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GENERAL REVIEW

Endosteal plating for the treatment of malunions and nonunions of distal femur fractures

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Abstract

Purpose To describe the surgical technique and the outcome of a case series of nonunion and malunion of distal femur fractures treated with an endosteal medial plate combined with a lateral locking plate and with autogenous bone grafting.

Methods We retrospectively analyzed a series of patients with malunion or nonunion of the distal femur treated with a medial endosteal plate in combination with a lateral locking plate, in a period between January 2011 and December 2019, Database from chart review was obtained including all the clinical relevant available baseline data (demographics, type of fracture, mechanism of injury, time from injury to surgery, number of previous surgical procedures, type of bone graft, and type of lateral plate). Time to bone healing, limb alignment at follow-up and complications were documented.

Results Ten patients were included into the study: 7 male and 3 female with mean age of 48.3 years (range 21–67). The mechanism of trauma was in 8 cases a road traffic accident and in 2 cases a fall from height. According to AO/OTA classification 5 fractures were 33 A3, 3 were 33 C1, 1 was 33 C2 and 1 was 33 C3. The average follow up was 13.5 months. In all cases but one bony union was achieved. Bone healing was observed in average 3.3 months after surgery. No intraoperative or postoperative complications were reported.

Conclusion A medial endosteal plate is a useful augmentation for lateral plate fixation in nonunion or malunion following distal femur fractures, particularly in cases of medial bone loss, severe comminution, or poor bone quality.

Level of evidence Level IV (retrospective case series).

Keywords Nonunion · Malunion · Distal femur · Endosteal plate · Bone graft

Introduction

Distal femoral fractures represent 3–6% of all femoral fractures [1]. Surgical treatment consistently demonstrated better outcomes compared to nonoperative management [2]. Several surgical techniques are available, such as lateral buttress plating, lateral fixed-angle plating, retrograde intramedullary nailing, association of nail and plate or the combination of a lateral and medial plate, external fixation and primary total knee arthroplasty [3]; however, the ideal treatment for this type of fracture is still controversial [4]. Indeed, distal femur fractures are in most of cases difficult to treat [5, 6], especially in cases with extensive medial cortical bone loss. Nonunions and malunions of the distal femur after surgical fixation are rare but potentially catastrophic complications that result in significant loss of function and severe disability [7, 8].

Nonunion is the most frequent complication and can occur from 5 to 19% of cases [4, 9, 10]. The principal causes of nonunion include inadequate fracture fixation, infection, excessive separation of soft tissue during the procedure, which undermines vascular supply at the fracture site, and patient-related factors, such as advanced age, smoking,

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diabetes, vascular disease, non-steroidal anti-inflammatory drugs and steroid use [11–14]. Although the use of fixed angle implants provides rigid construct that better withstands bending forces, implant failure is still possible because of significant eccentric load [6, 14].

Malunions are mainly related to improper metalwork and surgeon's experience [15]. Comminution at the fracture site and particularly medial bone loss are a common problem, that quite often leads to secondary screw loosening, varus collapse, and subsequent hardware failure [16].

Nonunions and malunions can be addressed by several methods [17], depending on the pathological findings and surgeon's confidence with specific implants. The mostly used fixation technique consists of fixed angle implants with cancellous autograft [17]. Recently, composite fixation or augmented fixation that foresee the association of nails and plates [18], both medial and lateral plates [19], or an endosteal plate associated with lateral plate [20, 21], are becoming more common. The original description of the technique by Mast et al. [22] consisted of a medial contoured intra-medullary plate to augment standard lateral plate fixation; this technique was originally used for distal femur nonunion, and for pathologic fractures [23]. Biomechanical studies [24] showed superiority of composite fixation respect to traditional lateral fixation.

The aim of the present study was to evaluate the efficacy of a modified Mast's technique for the treatment malunion and nonunion of the distal femur. The hypothesis of the study was that combination of an endosteal plate associated with a lateral plate is effective in promoting healing of malunion and nonunion of distal femur fractures.

Materials and methods

Study design

The study was designed as an observational retrospective study without control group (case series).

Participants

All the patients with a malunion or nonunion of the distal femur treated by combination of an endosteal plate and a lateral plate between January 2011 and December 2019 were considered eligible for the study. Nonunion was defined as an unhealed fracture with no clinical or radiographic signs of progression to healing, believed to have no chance for further healing without additional surgical intervention. Nonunion was confirmed by plain radiographs, CT, or by a combination of modalities, defined as an unhealed fracture with no radiographic signs of osseous union. Instead malunion was defined as fractured healed in an abnormal position, which can lead to impaired function of the bone or limb. Inclusion criteria were nonunion, or malunion of the distal femur associated with functional disability in daily activities. Exclusion criteria were septic nonunions, presence of growth nuclei and previously non deambulatory patients.

Most of the patients in our cohort had atrophic nonunion with insufficient medial bone support. This was the key factor for the choice for this type of surgical intervention because endosteal plating is able to provide medial column support and adequate alignment of the distal femoral metaphysis.

Surgical technique

All the surgical procedures were performed by three of the senior authors (M.O, E.J., A.C).

A standard lateral approach, with preservation of the soft-tissue sleeve and debridement of avascular bone, was used in all patients. A tibial tuberosity osteotomy was performed if severe knee joint stiffness was present to allow better articular reduction. At the end of the procedure the tuberosity was fixed in a more proximal position to achieve greater knee flexion.

An endosteal plate (DCP or LCP 4.5 mm plate; DePuy Synthes, West Chester, PA, USA) was introduced through the bone defect at the nonunion or osteotomy site, first in a retrograde direction inside the femoral canal until it overlapped the bone gap and reached the midshaft; then it was impacted distally into the epiphyseal fragment, inverting the insertion direction. The length of the medial endosteal plate is assessed by keeping it in front of the femur while doing AP fluoroscopic images at the knee and at then at the most proximal aspect of the plate, making sure that it bypasses the nonunion or malunion site. The plate is then contoured until it matches the endosteal surface on AP fluoroscopy. The endosteal plate was adequately shaped into the femoral canal in order to match the medial cortex, ending on the medial condyle [25]. The endosteal plate modelling was achieved with plate bending press (DePuy Synthes, West Chester, PA, USA) (Fig.1).

A "picador" (ball spike pusher) was used to advance the endosteal plate and once it was centered on the fracture defect a lateral plate was positioned. For the lateral support we used a condylar blade-plate (CBP, DePuy Synthes) or an LCP Condylar Plate (LCP–CP, DePuy Synthes).

The intramedullary plate should be maintained as close as possible to the endosteal portion of the medial cortex, to act as a support. At this aim, Mast et al. [22] utilized the schüli nut (DePuy Synthes), a device designed to lock a 4.5 mm cortical screw at a 90° angle, thus preventing toggling in the non-locking hole of the CBP. As the Schüli device was not available in our country, we overcame this issue using nuts that engaged cortical screws and buttressed the endosteal plate towards the medial cortex. Using the LCP–CP plate, nuts are not necessary and the endosteal plate can be pushed towards the medial cortex by a locking screw of appropriate length that pushes the endosteal plate. Cortical screws of 4.5 mm were placed through holes in both plates in a quadrilateral implant configuration. Screws were positioned using the method described by Matelic et al. [26], in which the lateral cortex is drilled and a k-wire is used to guide the direction of the drill and screw through a hole in the intramedullary plate. These screws must not be placed straight across but should be positioned on an angle so that they barely fit through the screw hole, blocking the plate itself, thus preventing torsion or shortening between the two plates. To avoid shortening, the endosteal plate was further supported by a proximal screw at the end of the construct and by the blade plate distally.

Autologous bone graft was harvested from the contralateral femur, as a separate procedure, or from the same femur with the Reamer–Irrigator–Aspirator (RIA) and placed into the bone defect to induce bone formation.

Antero-posterior and lateral radiographs were obtained after surgery to confirm reduction and the correct position of the implants.

In all patients, continuous passive motion of the knee was started the day after surgery. Partial weight-bearing was allowed in the early postoperative period and progressively increased depending on radiographic findings during the following 8 weeks.

Outcome measures

The primary outcome for this study was to assess radiographic bone union in distal femur nonunions or malunions with the association of a medial endosteal plate to a lateral plate.

For all patients included into the study, medical records and preoperative radiographs were reviewed to identify fracture patterns according to AO/OTA fracture classification, previous surgical procedures, time to surgery, and implant type. Postoperative radiographs were evaluated to assess coronal and sagittal alignment. No Postoperative complications were recorded including loss of reduction, infection and reoperation rate. Union rate was determined by radiographic evidence of healing in 3 of 4 cortices and by clinical evidence of weight-bearing without pain as reported at follow-up visits. Limb alignment was assessed at the last follow-up radiological exam.

Data analysis

Descriptive statistics were reported as means and standard deviations for normally distributed data as assessed by Shapiro–Wilk test. Otherwise, medians and ranges were used. Categorical variables were expressed as frequencies and percentages.

Results

A total of 10 patients were included. There were 7 men and 3 women. The mean age was 48.3 years (range, 21–67 years) (Table 1).

The mechanism of injury was motor vehicle accident in 8 patients and in 2 patients a fall from height. Five patients had associated fractures. According to AO/OTA classification the initial fractures were 5 fractures 33A3, 3 were 33C1, 1 was 33C2 and 1 was 33C3. One patient, who had a concomitant neoplastic disease, suffered from an open Gustilo C2. Patients have undergone a median of 2 (range, 1 to 7) previous unsuccessful surgical procedures to fix the initial fracture or to correct the nonunion or malunion without success. All the malunions and nonunions were associated with severe deformities on the sagittal and coronal planes.

The intramedullary plate (4.5 mm tibial DCP or Locking Compression Plate De Puy Synthes) was associated on the lateral side with a CBP in 8 patients, with a LISS plate in 1, and with a LCP Condylar Plate 4.5/5.0 in another. Bone graft was obtained using RIA (reamer-irrigator-aspirator; De Puy Synthes) from the contralateral femur in 9 patients, while 1 patient had bone grafting from posterior iliac crest.

The mean follow-up was 13.5 months.

Fracture union occurred at an average 3.3 months from the surgery. Treatment was unsuccessful on the patient with the C2 open fracture who also had a concomitant colon adenocarcinoma with hepatic metastasis that died 12 months after the initial treatment. In this case, the blade plate failed at six months after surgery, but function was maintained. All the patients but one had a range of motion from full extension to more than 90° of flexion, including the patient with unsuccessful fracture union. In three patients the preoperative shortening was not completely corrected and a residual shortening of 1–2 cm persisted (Table 2). No patient needed reoperation.

Example are shown in Figs. 2, 3, 4 and 5.

Discussion

Bone healing in distal femur fractures can be challenging to achieve. Local factors including metaphyseal bone loss, compromised bone vascular supply, mechanical issues, infections and patient-related factors like diabetes, obesity and smoking may lead to nonunion of the supracondylar femur fracture [27, 28]. This is a severe complication that can be associated with varus deformity, pain, loss of function and severe disability for the patient.

Table 1 Patient characteristic

Patient	Age	Sex	Type of trauma	Type of fracture	Exposition
1	67	M	Road traffic injury	33 C1	No
2	60	M	Road traffic injury	33 C2	No
3	52	M	Road traffic injury	33 A3	No
4	24	F	Road traffic injury	33 A3	No
5	50	F	Fall from height injury	33 A3	No
6	21	F	Fall from height injury	33 C3	No
7	56	M	Road traffic injury	33 A3	No
8	65	M	Road traffic injury	33 A3	No
9	40	M	Road traffic injury	33 C1	No
10	50	M	Road traffic injury	33 C1	Gustilo 2

Patient	No of months to surgery	No of prior surgery	Malunion/nonunion	Bone graft
1	12	1	Malunion	RIA
2	10	1	Nonunion	RIA
3	6	7	Nonunion	RIA
4	6	1	Nonunion	RIA
5	6	1	Malunion	RIA
6	4	1	Nonunion	RIA
7	10	3	Nonunion	RIA
8	8	2	Nonunion	RIA
9	6	2	Nonunion	Iliac Crest
10	5	2	Nonunion	RIA

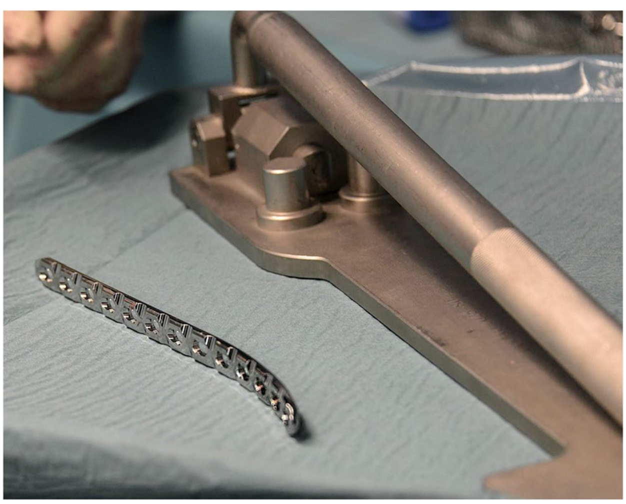

Fig. 1 Plate bending press (Synthes) and the 4.5 mm endosteal plate, adequately shaped to support the deficient medial column of distal femur

Treatment strategy in malunions and nonunions of distal femur is based on the achievement of medial cortex stability. Single lateral locked plate does not always provide adequate stability and is burdened with a high failure rate [17, 29]. In reason of this, the combination of an endosteal and a lateral plate is a versatile and successful technique to treat distal femur malunions and nonunions, where medial cortical bone loss makes standard plating insufficient to maintain adequate stability to reach bone healing [30].

The endosteal plate technique was first described in 1989 by Mast et al. [22], in an effort to diminish the eccentric loads on the lateral plate and to sustain the insufficient medial cortex. This implant combination creates a construct that temporarily supplies the bone loss of the medial cortex. This construct, ideally, is able to better resists to bending and torsional forces, especially if interlocked [8, 24, 26–28]. These statements were validated and confirmed by a biomechanical study, which showed that the use of an endosteal 4.5 mm plate combined with a lateral plate provides increased axial and rotational stability with lower gap motion, and decreased displacement at the fracture site [25].

According to our experience, the endosteal plate, once it reaches the distal epiphyseal fragment, automatically corrects the hyperextension and the varus or valgus malalignment of the distal fragment Table 1. Another advantage of this technique is the possibility to obtain an enhanced support through the same lateral surgical approach, without further dissection.

Matelic et al. [26], in a case series, treated 7 distal femoral nonunions with the endosteal plate technique and achieved a complete bone healing in all cases. Similar results were

Table 2 Outcomes

Patient	No of months of FU	Healing time	Complications
1	21	3	No
2	12	3	No
3	14	5	No
4	8	4	No
5	12	3	No
6	8	2	No
7	19	4	No
8	11	6	No
9	18	3	No
10	12	–	Exitus (pulmonary embolism)

Patient	ROM (pre)	ROM (post)	Axis deviation	LLLD
1	0°–100°	0°–120°	–	–
2	0°–75°	0°–95°	–	–
3	0°–90°	0°–115°	–	1,5 cm
4	0°–30°	0°–90°	10°varus, procurved	–
5	0°–60°	0°–110°	–	–
6	0°–30°	0°–100°	5°varus	2 cm
7	0°–30°	0°–95°	–	–
8	0°–45°	0°–100°	6°varus	1,5 cm
9	0°–40°	0°–110°	–	–
10	0°–60°	0°–100°	6°varus	–

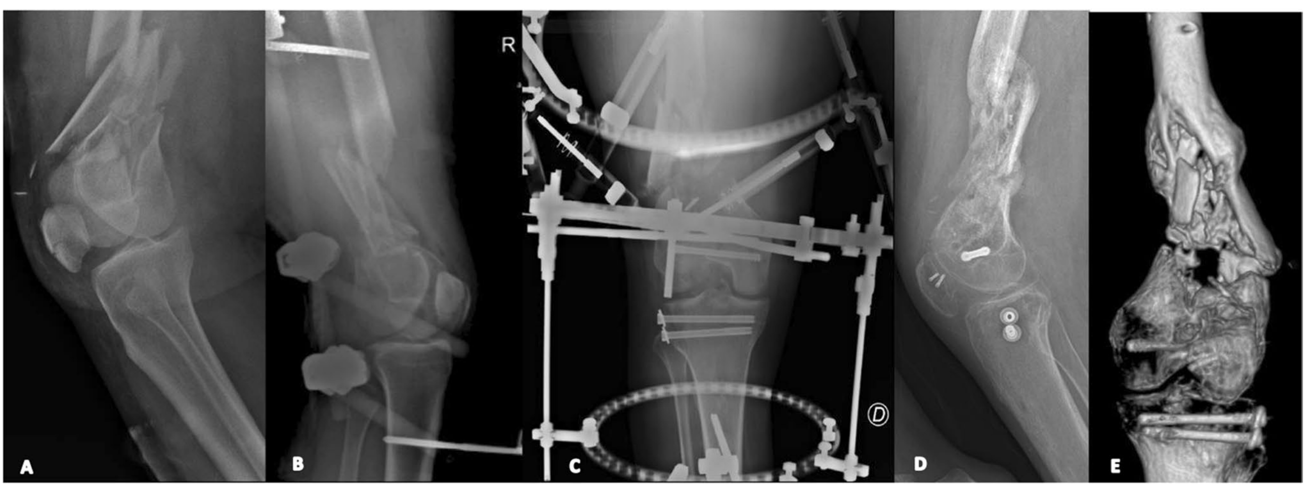

Fig. 2 Male patient 56 years old; road traffic injury, **A** lateral x-ray views of a 33 A 3 fracture of distal femur, **B** DCO with external fixation. **C** Treatment with circular external fixator 1 month after DCO. **D**, **E** 6 months after the trauma and 45 days after the removal of circular external fixator x-rays and CT-3D shows a non unon with severe medial cortex deficit

reported by Bergin et al. [21] in 7 patients with distal femur nonunions treated with the Mast's technique.

The association of an endosteal plate to a lateral plate is a construct that better withstand the forces because the plates are interlocked by screws that traverse both plates and by the blocking screws or nuts that push the endosteal plate against the medial cortex. The association of a medial endosteal plate to a lateral plate could appear apparently very sophisticated, but is not so demanding for the surgeon [25].

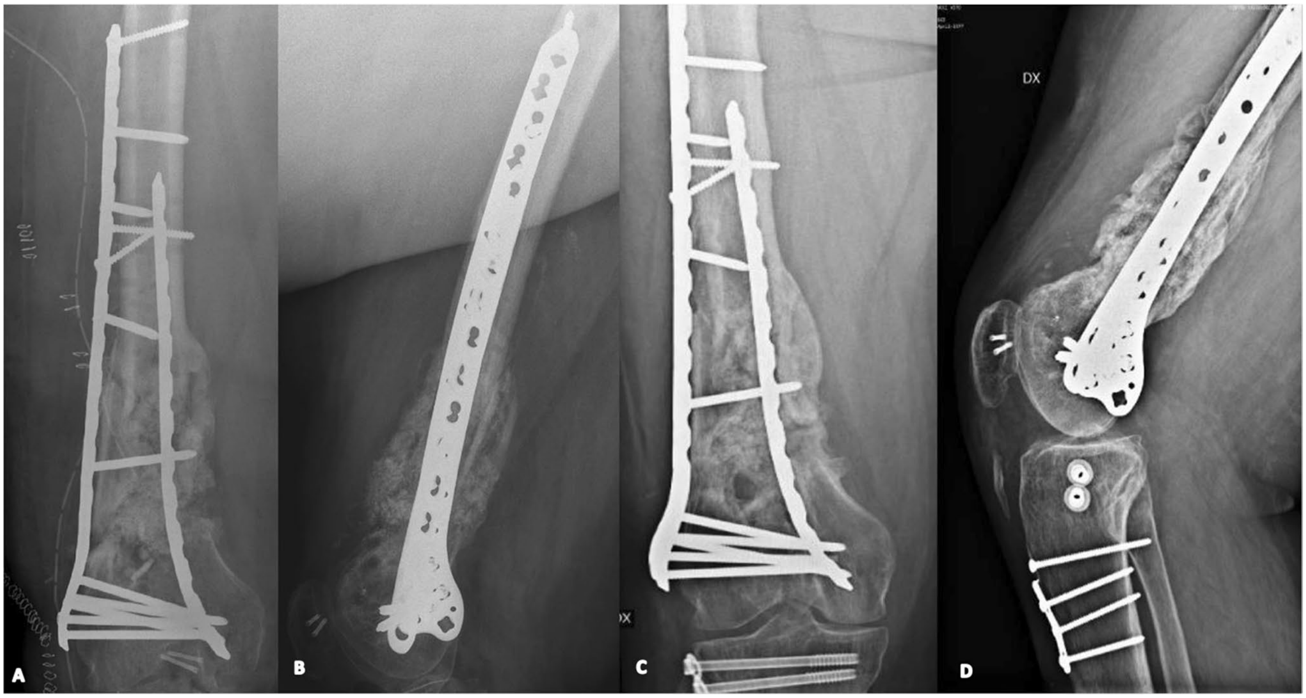

Fig. 3 Male patients 56 years old; road traffic injury. **A** AP postoperative x-ray view (surgery was performed 8 months after the car injury). **B** Lateral post op view. **C** AP x-ray view at 6 months; (Notice that tibial tuberosity was elevated to gain access to the distal femur). **D** Lateral x ray view at 6 months showing healing in 3 of 4 cortices; patient was able to bear weight without pain

Fig. 4 Women 50 years old; road traffic injury. **A** Long leg view (notice the deformity of the left lower limb and rigth foot; patient was not able to walk from 6 months). **B** Ap x-ray view of the left distal femur. Pin tracts of external fixator that was the only fixation performed in this case. **C** CT scan at 8 months showing malunion of the distal femur

There are other technical solutions to treat distal femur nonunions with deficiency of the medial cortex support. One of these is the addition of a medial plate by a second surgical approach. However, an additional medial approach may add a vascular insult on the medial aspect of distal femur, a more aggressive periosteal devascularization on the bony fragment and above all the medial plate has not any mechanical effect on correcting the femoral axis. The use of an intramedullary nail, as endosteal substitute for a deficient medial cortex, combined with a lateral locked plate in the distal femur, was described by Spitler et al. [20], who reported good results in the treatment of acute fractures and nonunions of the distal femur. Despite this, intramedullary nails in femoral epiphyseal regions are not canal-filling, do not align the distal segment as plates do and can lead to some degree of malreduction due to secondary axial and torsional deforming forces [25]. Further, retrograde intramedullary nail has the disadvantage of violating the knee joint. In addition to the other issues, in the presence of other implants, such as some total knee or hip arthroplasties and comminuted condyle femoral fractures, retrograde nailing technique is not always possible.

Ilizarov bone transport and tumoral total knee arthroplasties are other possible treatment options [31, 32]. Ilizarov external fixation presents some advantages including minimal soft tissue disruption, stable fixation and early weight-bearing. This technique is particularly effective in patients with infection, limb shortening or deformity. Nevertheless, Ilizarov external fixation technique has a long learning curve and requires strict patient compliance with frequent follow-up [33, 34].

Arthroplasty for distal femoral nonunion gained popularity related to good pain relief and return to ambulation and is considered a suitable option, especially as a salvage

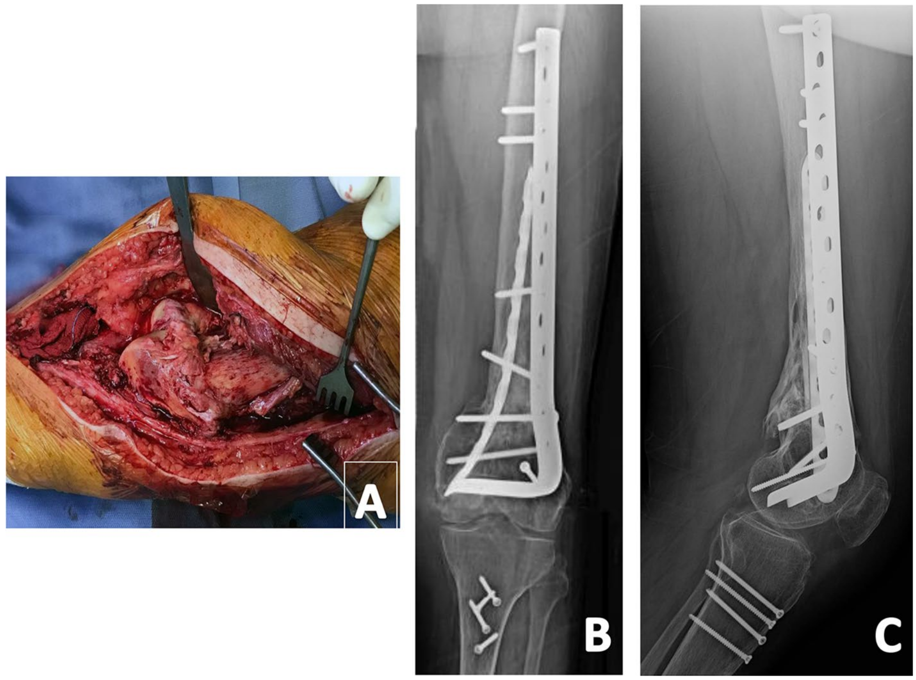

Fig. 5 Women 50 years old; road traffic injury. **A** Intraoperative view of the distal femur. **B**, **C** Postoperative AP and lateral views showing the combination of the endosteal plate and CBP for the treatment of malunion

procedure in elderly patients [35]. Despite good results, this surgical procedure is very challenging, because of difficult exposure due to previous scars and fibrosis, and the standard landmarks for assessing axial and rotational alignment of components may be distorted after fracture; furthermore, the durability of these implants remains inferior to that of primary TKA implanted for other conditions [36]. What is more, massive surgical exposure, long operative time, and compromised soft tissues might lead to an increased risk of postoperative infection.

The present study has some limitations, mainly related to the retrospective design and the small sample size. Indeed, further studies with larger sample size and comparative biomechanical and clinical studies would be necessary to confirm the efficacy of this technique.

Conclusions

The combination of an endosteal plate with a lateral plate associated with bone graft is an efficient technique for the treatment of distal femur nonunions or malunions. The endosteal plate, adequately shaped, aligns and stabilizes the distal segment, improves stability of the lateral plate and provides adequate support to the deficient medial cortex, thus offering a viable solution for these challenging situations.

Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethical approval Not applicable.

Consent to participate Not applicable.

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