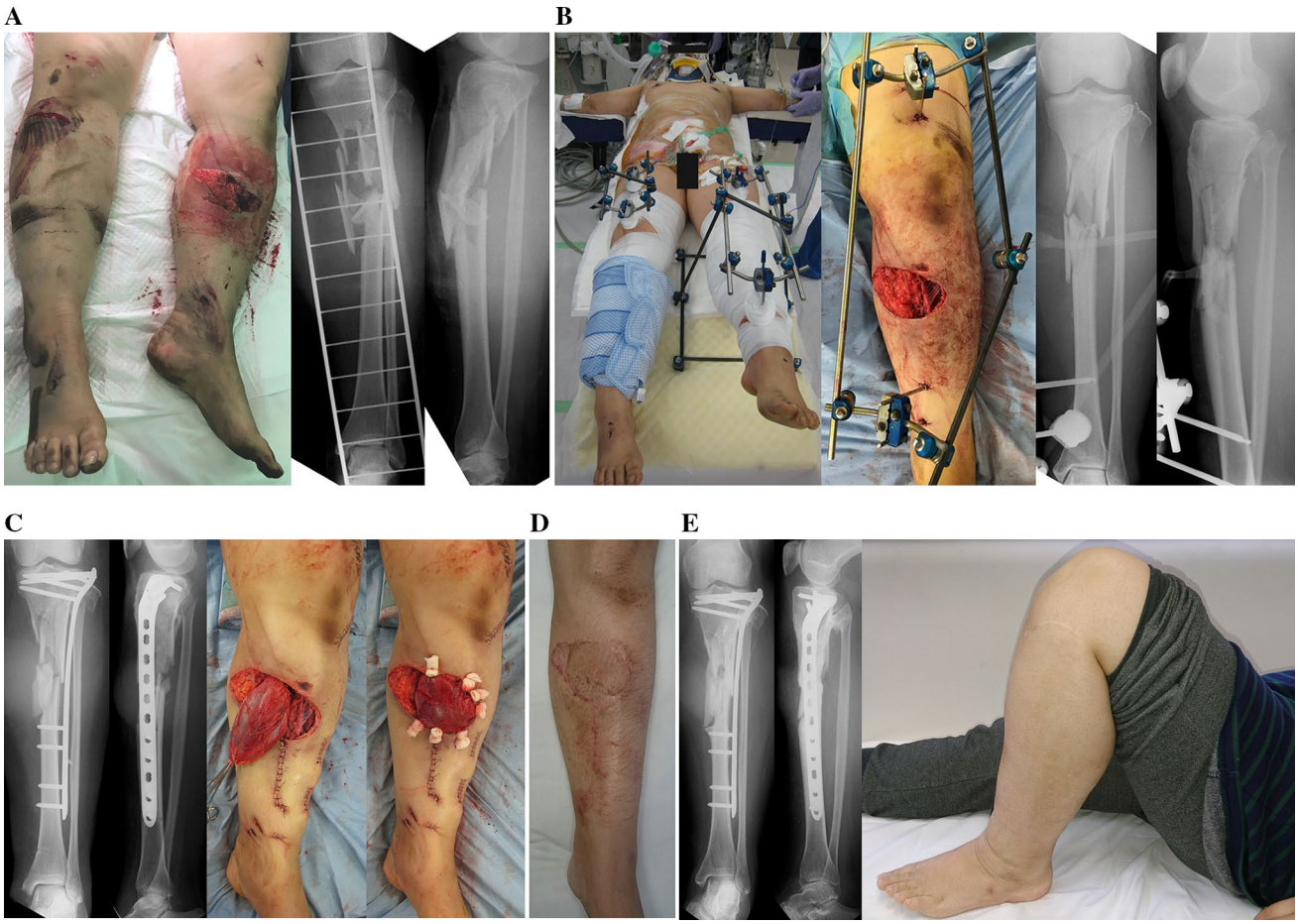

Fig. 2 Fracture No. 14 (Case 12). **a** Gustilo IIIb open fracture of the left lower leg in a polytraumatized 40-year-old woman. Injury severity score was 45. **b** Lower extremities were treated by external fixation as primary care, and the left tibial fracture site was completely exposed after debridement. Acceptable alignment of the left tibia was achieved by spanning external fixation. **c** On day 8 after injury, we performed definitive plate fixation, using the temporary external fixator for the initial treatment by a meticulous sterilization procedure illustrated in Fig. 1, and creation of a pedicled soleus muscle flap. **d** Macroscopic picture of the left lower leg at 5 months after injury. There were no soft-tissue complications. **e** Delayed but clinical union is achieved at 2 years after surgery. She is able to walk with excellent knee function

The period of infection risk associated with IF following EF has been reported to be 2 weeks for femoral shaft fractures and 50 days for tibial shaft fractures [14, 15]. In definitive IF, however, all of the EF components were basically removed before sterilizing the affected limb in these reports. The listed case series in the present report consisted of relatively severe cases of femur and lower leg fractures, and thus, a waiting period of within about 2 weeks for the described procedure should carry an acceptable risk of infection.

Cases 4, 12, and 16 in this article were Gustilo IIIb open fractures of the lower leg, and all 3 cases were treated with fixation and a flap, while the temporary external fixator for primary care was kept in place. The waiting period was 11 days in Case 4, 8 days in Case 12, and 11 days in Case 16. In these cases, postoperative infection did not occur. The plate fixation method reported here can, therefore, also be applied to Gustilo IIIb open fractures, but we suggest that the waiting period from initial EF to definitive IF could be best limited to within about 1 week in cases with Gustilo IIIb open fractures.

This report had several limitations. Although a prospective clinical case series of consecutive patients treated with the treatment protocol described here showed no cases with postoperative infection, this series was not a comparative study and included a small number of patients. Furthermore, before the decision to perform IF using the present method, infection in the EF pin insertion site or the open wound was only assessed clinically without any bacterial culture. Thus, a prospective randomized-controlled

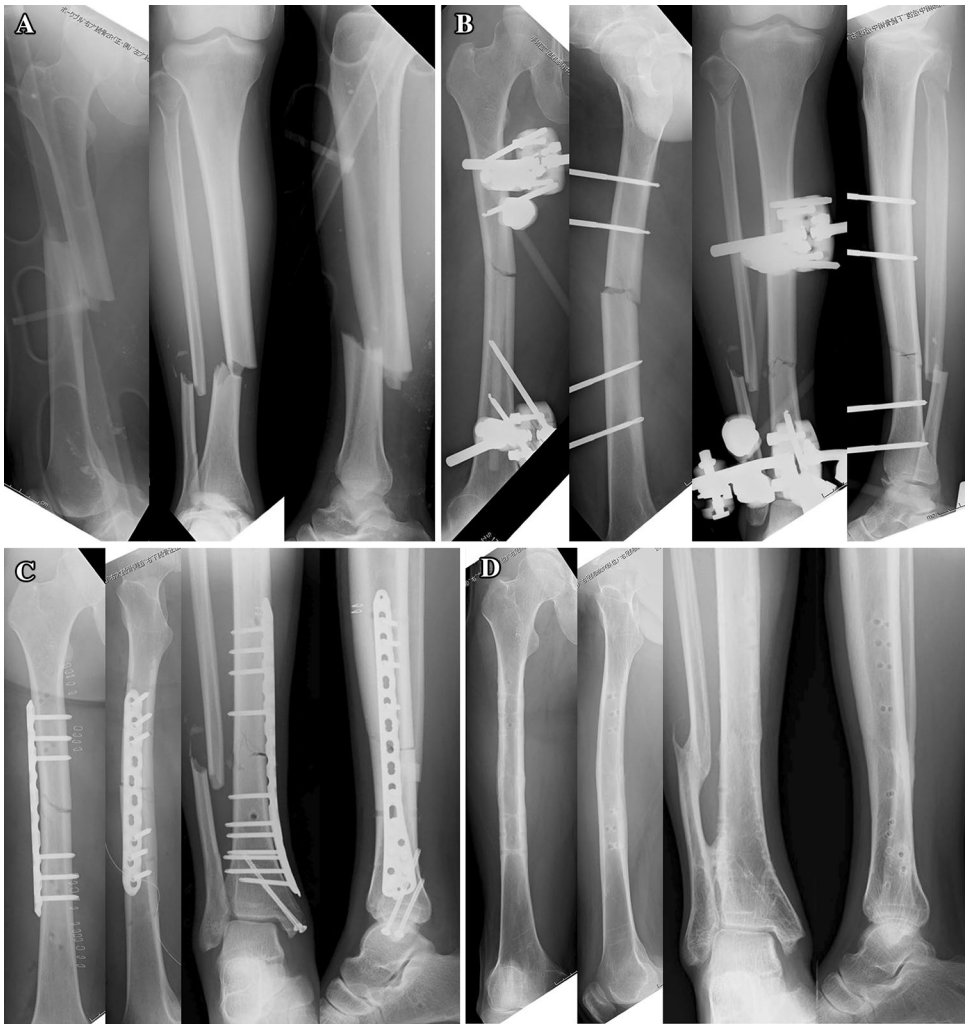

Fig. 3 Fracture No. 7 and 8 (Case 7). **a** Floating knee injury of the right lower extremity in a 38-year-old man complicated by severe fat embolism syndrome immediately after the injury. **b** External fixation was performed as damage-control orthopaedic care. **c** On day 6 after injury, definitive plate fixation with the temporary external fixator for primary treatment in place was performed. The alignment of the femur was fine-tuned just before sterilization. **d** Radiographs at 2 years after injury. Bone union is achieved and implants are removed

study in a larger number of patients is needed to confirm our suggestions.

Conclusions

We have described a novel and completely meticulous sterilization procedure for staged plate fixation of lower extremity fractures using a temporary external fixator for the initial treatment. We suggest that the infection risk associated with this technique might be little to none provided, however, that the established protocol with multiple changes of sterile gloves is followed strictly. Since the infection risk caused by an overlap of the EF pin insertion site and plate fixation area should be considered, this procedure requires a set goal of definitive IF at the time of initial EF.

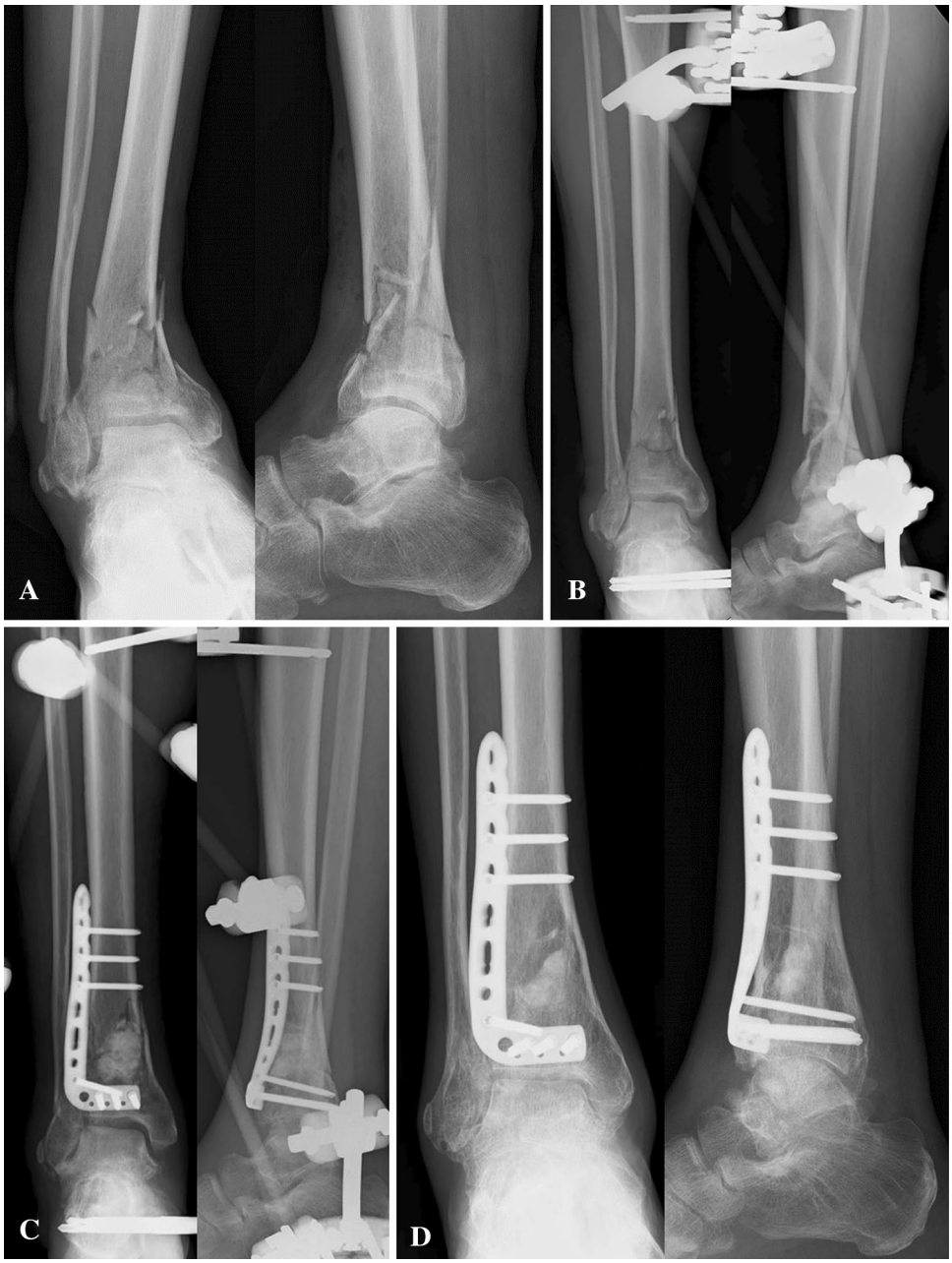

Fig. 4 Fracture No. 16 (Case 14). **a** 60-year-old man suffered a Gustilo II open pilon fracture of the right tibia in a fall. **b** Spanning external fixation was performed just after the injury. At this point in the treatment course, pin insertion sites were located well away from the planned plate fixation area. **c** On day 9 after injury, plate fixation using the temporary external fixator, and artificial bone graft were performed. **d** Firm bone union is achieved at 13 months after surgery

1. **Never loosen the clamps of the EF after beginning asepsis.**
2. **Preliminarily sterilize the EF components using fast-acting chlorhexidine-alcohol.**
3. **Sterilize the operative field (including EF components) with a brush using povidone-iodine, while wearing sterile gloves.**
4. **Wipe with a sterile cloth.**
5. **Scrub, change into new sterile gloves and put on a sterile gown.**
6. **Sterilize the operative field (including EF components) again using povidone-iodine.**
7. **Cover the EF components with a sterile plastic wrap, and apply tape.**
8. **Change to another set of sterile gloves again, and then start the internal plate fixation.**

Fig. 5 Specified sterilization protocol. *EF* external fixation

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Compliance with ethical standards

Ethical approval This study was approved by the institutional review board of the authors' institutions. All procedures performed involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all participants included in the study.

Conflict of interest The Department to which the first author belongs received funding for operating costs from Saku Central Hospital of the Nagano Prefectural Federation of Agricultural Cooperatives for Health and Welfare, Medtronic Sofamor Danek Co., Ltd., Stryker Japan Co. Ltd., HOYA Technosurgical Co., Ltd., and A-Z Co. Ltd. All other authors declare that they have no conflicts of interest.

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