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Application of Ortho-Bridge System after Femoral Bone Transport

Aplikace systému Ortho-Bridge po transportu stehenní kosti

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SUMMARY

The bone transport technique uses the principle of distraction-osteogenesis and fill bone defects with the aid of an external fixator. In order to evaluate the clinical effect of femoral internal fixation with Ortho-Bridge System after bone transport, 4 patients after femoral bone transport from October 2020 to October 2022 are studied in this paper. Among them, 3 patients ran refracture of femur after removal of the Limb reconstruction system, 1 patient just finish femoral bone transport and request internal fixation. The surgery results show that Ortho-Bridge System can be used in the situation that conventional Locking compression plate and intramedullary nail are not suitable due to anatomical variation after femoral bone transport.

Key words: femoral fracture; Ortho-Bridge System; bone transport; postoperative complications of bone transport.

1 INTRODUCTION

The bone transport technique is invented by Gavril Abramovich Ilizarov of the Soviet Union in 1950. This technique uses the principle of distraction-osteogenesis and can fill bone defects with the aid of an external fixator (1, 7). It is usually applied to treat diseases that cause bone defects such as chronic osteomyelitis, fracture nonunion, limb deformity, and bone tumor (5). To date, it has gradually become the main treatment for bone defects (4), but high complications of this method have been reported in some clinical studies, such as pin tract infection, limitation of joint movement, long fixation time, and refracture after removal of external fixator (8, 10). In order to reduce these complications, it is recommended to change into internal fixation after bone transport. The conventional internal fixation devices are intramedullary nail and anatomical locking plate (6). As for some long-segment bone transport cases, the femoral bones lost their anatomical contours, such as the loss of anterior arch, proximal or distal axial deviation and so on. These cases are difficult to apply internal fixation with normal intramedullary nails or anatomical locking plates.

Ortho-Bridge System is mainly composed of connecting rod, fixing slider and screw, and it is made of titanium alloy. Cylindrical connecting rods are available in various sizes from 2.5 mm to 6 mm in diameter. The fixed sliding block has various types such as single rod single hole, single rod double hole, double rod single hole, and double rod double hole, which are rectangular, with holes at the edge to facilitate the passage of connecting rod. The screw hole is designed in the center. The specially designed screws can be locked by "clasping" the connecting rod by squeezing the fixation slide. It has several advantages, such as its three-dimensional fixation, its locking combined structure which can disperse stress more effectively, and the same nail which applies to patients with osteoporosis. It is also a minimally invasive operation that protect the blood supply around the fracture end, and an elastic fixation that can effectively reduce stress shielding. Because the bridging combined internal fixation system has different specifications, it can flexibly select the screw placement position and combined plan, individualize the customized surgical plan, and effectively solve complex cases. As a new type of internal fixation device, the bridging combined with the internal fixation system is a meaningful attempt in the treatment of the situation that the

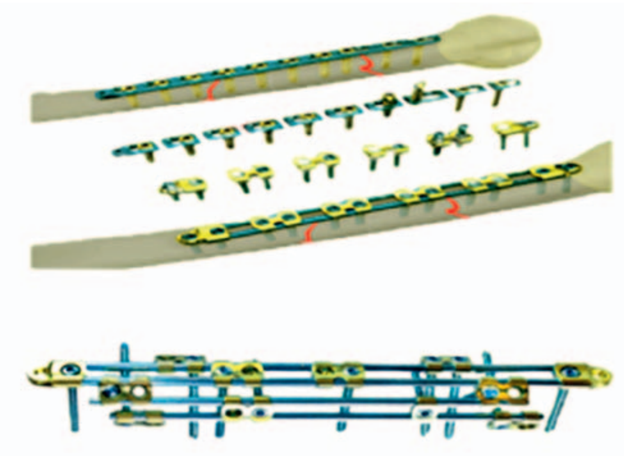

Fig. 1. Bridged modular internal fixation system.

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conventional plate and intramedullary nail cannot be used due to anatomical variations after femoral bone transport. From October 2020 to October 2022, the system is used to immobilize 6 patients after the completion of femoral bone transport, as shown in Figure 1.

The rest of this paper is organized as follows: Section 2 discusses relevant research and summary analysis, followed by the Patients information and surgical methods in Section 3. The comparative analysis and data statistics is discussed in Section 4. Section 5 concludes the paper with summary and future research directions.

2 RELEVANT WORK

Ilizarov bone transport technique (IBT) has good clinical efficacy in the treatment of lower limb traumatic osteomyelitis, infectious bone defects, and other diseases caused by high-energy trauma such as traffic accidents and falls from height. According to clinical reports, patients after bone transport are associated with many complications, such as poor osteogenesis at the transport end, and long-term external fixator fixation that makes the patient's knee stiff and causes anxiety (3). Therefore, they often require the replacements of internal fixations. However, after handling, the femoral carrying end often deviates axially, causing anatomical variations. In this case, conventional Locking compression plates with intramedullary nails are not suitable.

The Ortho-Bridge System includes connecting rod, fixing block, and locking screw. The connecting rods are divided into two types: threaded type and smooth type. The diameter varies from 2. 5 mm to 6 mm. Fixed sliders are available in single rod single hole, single rod double hole, double rod single hole, and double rod double hole. Locking screws rivet with block threads, block gap compression, connecting rod tightening, tail cap and connecting rod tightening, and triple locking mechanism form a stable three-dimensional stereoscopic fixation structure (2). In the treatment of replacement of internal fixation after femoral bone transport, the fracture is directly reduced after limited dissection of the soft tissue of the fractured segment by incision and short segment single rods are placed anteriorly. The single rod slider can be rotated in all directions around the connecting rod, and the screw can be inserted at an angle that avoids important blood vessels and nerves. The cortical penetration length of the screw can be extended as far as possible to improve stability. The initial reduction facilitates the placement of the lateral dual rod construct using the MIP0 technique. Depending on the fixation needs, the slider can slide freely on the connecting rod, avoiding the anterior screws, and creating an optimal screw distribution. The anterior single rod and the lateral double rod can also be connected by the double rod slider, if necessary, to form a polyaxially locked overall construct. These internal fixations are located on the tensile side of the femur, which can effectively resist the coronal and sagittal bending forces and provide a convenient solution for complex surgical conditions. Different specifications, models, three-dimensional multi-directional locking fixation, and more choices in the direction of screw placement position meet the clinical needs of personalized internal fixation after bone transport, and conducte finite element analysis and biomechanical analysis on the bridging internal fixation system and steel plate, and conclude that in the internal fixation of femoral fracture, the bridging system internal fixation has better biomechanical properties than the Locking compression plate - the fixation is more reliable, the stress is more effectively dispersed, and the risk of fracture failure is lower, which is a better choice for internal fixation of fracture (9).

The advantages of bridging combined internal fixation system in the treatment of femoral bone transport after the operation are that there is no need to dissect the periosteum too much during the operation, which does not affect the fracture end; the fixation module can slide axially, which can reduce the rejection reaction of internal fixation, does not produce stress shielding, and is conducive to promoting fracture healing. In addition, the bridging combined internal fixation system has the characteristics of three-dimensional fixation, which conforms to the biomechanical fixation principle and can prevent the loosening or breakage of internal fixation, especially suitable for elderly patients or patients with osteoporosis, which is conducive to their early functional exercise.

3 PATIENTS INFORMATION AND SURGICAL METHODS

3.1 Clinical data

Four patients (3 males and 1 female, aged 41, 57, 62, 32, mean 48 years) who underwent internal fixation replacement after femoral bone transport in our hospital are retrospectively analyzed. This time, all cases are Left. In all cases, preoperative high-quality anteroposterior radiographs are used to assess femoral anatomic characteristics and bone quality after handling. All cases could be used an Ortho-Bridge System by referring to the patient's most recent visit to the orthopedic surgeon for discussion, as shown in Table 1.

Table 1. General characteristics

Patient No.	Age (years)	Sex	Side
1	41	Male	Left
2	57	Male	Left
3	62	Female	Left
4	32	Male	Left

3.2 Patients underwent open reduction and internal fixation of femoral fractures after excluding significant surgical contraindications

Open reduction and internal fixation combined with minimally invasive plate technique is used, and the internal fixation device is a bridging combined internal fixation system, which is completed by the same group of physicians. The patient lies supine on a fluoroscopically feasible operating table under combined spinal-epidural or general anesthesia. After the onset of anesthesia, an incision of approximately 12 cm in length is made in the inner thigh. The skin and subcutaneous tissue are incised and separated beneath the muscle. A submuscular tunnel is created beneath the muscle. A bridging internal fixation system (Tianjin Weiman) is installed intraoperatively from the medial femoral condyle to the anterior. After fluoroscopy confirmed good position, drilling is performed and screws are placed to complete the internal fixation. After fixation and fluoroscopy confirmed good fracture reduction and fixation, the wound is irrigated and sutured layer by layer. The drainage tube is routinely indwelled after surgery. After surgery, patients are encouraged to bear partial weight under the protection of early crutches, as shown in Figure 2. The fixation need to span two fracture ends and bone transport segments, requiring long-segment fixation. The bone shape is inconsistent with normal, with multiple mechanical weak points. Therefore, the bridging internal fixation system is used for fixation. The patient has fracture healing 4 months after operation.

3.3 Patients underwent external fixator removal and internal fixation after excluding significant surgical contraindications

Open reduction and internal fixation combined with minimally invasive plate technique are used, and the internal fixation device is a bridging combined internal fixation system, which is completed by the same group of physicians. The patient is under combined spinal-epidural or general anesthesia and is positioned supine on a fluoroscopically feasible operating bed. The fracture is maintained by the external fixator during the operation. After the onset of anesthesia, an incision about 6 cm in length is made in the medial thigh knee joint, middle thigh, and anterior knee joint, respectively. The skin and

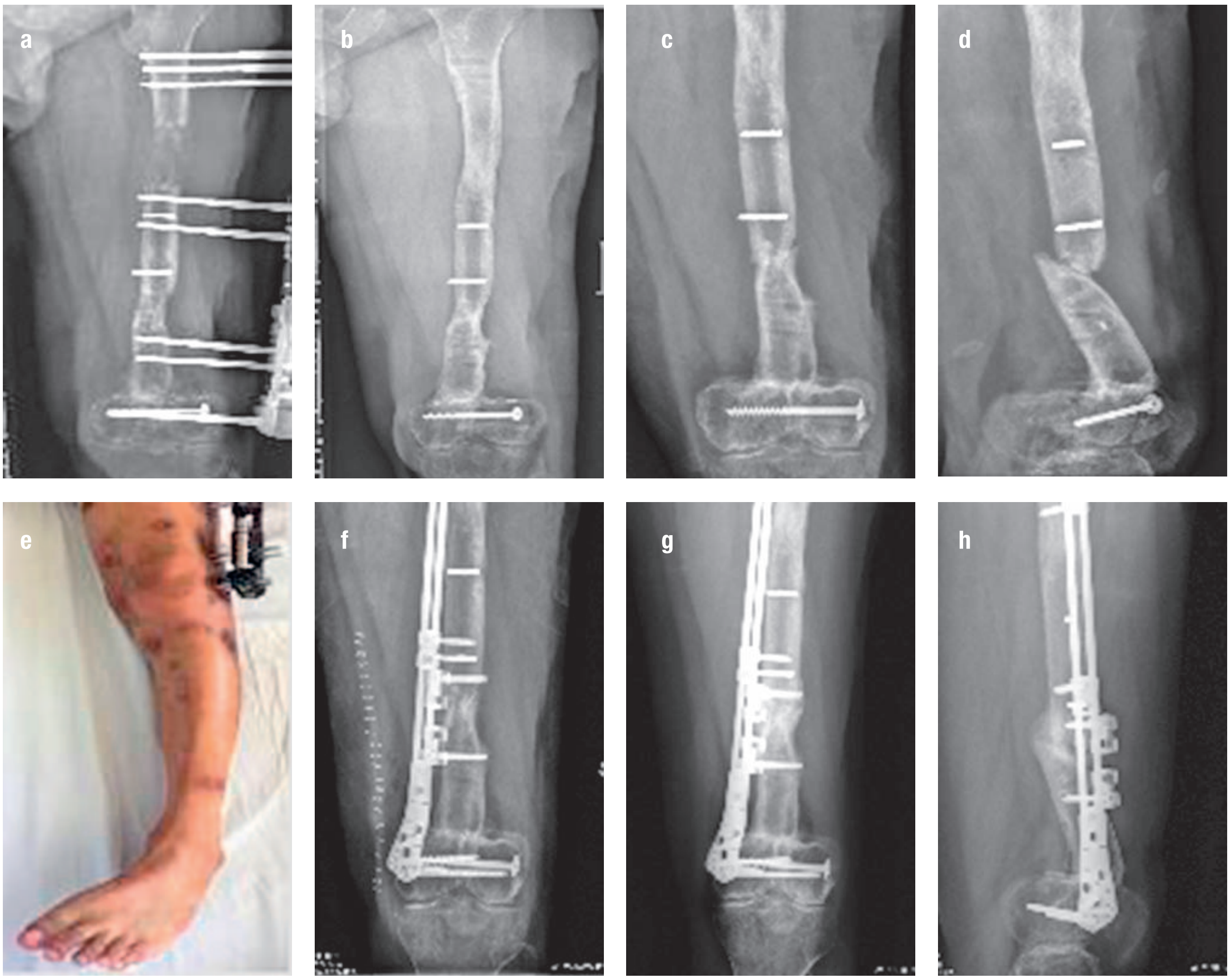

Fig. 2. 41-year-old male patient suffered from recurrent fracture 2 week after removal of external fixator after multi-segment bone transport of left femur: (a) the femoral anteroposterior X-ray after removal of femoral bone transport; (b) the femoral anteroposterior X-ray after removal of external fixator; (c) the femoral anteroposterior local X-ray after removal of external fixator; (d) the femoral lateral X-ray after fracture; (e) the femoral lateral thigh skin difference; (f) the femoral anteroposterior X-ray; (g) the 4 months after operation; (h) the 4 months after operation, femoral lateral X-ray.

subcutaneous tissue are incised and separated below the muscle. A submuscular tunnel is established under the muscle. From the medial femoral condyle to the anterior intertrochanteric region, a bridging internal fixation system (Tianjin Weiman) is installed during the operation. After the position is confirmed to be good by fluoroscopy, a hole is drilled and a screw is placed to complete the internal fixation. After fixation and fluoroscopy to confirm good fracture reduction and fixation, the wound is ished and sutured layer by layer. Finally, the external fixator is removed. The drainage tube is routinely indwelled after surgery. After surgery, patients are encouraged to bear partial weight under early crutch protection, as shown in Figure 3. The bone transport segment had poor osteogenesis after operation. One and a half years after operation, the patient required removal of external fixator to replace internal fixation due to serious effect on knee flexion and extension. The anterior femoral arch disappeared, long-segment fixation is required and there are mechanical weak points in the femur. Therefore, the bridging internal fixation system is required. Four months after operation, the fracture healed.

Open reduction and internal fixation combined with minimally invasive plate technique is used, and the internal fixation device is a bridging combined internal fixation system, which is completed by the same group of physicians. The patient lies supine on a fluoroscopically feasible operating table under combined spinal-epidural or general anesthesia. After the onset of anesthesia, a shuttle incision is made at the lateral, distal, middle, and original external fixator screw channels of the left thigh, which are 10.0 cm, 5.0 cm, and 8.0 cm long, respectively, and the fractured end is exposed by incision layer by layer, and the bone shape is inconsistent with normal. After the fractured end is cleaned, the fracture is reduced, and the preset Weiman bridging

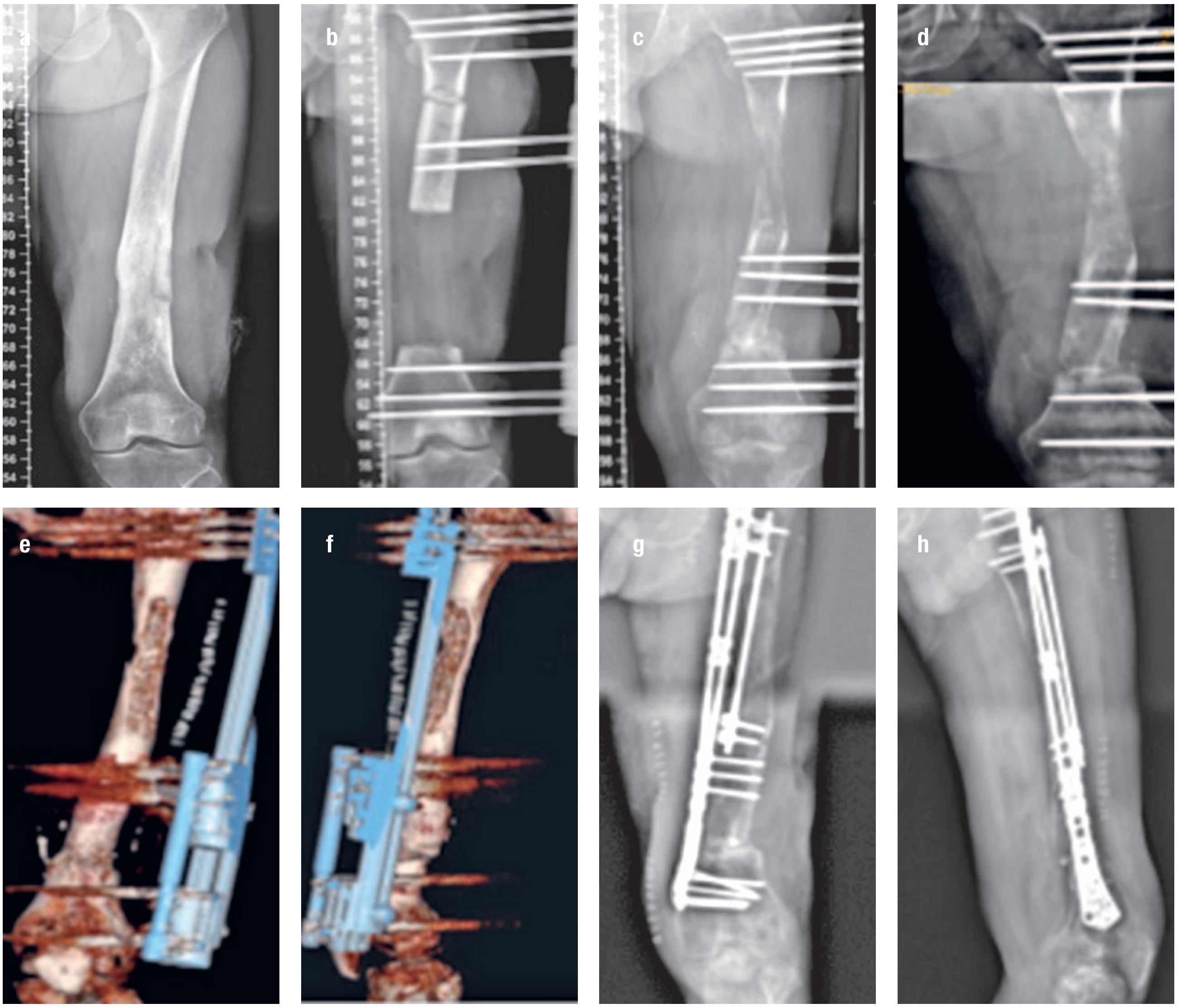

Fig. 3. 57-year-old male patient underwent bone transport after resection of infected bone segment for chronic osteomyelitis of left femur:(a) the bone transport is performed before femoral anteroposterior X-ray; (b) the infection bone resection and bone transport is performed postoperative femoral anteroposterior X-ray; (c) the bone transport is performed postoperative X-ray; (d) the multiple mechanical weak points in the femur; (f) the CT three-dimensional reconstruction; (g) the 4 months after operation, femoral anteroposterior X-ray; (h) 4 months after operation, femoral lateral X-ray.

combined internal fixation system is placed to fix the total length of the femur. After the position is confirmed to be good by fluoroscopy, screws are placed, and the placement is completed. After the fracture fixation is confirmed to be good by fluoroscopy, the incision is sutured layer by layer, and a drainage tube is routinely indwelled after surgery. After surgery, patients are encouraged to bear partial weight under the protection of early crutches, as shown in Figure 4. After carrying external fixator for 1 year and 3 months, the fracture end and femoral transport segment healed well. The fracture recurred 2 weeks after removal of external fixator. The fixation needed to cross the existing fracture end and bone transport confluent end and needed long-segment fixation. The femoral anatomy showed variation and the bone is inconsistent with normal. Therefore, the bridging internal fixation system is used for fixation.

The external fixator is removed after nearly 2 years. The fracture recurve 1 week later. The fixation needed to cross the current fracture end and the confluent end of bone transport. The long bone fixation is required. The anterior femoral arch disappeared, as shown in Figure 5. Therefore, the bridging combined internal fixation system is used. The fracture healed 3 months and a half after operation. Table 2 is the data statistics.

5 CONCLUSIONS

The treatment results of this group of patients show that the bridging combined internal fixation system in

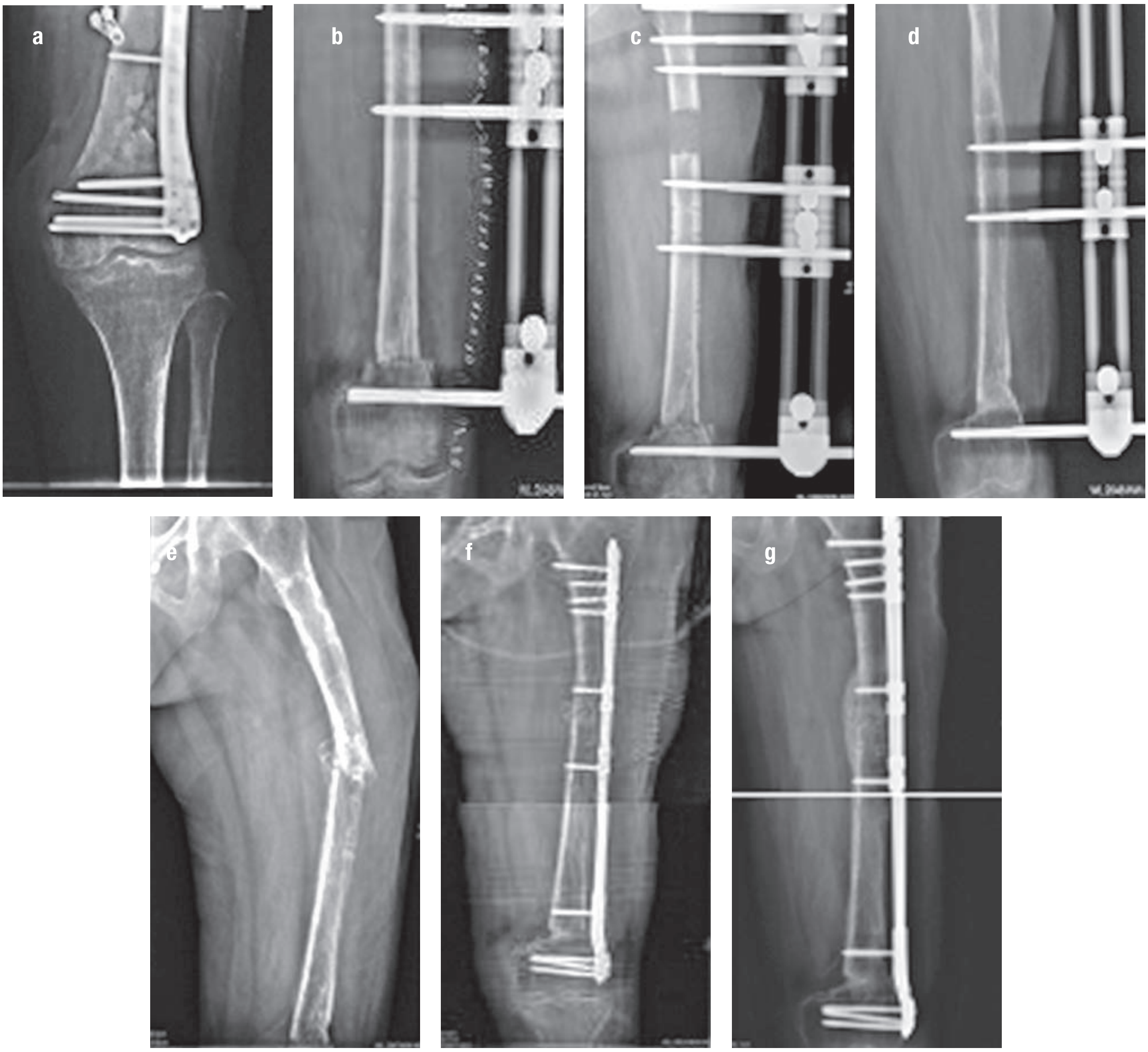

Fig. 4. 62-year-old female patient underwent bone transport after resection of infected bone segment of infected nonunion of left femur:(a) the postoperative bone transport preoperative femoral anteroposterior X-ray; (b) the infection bone segment resection postoperative femoral anteroposterior X-ray; (c) the bone transport postoperative femoral anteroposterior X-ray; (d) the Bone transport completed femoral anteroposterior X-ray; (e) the postoperative femoral anteroposterior X-ray; (f) internal fixation postoperative femoral anteroposterior X-ray; (g) the Postoperative 4 months and a half after femoral anteroposterior X-ray.

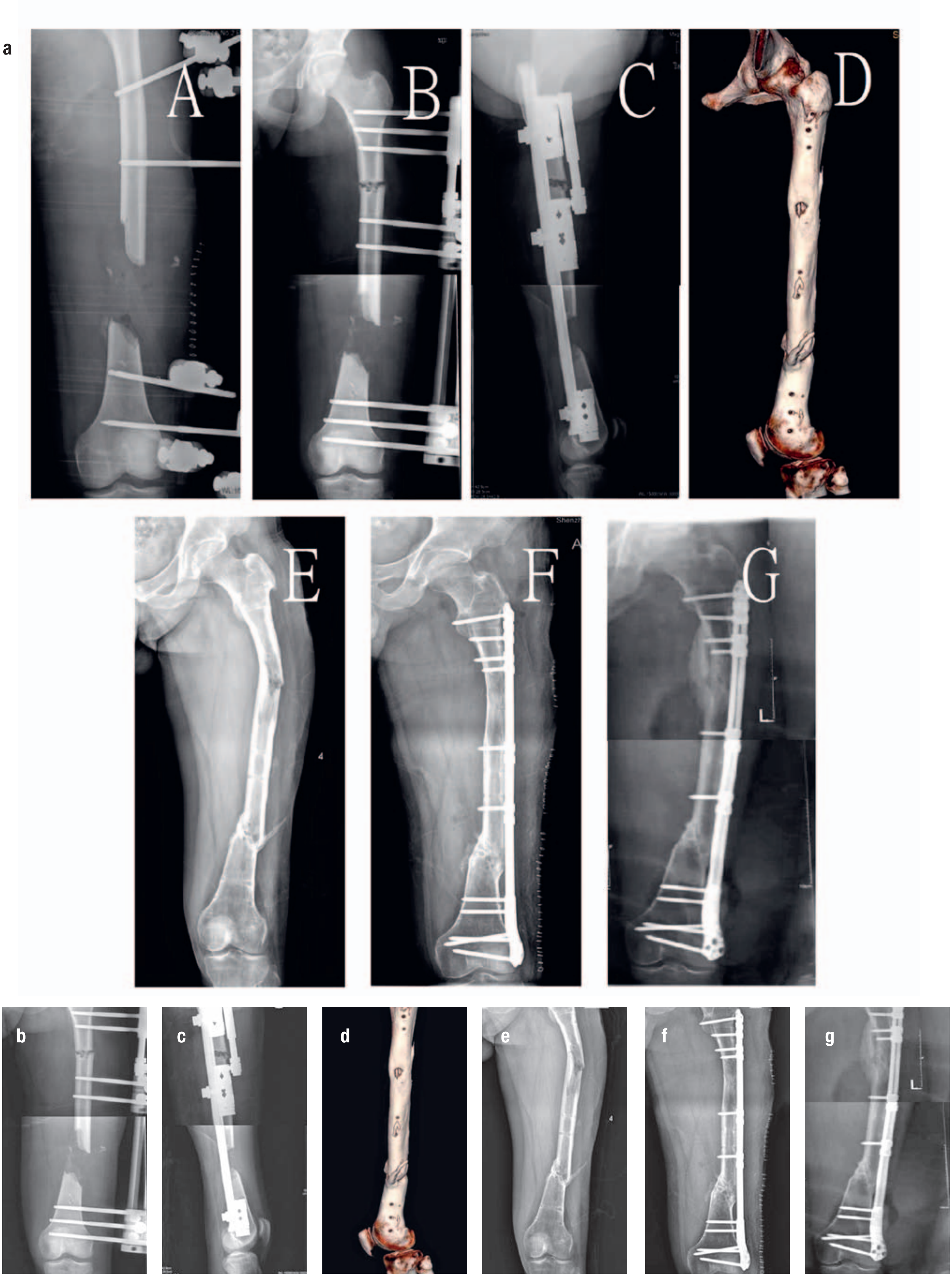

Fig. 5. 32-year-old male patient with open bone defect of left femur underwent bone transport:(a) the open fracture debridement is followed by anteroposterior X-ray of the femur; (b) the osteotomy transport is followed by anteroposterior X-ray of the femur; (c) the osteotomy transport is followed by lateral X-ray of the femur; (d) the removal of external fixation is followed by three-dimensional reconstruction of the femoral CT; (e) the internal fixation is followed by anteroposterior X-ray of the femur; (f) anteroposterior X-ray of the femur 3 months; (g) the anteroposterior X-ray of the a half after operation.

Table 2. Data statistics

Serial number	Operative Time (min)	Intraoperative bleeding (ml)	Hospital stay (days)	Fracture Healing Time (weeks)	Preoperative Harris Score	HSS score before surgery	Postoperative Harris scores	HSS score after surgery
1	120	100	8	16	40	42	70	75
2	150	200	15	16	65	61	82	81
3	120	100	20	18	48	43	69	70
4	110	250	15	18	68	58	86	85

the treatment of femoral bone transport have high fracture healing, good recovery of hip joint and knee joint function, and less complications, which is worthy of clinical application. However, the sample size of this study is limited, and a large-sample, high-quality randomized controlled trial should be conducted in the future to further improve the relevant studies.

In summary, bridging internal fixation systems have a wider prospect in the treatment of postoperative femoral bone transport. Locking compression plates and intramedullary nails are not suitable for anatomical variations which are caused by bone transport. Bridging internal fixation system, for different ages, different parts, different types, and different stresses of the implementation of targeted, along with the biological mechanism of internal fixation surgery, are able to achieve better internal fixation effect for the anatomical variations after femoral bone transport.

Data Availability

The simulation experiment data used to support the findings of this study are available from the corresponding author upon request.

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