ORIGINAL STUDY

acta orthopaedica belgica, 2023, 89, 609-612

doi.org/10.52628/89.4.11912

Distal femoral osteotomy for multidirectional malunion using 3D printing technology: a case-report

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Multidirectional distal femoral malunion and limb shortening lead to functional deficit and decreased quality of life. A corrective osteotomy might be necessary to cope with these issues. The inception of computer-assisted planification and the introduction of patient-specific instrumentation based on 3D printing technology with personalized osteotomy guides provide high correction accuracy, effectiveness, time-saving, and reduce potential complications. The present study describes a case of correction osteotomy using this procedure in a young patient with multidirectional malunion who recovered from a painful joint with functional limitations at a two-year follow-up.

Keywords: personalized osteotomy guides, femoral malunion, 3D-printing, patient-specific instrumentation

INTRODUCTION

Distal femoral fractures are challenging injuries accounting for less than 1% of all fractures and only 3 to 6% of all femoral fractures[1]. They are associated with high-energy trauma in young patients while with a low-energy mechanism in the elderly[2]. Open and comminuted fractures are often associated with multiple life-threatening injuries and limb deformities, including malalignment, malrotation, and leg length discrepancy. The conservative treatment is applied only in patients with non-displaced fractures, with significant risks in case of surgical intervention and non-ambulatory preinjury status. It includes immobilization with splints, casts, and skin or skeletal traction[3].

However, operative management is still the gold standard, and several fixation methods have been described, such as external fixation, open reduction and internal fixation (ORIF), and nailing[4]. Nonetheless, an intraarticular fracture extension indicates plate fixation for better reduction[5]. Indeed, non-anatomical reduction and comminution are related to fracture malunion, most often in a varus and hyperextended position, and limb shortening[6].

For fracture malunion, the patients should be treated operatively through corrective osteotomy. Nevertheless, this can be challenging, especially if malunion requires correction in multiple planes, and meticulous preoperative planning is necessary to correct the deformity and optimize patient outcomes[7]. Therefore, the surgical procedure should be planned preoperatively based on a computed tomography (CT) scan to appropriately evaluate the fracture's characteristics. In addition, custom-made personalized cutting guides could also be used to achieve accurate results and minimize complications[8].

MATERIALS AND METHODS

In 2016 a 26-year-old man with a free medical history and no previous surgical procedures was involved in a motorcycle accident resulting in an open distal femoral fracture of his right leg associated with ipsilateral radial and ulnar fractures. He was initially treated in another institution, with an internal two-plate osteosynthesis for his forearm and by skeletal traction, followed after two months by an open reduction and internal fixation for his femoral fracture. A CT scan was performed to template the definitive treatment, and a supracondylar locking plate was used for fracture fixation. Due to the comminution of the fracture, full weight bearing was authorized only six months after the fracture. However, a length leg discrepancy (LLD) was observed, influencing the gait negatively and necessitating a cane during the walking.

The patient presented to our institution approximately twelve months after femoral osteosynthesis, complaining of stiffness and inability to walk due to LLD.

The physical examination revealed a decreased range of motion (ROM) measured in flexion to extension as 90-0-0 and laxity of the medial collateral ligament. Radiological evaluation was performed using x-rays, CT scans, and a scanogram (Fig. 1). They showed an irregular bone consolidation with many bridges and sclerotic margins, an intraarticular protrusion of one distal plate screw, and a length leg discrepancy of 4 cm with a pelvic tilt to the right side of 2 cm. Further radiological analysis highlights a malunion with the lateral condyle flattened on the anterior side (Fig. 2). Consequently, the authors decided to use personalized 3D osteotomy guides for a correction osteotomy. Surgical planification was performed using the Mimics software (Materialise N.V., Leuven, Belgium) software and consisted of a biplanar distal femoral osteotomy (Fig. 3-4).

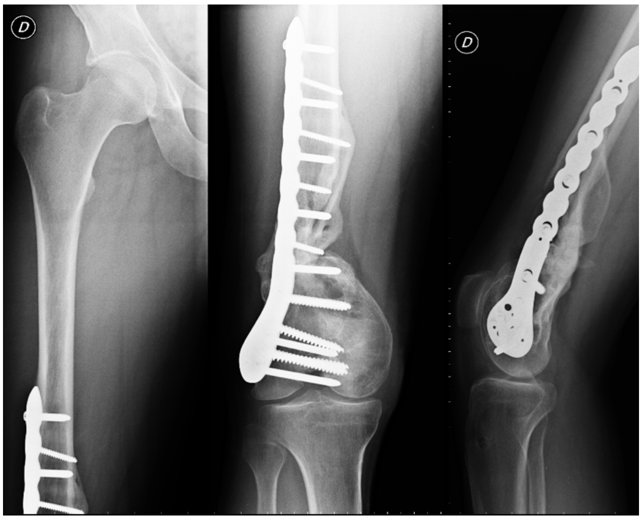

Fig. 1. — X-rays demonstrated femoral osteosynthesis one year after the initial trauma.

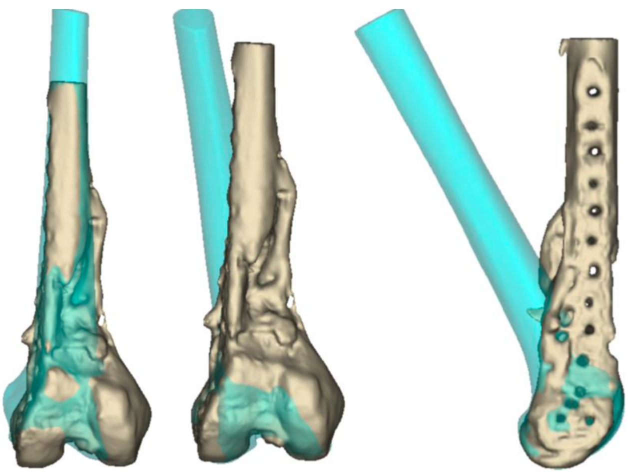

Fig. 2. — Three-dimensional computed tomography model visualizing femoral malunion.

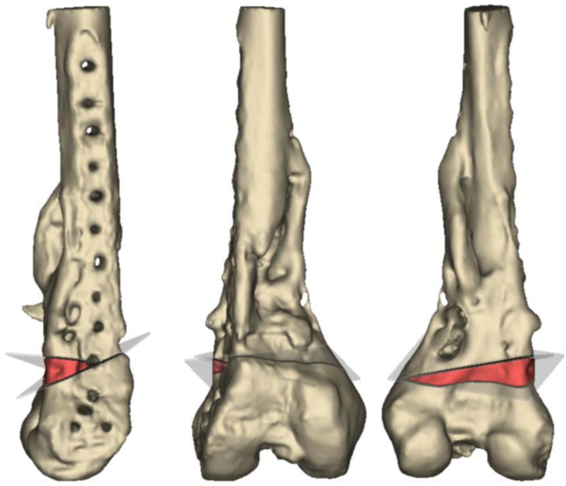

Fig. 3. — Planification of the osteotomy as shown by the lateral, anterior, and posterior views.

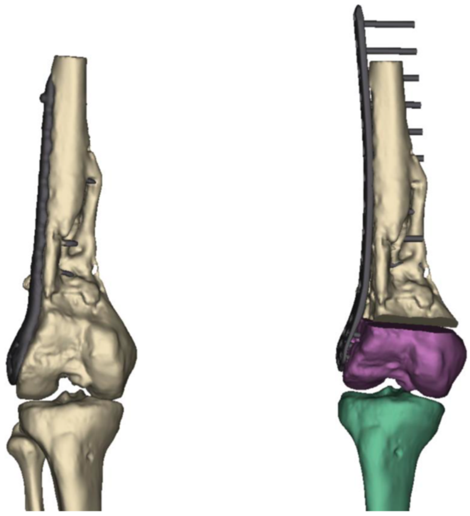

Fig. 4. — Preoperative condition of the femur and planned outcome.

RESULTS

The surgical procedure started with the easy removal of the existing plate through a lateral approach using the same incision from the former procedure. Afterward, the personalized osteotomy guide was placed and stabilized using multiple Kirschner wires (Fig. 5a-5b). An oscillating saw blade performed the biplanar osteotomy according to the surgical planification (Fig. 6). Next, lyophilized bone grafts filled the osteotomy site, and an eleven-hole distal femoral Locking Compression Plate (LCP) (DePuy-Synthes, Zuchwil, Switzerland) was applied to stabilize it (Fig. 7). Physiotherapy was prescribed and undergone daily immediately after surgery. A full range of motion was authorized with a non-weight-bearing period of 6 weeks.

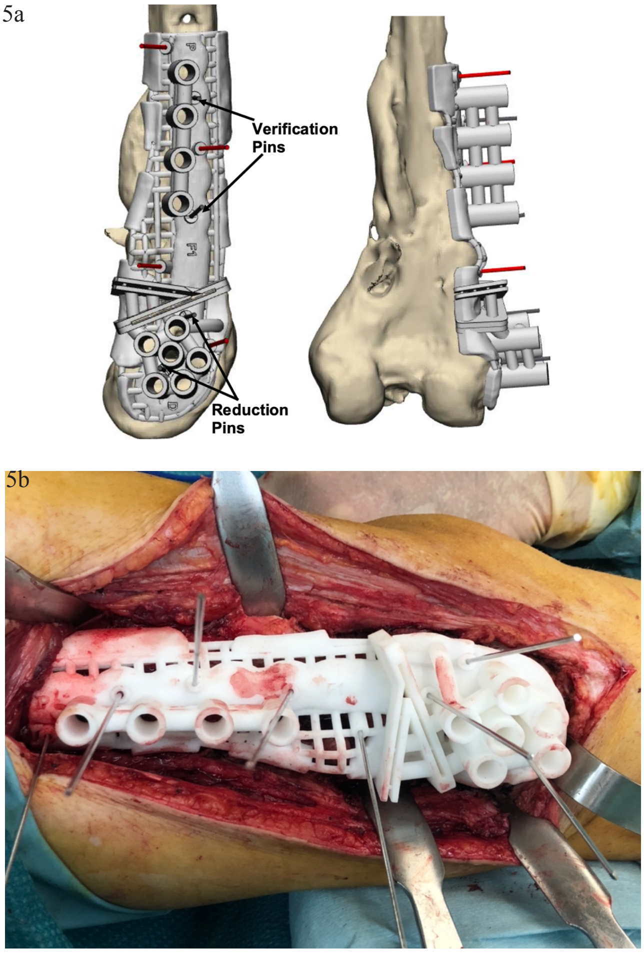

Fig. 5a-5b. — The personalized osteotomy guide is placed on the bone surface.

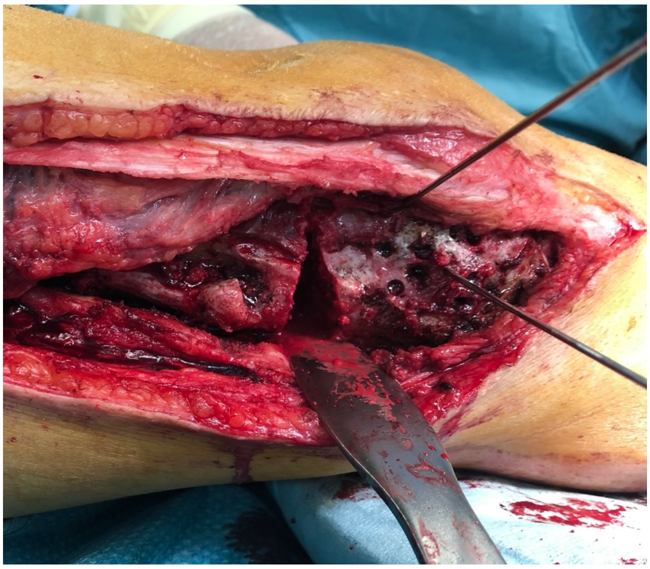

Fig. 6. — The biplanar femoral osteotomy was performed.

At two years of follow-up, the patient presented a stable knee with full extension and 115 degrees of flexion. Consolidation was acquired, axial realignment achieved, and rotation regained. However, a shortening of 2cm of the right lower limb persisted and was corrected with orthopedic shoes with a heel.

Fig. 7 Radiological evaluation of the result at two-year follow-up.

DISCUSSION

The most important finding of the current study was that osteotomy using personalized guides is an accurate, feasible, and safe procedure to treat distal femoral malunion with good clinical and radiological outcomes at a two-year follow-up.

Generally, distal femoral fractures are challenging injuries that usually need to be treated surgically with ORIF. The main goal of the treatment is to restore limb alignment and intraarticular congruity, both crucial for successful outcomes. However, initial stabilization using an external fixator or skeletal traction is also used in open fractures with severe soft tissue involvement, followed by a conversion into ORIF when possible[9,10]. Comminution is another critical issue for such fractures, which may lead to malunion and, or leg length discrepancy (LLD). In most cases, malunion is a varus deformity in the coronal plane and a recurvatum in the sagittal plane[11]. Restoring this malalignment, usually by femoral osteotomy, is essential as it is related to patient dysfunction and leads to secondary osteoarthritis[12,13].

This challenging and demanding procedure necessitates meticulous preoperative planning, particularly in the presence of multiplanar deformities. Therefore, radiological evaluation is fundamental; Computed tomography is mandatory as it allows a three-dimensional modelization of the bone, helping to understand the deformation and accordingly to plan and perform the osteotomy more accurately[14,15].

Further, personalized osteotomy guides have been recently proposed to provide better functional outcomes. Indeed, Saka et al.[16] performed a corrective intraarticular osteotomy for an articular malunited distal femur fracture using a 3D-printed model and concluded that this method is helpful for the planning and evaluating the osteotomy. Sun et al.[17] reported using 3D-printed navigation templates during minimally invasive percutaneous plate osteosynthesis of complex distal femoral fractures. They highlighted the improved surgical accuracy and the elimination of rotational deformity compared to the conventional technique. Oraa et al.[18] used customized 3D-printed cutting guides to correct the rotational deformity secondary to malunited closed femoral shaft fractures in six patients. They performed a derotational osteotomy and achieved a normalized anteversion angle of the femur.

In the present case, a 3D-printed personalized osteotomy guide was used to address a complex multiplanar post-traumatic femoral deformity. The main goal of the surgical procedure was to restore anatomical alignment and improve knee function. The surgical result was optimal, with the patient being highly satisfied. Complex osteotomy cases could benefit from this technology; however, the economic aspect may be challenging or even prohibitive for the involved hospitals.

CONCLUSION

3D printing technology and personalized osteotomies guides provide high correction accuracy in the case of multidirectional malunions. At the same time, it reduces surgical time and potential complications. Thus, it should be part of the possible treatment options.

Dual first Authorship: T. Kyriakidis and A. Lucidi have been contributed equally to this article and share first authorship.

Conflict of Interests: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding: The authors received no financial support for the research, authorship, and/or publication of this article.

Ethical Approval: All procedures 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: Written informed consent was obtained from all subjects before the study.

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