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Total femur fixation using the "nail-plate docking technique" for ipsilateral femur shaft fracture

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ABSTRACT

In an aging society, the number of femoral fractures is increasing, as well as the incidence of periprosthetic fractures. These secondary fractures are often difficult to fixate stably because of the osteoporotic bone and the existence of the former implant. Herein, we present two cases of secondary femoral shaft fractures after osteosyntheses for distal femur fractures with polyaxial locking plates (Non-Contact-Bridging Distal Femur, NCB-DF®, ZimmerBIOMET, Winterthur, Switzerland). Antegrade intramedullary nails (Natural Nail®-GT Femoral, ZimmerBIOMET, Winterthur, Switzerland) were utilized without removal of the NCB-DFs. In these osteosyntheses, proximal locking screws of NCB-DFs were inserted and locked into the distal inter-locking holes of Natural Nails. This "nail-plate docking technique" could allow for more stable fixation of the whole femur with minimally invasive surgical intervention while preserving the existing implant. Although there are a few surgical technical knacks and pitfalls in inserting the screw, further fractures of the femur could also be prevented with this technique.

Introduction

Because of the aging population, the number of surgeries for femoral fractures is increasing, as well as the incidence of periprosthetic fractures. Osteosynthesis is often difficult to perform on secondary fractures because of the osteoporotic bone and the existence of the former implants [1,2]. We encountered two cases of secondary femoral shaft fractures after osteosyntheses for distal femoral fractures with a polyaxial locking plate (Non-Contact-Bridging Distal Femur, NCB-DF®, ZimmerBIOMET, Winterthur, Switzerland). Antegrade intramedullary nails (Natural Nail®-GT Femoral, ZimmerBIOMET, Winterthur, Switzerland) were inserted without removal of NCB-DFs. In these osteosyntheses, proximal locking screws of NCB-DFs were inserted and locked into the distal holes of Natural Nails. We report on the knacks and pitfalls of this minimally invasive "nail-plate docking technique".

Surgical technique

Ipsilateral femoral shaft fracture after osteosynthesis for distal femoral fracture with NCB-DF is an indication for the "nail-plate docking technique". The proximal locking and non-locking screws of NCB-DF must first be removed to insert the femoral nail. After reduction and temporary fixation using a bone gripper or wiring system, an antegrade femoral nail is inserted for total femur fixation.

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While checking the position with a fluoroscopic C-arm, the guide wire of the antegrade intramedullary nail should be induced to the center of the locking hole of NCB-DF (Fig. 1a). When the antegrade intramedullary nail is inserted to the appropriate depth, the distal locking hole of the nail and the screw hole of NCB-DF are in matched positions. Kirschner-wire (K-wire) or depth-gauge should be passed smoothly at this time (Fig. 1b–c). As the K-wire is placed in the two holes, the proximal screws of the nail should be checked to ensure that they are inserted to the appropriate height and orientation with the proximal screw sleeve through the device. After drilling through the two holes, the screw of NCB-DF is inserted into the distal locking hole of the nail and locked with the nut of NCB-DF, thus achieving bi-cortical screw fixation (Fig. 1d). To obtain a more stable fixation, wiring systems and hemi- or bi-cortical screws of NCB-DF should be added (Fig. 1e). The locking screws of the nail should be inserted depending on the fracture type. At least one recon screw is needed to prevent further femoral neck fracture.

Informed consent

Written informed consent was obtained from the patient for publication of this case report and the accompanying images.

Case 1

An 87-year-old woman with a height of 145 cm and weight of 45.6 kg (body mass index: 21.7 kg/m^2) fell and incurred a left periprosthetic supracondylar fracture (Fig. 2a). She had undergone bilateral total knee arthroplasties (TKAs) more than 10 years ago. Open reduction and internal fixation were performed with NCB-DF (6-holes) (Fig. 2b); however, the plate was broken 4 months after the osteosynthesis (Fig. 2c). Re-operation using NCB-DF (9-holes) successfully achieved bone union (Fig. 2d). Eight years after the last operation she fell again and incurred an ipsilateral femoral shaft fracture at the tip of the NCB-DF (Fig. 2e). After removing only the proximal screws of the NCB-DF, an antegrade femoral nail was inserted for total femur fixation (Fig. 2f). We did not remove the NCB-DF itself. The screw of the NCB-DF was inserted into the distal dynamic hole of Natural Nail and locked with the locking nut of the NCB-DF. Two mediolateral femoral cortexes were fixed by the screw. One more distal locking screw of Natural Nail fixed two anteroposterior femoral cortexes. A total of four cortexes cross-locking of the Natural Nail had been performed. Wiring and hemilocking screws were also added to secure the fixation (Fig. 3). One year after the osteosynthesis with the "nail-plate docking technique", the patient was able to walk with the help of the walker without any complications.

Case 2

An 86-year-old woman with a height of 153 cm and weight of 54.5 kg (body mass index: 23.3 kg/m^2) fell and incurred a left femoral

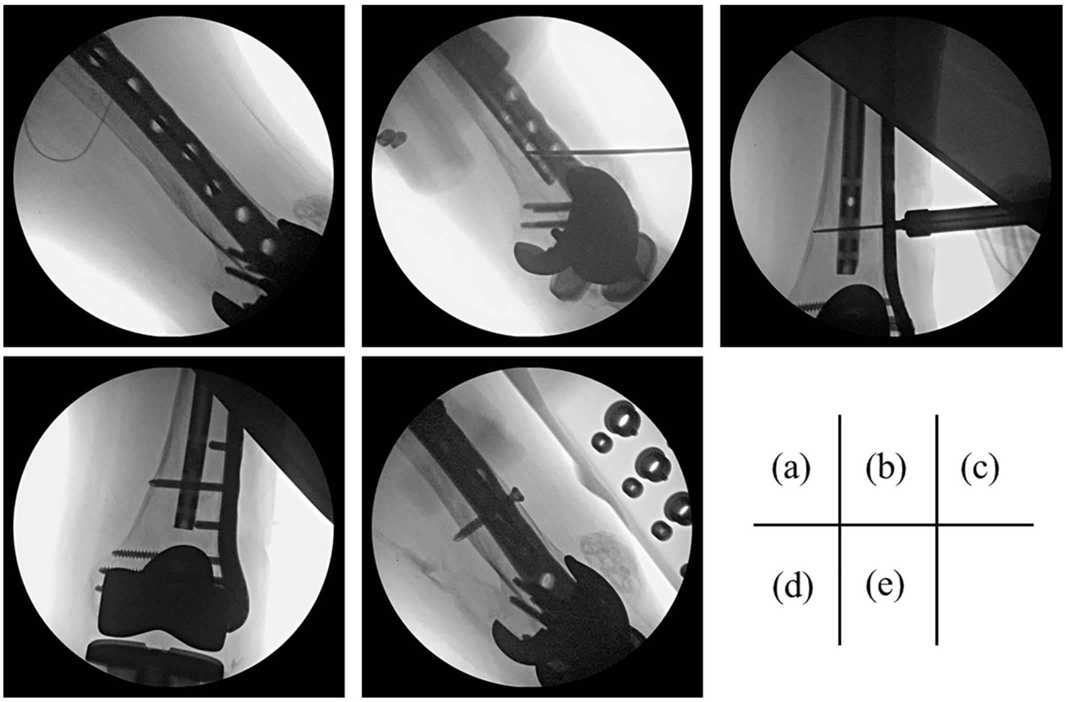

Fig. 1. Intraoperative radiographic images using C-arm.
Intra-operative images check the position of guide-wire of the femoral nail (a). Kirschner wire or depth gauge pass from the screw hole of the NCB-plate to the inter-locking hole of Natural Nail (b, c). Inter-locking screws fix two cortical bones: mediolateral (d) and anteroposterior (e).

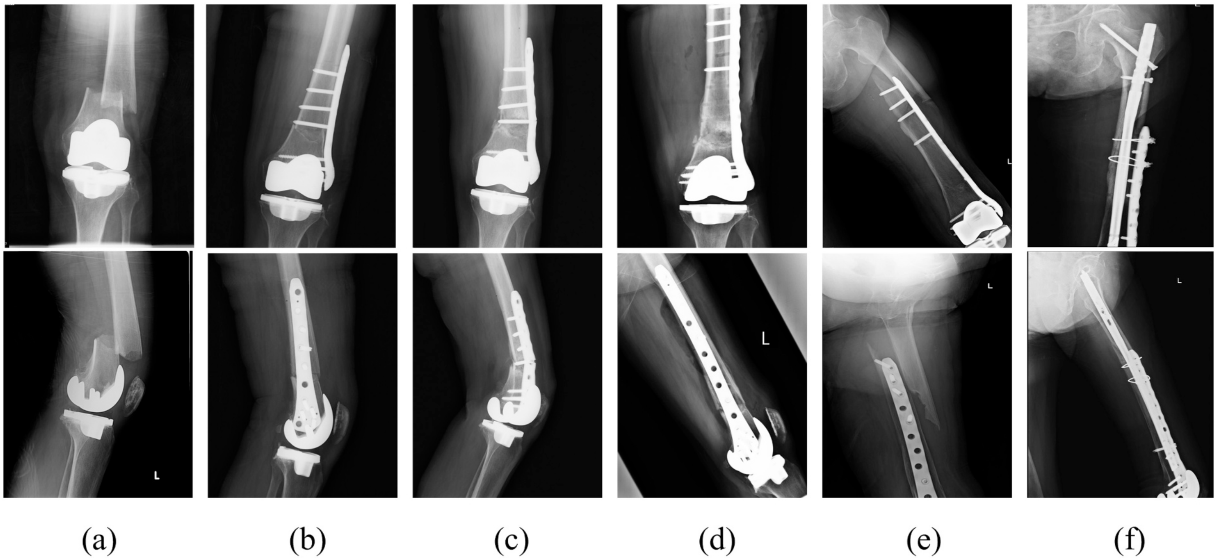

Fig. 2. Sequential radiographs (Case 1)
Radiographs show the medical history of the patient in case 1. (a) The first supracondylar fracture after total knee arthroplasty. (b) Osteosynthesis using NCB-DF 6-holes. (c) Breakage of NCB-DF 6-holes caused by delayed union. (d) Re-operation using NCB-DF 9-holes. (e) Femur shaft fracture at the proximal point of NCB-DF. (f) Total femur fixation using Natural Nail with the "nail-plate docking technique".

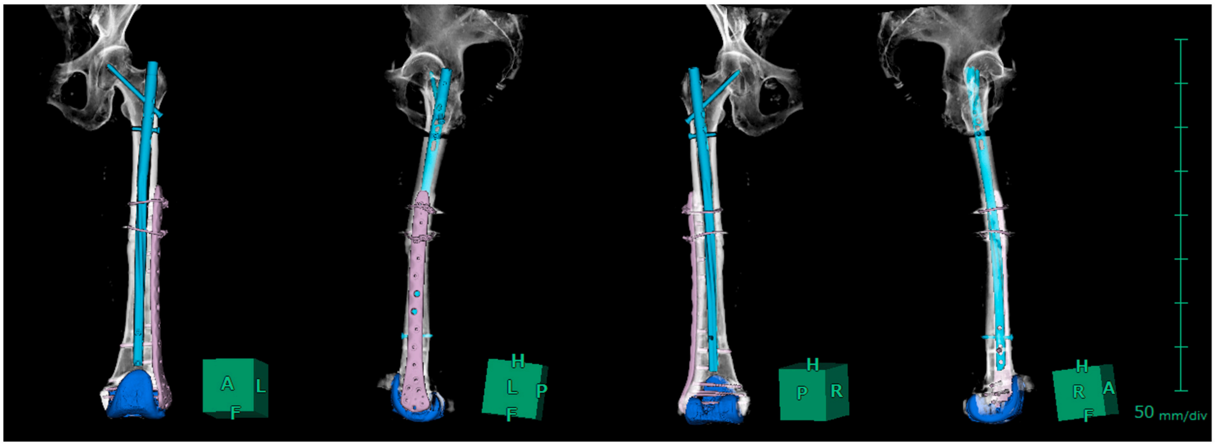

Fig. 3. Post-operative computer tomography scan (Case 1)
CT scan images of the patient in case 1 show total femur fixation docking Natural Nail and NCB-DF. The proximal locking screw of NCB-DF surely passes through the distal inter-locking hole of Natural Nail.

distal fracture with a long vertical crack (Fig. 4a). Two years ago, she underwent balloon kyphoplasty for osteoporotic vertebral fractures. She also has bilateral severe knee deformities caused by rheumatoid arthritis. Open reduction and internal fixation were performed using the NCB-DF-PP (periprosthetic 9-holes) (Fig. 4b). Four months later, she incurred an ipsilateral femoral shaft fracture at the tip of the NCB-DF-PP in a traffic accident (Fig. 4c). At that time, bone union has not been completed yet; therefore, we could not remove the NCB-DF-PP. After removing the proximal screws of NCB-DF-PP, an antegrade femoral nail was inserted for total femur fixation (Fig. 4d). The screw of the NCB-DF was inserted into the dynamic hole of Natural Nail and locked with the locking nut of the NCB-DF-PP. Two mediolateral femoral cortexes were fixed by the screw. One more distal locking screw of Natural Nail fixed two anteroposterior femoral cortexes. A total of four cortexes cross-locking of Natural Nail was performed (Fig. 5). Hemi-locking screws were also added to secure the fixation. To prevent further femoral neck fracture, a cannulated cancellous screw was inserted (Fig. 4d). At the final follow-up, 3 years and 10 months after the osteosynthesis with the "nail-plate docking technique", bone union was completed and the patient was able to walk using the walker albeit with some original knee pain. She still regularly comes to our hospital for treatment of rheumatoid arthritis.

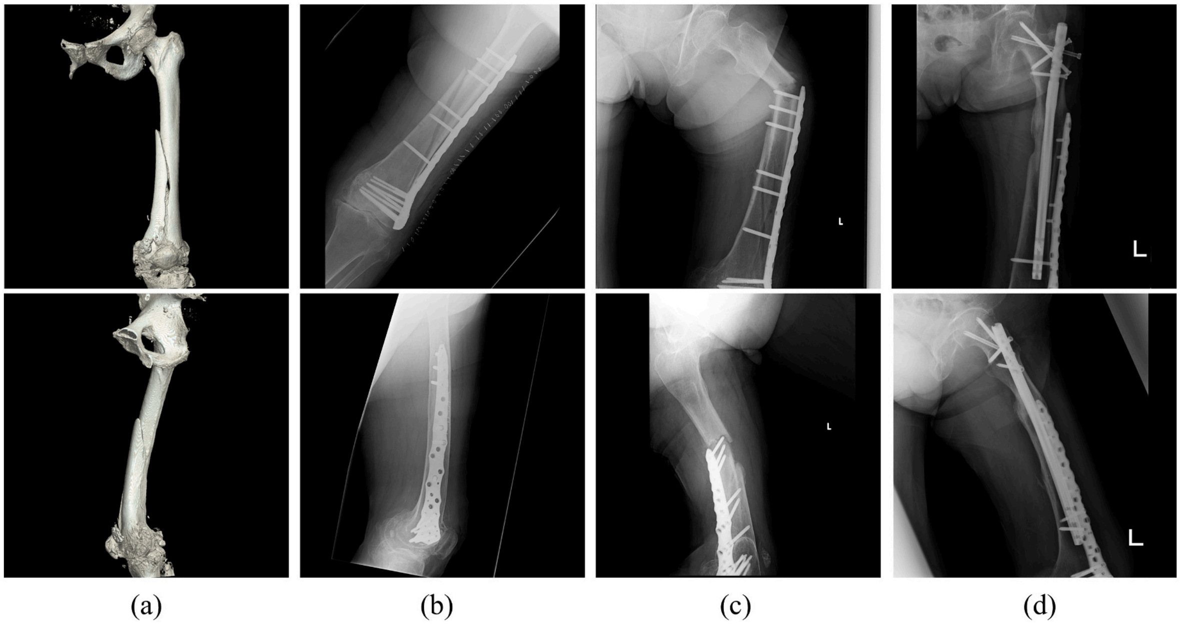

Fig. 4. Computer tomography and sequential radiographs (Case 2)
CT scans and radiographs show the medical history of the patient in case 2. (a) The CT scans show vertical cracking supracondylar fracture. (b) Osteosynthesis using NCB-DF-PP (periprosthetic 9-holes). (c) Femur shaft fracture at the proximal point of the NCB-DF-PP. (d) Total femur fixation using Natural Nail with the "nail-plate docking technique".

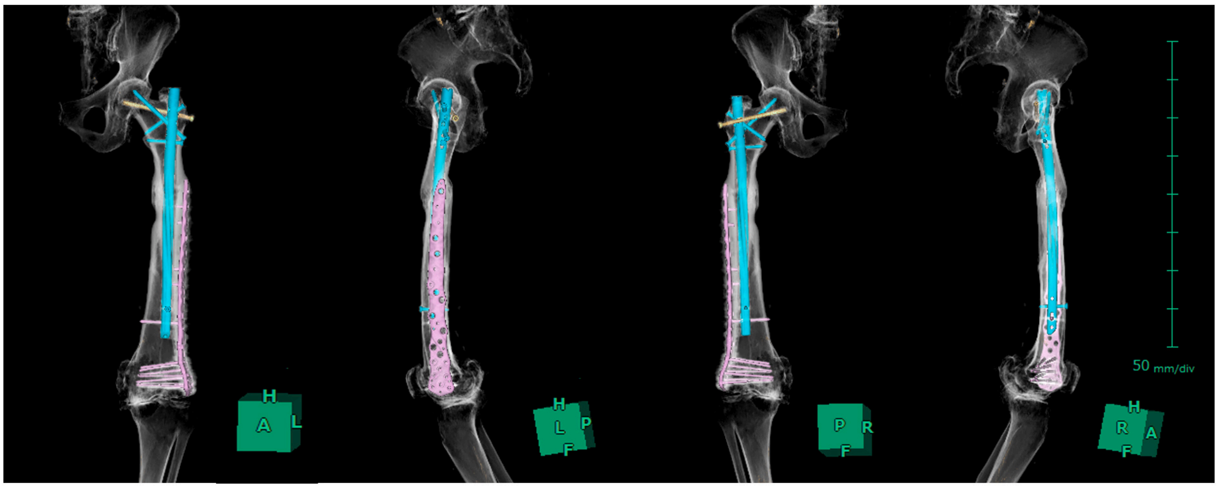

Fig. 5. Post-operative computer tomography scan (Case 2)
CT scan images of the patient in case 2 show total femur fixation docking Natural Nail and the NCB-DF. The proximal locking screw of NCB-DF surely passes through the distal inter-locking hole of Natural Nail. Cannulated cancellous screw is inserted alone for the prevention of further femoral neck fracture.

Discussion

Many screws of conventional locking plates have monoaxial directional restriction. In contrast, the screw of the Non-Contact-Bridging (NCB) locking plate system has polyaxial flexibility up to 30 degrees while maintaining enough mechanical strength [2–4]. The nut of the NCB locking system can maintain the screw angular stability and prevent the back-out of the screws (Fig. 6). The "nail-plate docking technique" utilizes these characteristics of the NCB locking system.

There are two knacks of this surgical technique. The first one is the selection of the femoral nail length. The adjustment of the height between the screw hole of the NCB-DF and the distal locking hole of the femoral nail is essential. We have to check the length from the end of the nail to the targeted locking hole of the nail before surgery. If possible, we can insert the locking screw of NCB-DF into the

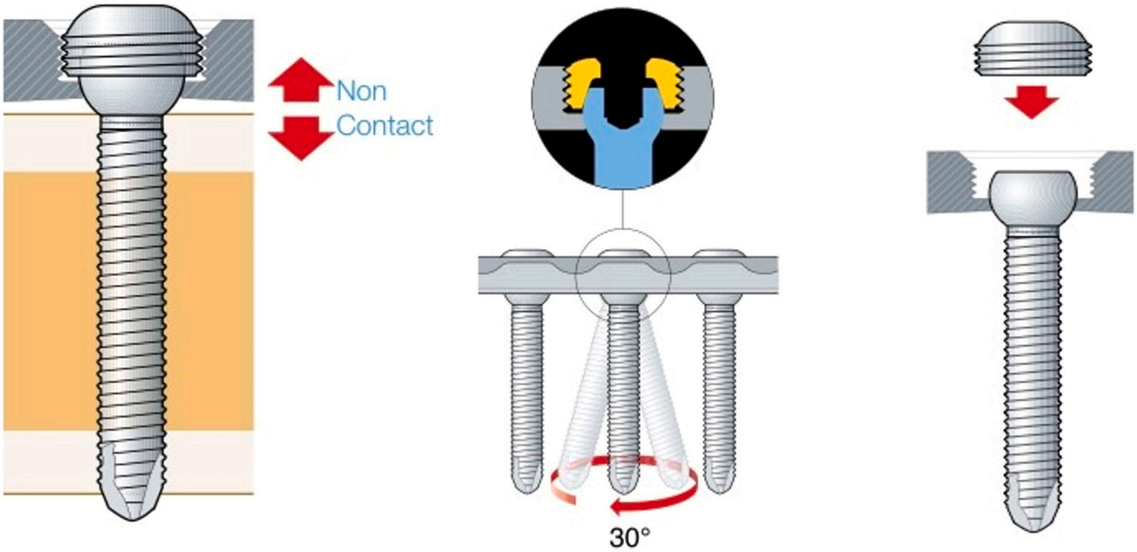

Fig. 6. Locking mechanism of the NCB-plate
The schema shows the locking mechanism of NCB-DF. NCB is the abbreviation of Non-Contact-Bridging. This locking screw has polyaxial flexibility up to 30 degrees. Furthermore, the nut of NCB locking system can keep the screw angular stability and prevent the back-out of the screws.

static hole of the femoral nail. However, it is easier to insert the locking screw into the dynamic hole of the nail. Thus, we recommend inserting the screw into the dynamic hole of the nail to avoid excessive mechanical stress on the screw. The second knack of this technique is the minute adjustment of the depth of the inserted femoral nail. We can control the depth of the nail using the end-cap, which varies as 0 mm, 5 mm, 10 mm, and 15 mm in Natural Nail. There are some restrictions regarding the length and the direction in the proximal locking screw of the femoral nail. We have to control the depth of the nail in the range of appropriate proximal screw insertion. The interval of the proximal screws of NCB-DF is 20 mm. There are more holes in NCB-DF-PP (for periprosthetic fracture). There are four distal interlocking holes in Natural Nail: two mediolateral static holes, one anteroposterior static hole, and one mediolateral dynamic hole. The dynamic hole of the nail is wide enough to insert the screw of the NCB-DF smoothly. It is not very difficult to control the depth of the nail within these ranges.

The biggest advantage of this surgical technique is there is no need to remove the plate, which can be utilized for the secondary osteosynthesis itself. Removing the implanted plate results in more surgical invasion [5]. Early second fractures without bone healing or compound fractures are also good indications for the “nail-plate docking technique”.

In cases of compound fracture or periprosthetic fracture, separated osteosynthesis is likely to cause stress concentration and fracture between the implants. The “nail-plate docking technique” makes it possible to fix the femoral bone completely while overlapping the nail and the plate [6], which prevents further inter-implant fracture [1,7,8]. Using the femoral nail with distal anteroposterior locking hole, distal femoral bone can be fixed strongly by cross-locking at four bone cortexes without interfering with the NCB plate.

However, this technique has some limitations. First, it is limited only to polyaxial NCB locking plates. Inserting the locking screw of the monoaxial locking plate into the locking hole of the femoral nail is extremely difficult like a hole-in-one in golf. If the other monoaxial plate had been used before, non-locking screw is recommended to insert into the locking hole of the femoral nail.

In the case of an inadequately positioned plate, the proximal screw of the femoral nail may be inserted eccentrically to insert the screw of the NCB plate into the locking hole of the nail. The rotation of the nail should match the rotation of the plate as far as possible. When the proximal screw of the femoral nail is inserted unacceptably, the surgeon must not push through with the “nail-plate docking technique”. We should also consider surgical treatment choices using multiple hemicortical screws and/or wiring systems for a secure fixation [9,10].

Conclusion

The “nail-plate docking technique” could allow for more stable fixation of the whole femur with minimally invasive surgical intervention while preserving the existing implant and preventing periprosthetic fractures.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that have influenced the work reported in this paper.

Acknowledgments

None.

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