ORIGINAL ARTICLE

NCB-plating in the treatment of geriatric and periprosthetic femoral fractures

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Summary

Background: The aim of this study is the presentation of the polyaxial locking NCB-plate in the treatment of femoral fractures, especially in elderly patients and in proximity of a prosthetic implant. The reduction and fixation of these fractures is a challenging surgical procedure with high complication rates reported up to 40%.

Patients and methods: A total of 72 patients with femoral fractures had polyaxial locking plate osteosynthesis. Indications included fractures of the shaft and around an implant. Concerning surgical procedures, three different standardized techniques were performed: (1) minimally invasive with percutaneous distal insertion using a targeting device; (2) mini-open with additional cerclage wire via the same approach and (3) a conventional open reduction and internal fixation. Data collection included intraoperative data and early complications at 6, 24 and 52 weeks. Fifty-two patients had an implant or prosthesis in situ. Thirty-three patients were treated by technique (1), 32 patients had mini-open surgery and seven patients conventional open surgery.

Results: Thirty-nine patients attended clinical follow-up after 52 weeks. Twenty-two patients were interviewed by telephone, two were untraceable and nine patients had died. Bony consolidation without secondary loss of reduction was confirmed after 52 weeks in all patients but two. Plate breakage occurred in these two at 25 and 31 weeks after surgery due to non-union. Implant related complications (17% in total) lead to surgical revision in five other cases: two deep wound infections as well as three minor revisions. When itemizing complications according to surgical technique used, most major complications occurred following open surgery.

Conclusion: The availability of polyaxial locking implants widen the range of indications for plate fixation in femoral fractures. The advantages of the polyaxial locking implant combined with minimally invasive surgical technique contribute to successful management of this population category. Early revision rate is noticeably lower compared to similar procedures.

Level of evidence: IV retrospective series.

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Introduction

The incidence of periprosthetic fractures after primary knee- and hip arthroplasty is around 2.5% and is increasing after revision surgery up to 4% [1–3]. That results in a number between 7500 and 12000 fractures following arthroplasty yearly.

Fractures of the femur especially after arthroplasty or osteosynthesis are most common in geriatric patients. They represent challenging surgery since they are often pathologic fractures or associated with low bone quality. Conservative therapy (in elderly patients) is obsolete [3] due to both high general complication rates with prolonged immobilisation (pneumonia, thromboembolic events, decubitus, etc.) as well as fracture related complications (higher rates of non-union, decrease of range of motion and higher pain rates).

Intramedullary nailing provides favourable stability and can be successfully performed in bilateral or multisegmental fractures of the lower extremity as well as in extra-articular fractures [4]. Concerning intramedullary nailing as an alternative to plating the "box" of a cruciate-sacrificing, total knee design often blocks the optimal placement of a distal femoral blade plate. Similarly, many femoral prostheses can displace the starting point for an intramedullary nail posteriorly, resulting in a recurvatum deformity of the distal femur. Placement of a nail may be impossible in prosthetic designs with a "closed box" [5]. Also small distal femoral fracture fragments are frequently not large enough to accommodate distal locking bolts, effectively prohibiting the use of a nail. Furthermore, short nails may increase the risk of a recurrent nail tip fracture.

The implants in use for (periprosthetic) femoral fractures including long-stem prostheses, intramedullary nails and locking plates of first and second generation have complication rates of up to 40% [6,7]. These include unstable fixation in osteoporotic bones, especially in fractures of the femoral diaphysis and secondary displacement, dislocation, implant breakage, loosening of screws and blades and non-union [8]. Transverse diaphyseal fractures are commonly treated by intramedullary nailing, keeping the fracture haematoma intact and not disturbing the periosteal blood supply. The downside of that procedure is the frequent need for second surgery for dynamisation (15–33%) and secondary displacement.

Locked plating represents a working alternative if nailing is not possible. Locking screws allow a secure fixation even of small (distal) fracture fragments. Locked plating can be used for all distal femoral fractures including complex type C fractures, periprosthetic fractures, as well as osteoporotic fractures [4].

Aim of this study is the evaluation of polyaxial locking plate in these indications.

Patients and methods

Study design

A standardized registration of all distal femoral and shaft fractures was performed, which could not be treated by intramedullary nailing. These were mainly geriatric fractures in the metaphyseal area, osteoporotic fractures and fractures following prior osteosynthesis or arthroplasty with an intramedullary implant in situ. Indications included all kinds of primary distal femoral fractures classified A–C following AO due to better stability in the geriatric bone. Due to reported complications with intramedullary nails in geriatric patients, polyaxial locked plating was preferred. Especially in periprosthetic fractures plating seemed to be suitable in most cases despite pre-existing hardware in or on the bone and low bone quality. In these patients, stability of implants was assured by standard radiographs in two planes and intraoperative evaluation under anaesthesia.

Preoperative mobility as well as intraoperative parameters were recorded. Patients were evaluated after 6, 24 and 52 weeks. Follow-up included evaluation of wound healing, functional assessment, bony consolidation (both cortices bridged, fracture line no longer evident, no pain at loading), evaluation of the GOS and general complications. The Glasgow Outcome Scale (GOS) was used to estimate participation in daily life [9] (Table 1). It was used for its easy intra-/interobserver comparability pre- and postoperatively. In such a special collective, the possibility of telephone interview is essential. For easier comprehension, GOS was inverted as other authors did too [10] (1 = good recovery and 5 = death).

The study design was approved by the Ethical Committee of Philipps-University Marburg, reference no. 110/10.

The polyaxial locking implant

All fractures were reduced and fixed with the polyaxial locking Non-Contact-Bridging-plate Distal-Femur (NCB-DF® Zimmer Inc., Winterthur, Switzerland) [11]. This implant offers the possibility of locking screw fixation where the screws can be directed in an angle of up to 30° in any direction to the plate level to avoid an intramedullary implant. The NCB-DF® plate is available in three different lengths 167 mm (5-holes), 246 mm (9-holes) and 324 mm (13-holes), and in a different design for each side.

Another important feature of the implant is the possibility of minimally invasive implantation via aiming device, which follows the principles of biological osteosynthesis preserving vitality of the fracture region. A 4-point-fixation

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Modified Glasgow Outcome Scale.</th>
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<tbody>
<tr>
<td>GOS 1</td>
<td>Good recovery</td>
</tr>
<tr>
<td>GOS 2</td>
<td>Moderate disability (disabled but independent), no assistance in daily life needed</td>
</tr>
<tr>
<td>GOS 3</td>
<td>Severe disability (conscious but disabled), needing assistance in daily life</td>
</tr>
<tr>
<td>GOS 4</td>
<td>Persistent vegetative state</td>
</tr>
<tr>
<td>GOS 5</td>
<td>Death</td>
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</table>
system attaches the plate to a carbon frame. The holder is a highly accurate guide for drilling the plate holes (Fig. 1).

**Indications and surgical technique**

The classification of the primary fractures followed AO, while periprosthetic fractures were based on the Vancouver-classification [12] in the proximal and on the Rorabeck-classification [13] in the distal femur.

For fracture stabilisation, two operative techniques were defined: the "mini-open" technique and the "minimal invasive" technique. The indication for the "mini-open" approach was made in two-part long spiral fractures. Indications for the "minimal invasive" approach were all other fracture types, mainly multi-fragmented fractures or short oblique fractures.

**"Minimal invasive" technique**

The main concept of this technique is a closed reduction. This was achieved by either ligamentotaxis and/or the application of the plate as a template (Fig. 2). Therefore, correct alignment by axial traction was maintained throughout the whole procedure. Traction was performed by the assistant surgeon. In cases with mid shaft fractures, a traction table was used. Subsequent closed reduction the plate was inserted through a short 3–4 cm incision (Fig. 2). After this step, the plate was temporarily fixed with K-wires proximally and distally. The length of the plate should allow the placement of at least three to four screws in the diaphyseal area of the femur. Before the screws were set, a lateral view to control the plate position was performed with the image intensifier. By setting the shaft screws first, the plate was used as a reduction tool. The screws were locked with a cap when the plate was running parallel to the diaphysis. Before the screws were placed in the metaphyseal area, a control of the axis was performed. In our institution, the "cable-technique" is applied [14]. With this method, the straightened cable of the coagulation simulates the mechanical axis. Correct reduction was achieved when the image intensifier showed that the cable was running through the centres of the hip, knee and ankle joint. Thereafter the screws were set in the metaphysis.

"**Mini-open" technique**

Before the NCB-plate was inserted, an open reduction and temporary fracture fixation was performed (Fig. 3). For this step, an incision at the level of the plate insertion was made that was sufficiently long to expose the fracture region. The two fragments were reduced by the help of a forceps until an optimal contact with anatomical alignment of axis and rotation was achieved. The reduction forceps was then replaced by one or two cerclage wires. After this step, the plate was inserted with the jig and temporarily fixed with K-wires proximally and distally. The length of the plate should allow the placement of at least three to four screws in the diaphyseal area of the femur. Before the screws were set a lateral view to control the plate position was performed with the image intensifier. In the metaphyseal area, as much screws as possible were set around the prosthesis. The screws in the diaphyseal region were inserted percutaneously by the
Figure 3  Technique II in long spiral fractures: ’’mini-open’’ with primarily cerclage wire fixation.

jig. The femur was not exposed in this area. All screws were locked with a cap.

Only a few cases e.g. with intraoperative fracture during revision hip arthroplasty at open surgical approach needed conventional open reduction and internal fixation.

In proximal femoral shaft fractures, the NCB-DF®-plate of the opposite side could be inserted antegrade via a proximal lateral approach. This could be a useful alternative in subprosthetic fractures below hip arthroplasty or osteosynthesis.

The impact of three different surgical options on result and complications was examined.

Patients

From October 2007 to July 2011, 84 NCB-DF® plates were implanted. Follow-up at the time of the study passed 52 weeks in 72 patients: 39 fractures were periprosthetic fractures not disturbing the stability of the arthroplasty and 13 were peri-implant fracture. In 42 patients suffering a known bone disease as osteoporosis (measured by DXA), osteomalacia or another pathological bone disorder, fractures were called ’’geriatric’’. Thirty-five fractures were left sided and 37 on the right side. Mechanism of fracture was a low-energy trauma e.g. a fall in the house in 64 patients, eight patients had a high energy trauma falling down several stairs or road traffic accidents.

Average patients’ age was 76.1 years (39–99 years), average ASA-Score was 2.7 [1–4]. Fifty-two patients had three and more relevant comorbidities, 16 patients had two or less relevant comorbidities and 4 patients had none.

Forty patients were admitted to hospital directly from their homes, 15 were living in nursing homes, and 17 patients were referred from other hospitals. Seventeen patients were bed-ridden prior to the trauma.

Of the 52 periprosthetic/-implant fractures with an intact and stable implant, 22 had a hip arthroplasty. According to Johansson [15] they were classified 1 × type 1, 13 × type 2 and 8 × type 3. All 12 fractures occurring in knee arthroplasty were classified type 2 according Rorabeck and Taylor [5]. Five fractures were ’’interprosthetic’’ between hip and knee arthroplasty. The other 13 fractures occurred following hip fracture.

In 20 patients, NCB-DF® plating was performed after distal femoral fracture as primary fracture treatment. These were classified according AO (Table 2).

Results

Follow up

In 33 fractures, a minimally invasive closed technique could be performed and in 32, an additional cerclage wire was necessary following ’’mini-open’’ technique.

In six cases after proximal periprosthetic femoral fracture and stable hip arthroplasty, a NCB-DF®-plate of the opposite side was implanted via a proximal lateral approach. The duration from admission to operation was in median 30 h (1–125 h). Surgery lasted 103.7 min. (40–197 min) in median and intraoperative image intensifier time averaged 2.8 min. (0.3–5.4 min.). The intraoperative blood loss measured by intraoperative transfusion was 1.7 unit of
erythrocyte concentrate (0–7) on average per patient. The average stay in hospital was 17.7 (5–45) days.

The rehabilitation program was standardized with no weight bearing of the affected extremity for 6 weeks. Seventeen patients were bed-ridden due to prior disease and could not be mobilized out of bed. Twenty-one patients were transferred to rehabilitation or geriatric centres, 27 patients were discharged home and 24 to (temporary) nursing homes.

No patient died in hospital. Nine patients died at a mean age of 88.8 (84–99) years during further follow-up on average 2.7 months after surgery.

After 52 weeks, 39 patients attended the clinical follow-up and 22 patients received a telephone survey. Nine patients had died and two patients were untraceable. All but 13 patients interviewed by telephone had a radiological control. Bony consolidation was confirmed in 48 patients. Range of motion of the knee was sufficient (0–≥ 90°) in all cases. Bony consolidation in malposition due to suboptimal reduction was seen in two patients without influence on mobility. Two patients with delayed radiological union developed a mechanical failure with implant breakage 25 and 31 weeks after surgery. One patient suffered primarily a long spiral diaphyseal fracture with interposition of soft tissue the other a transverse fracture. In both patients the surgical strategy was an open approach and plate fixation. Revision surgery in one patient consisted of implant removal and retrograde intramedullary nailing; the second patient received a non-cemented long stem hip arthroplasty.

The GOS at 52 weeks showed a decrease of three points in four patients, of two points in five patients, of one point in 21 patients and was back to the preoperative level in 40 patients (Table 3).

## Complications

In total, seven patients developed complications that needed subsequent surgery. In two patients with known osteomalacia, a distal femoral fracture was preoperatively underestimated; an AO "C"-fracture was treated as a "B"-fracture, the condylar screws were too short and were replaced after the first postoperative control radiograph with longer screws. In another patient, a protruding screw caused irritation of the medial collateral ligament and was removed after bony consolidation. Wound healing disturbances were seen in two patients: in the first case, a wound debridement 5 weeks after surgery was sufficient. In the other patient, deep infection ended with implant removal at 3 months and a Girdlestone situation at 12 months. The medical history of that 82-year-old patient showed Johansson two femoral fracture occurring 10 days after second exchange of hip arthroplasty in another institution. NCB-DF® surgery was performed in mini-open technic in a tolerable surgery time of 106 min. Noticable is a long image intensifier time at 5.06 min, indicating demanding surgery and difficult reduction. Moreover this patient developed a urinary tract infection during hospital stay. All these details might help to explain the deep infection of the arthroplasty and internal osteosynthesis.

Complications without need for surgical revision were seen in 36 patients. Five were technique related: two patients with obvious malalignment (15° internal rotation, 15° valgus) were not revised because sufficiently mobile. One femoral nerve lesion recovered completely within 5 months. This patient suffered a proximal comminuted Johansson two fracture at short hip stem. Reduction and

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### Table 2 Classification of fractures.

<table>
<thead>
<tr>
<th>Periprostatic fractures, hip-arthroplasty in situ n = 22</th>
<th>Periprostatic fractures, knee-arthroplasty in situ n = 12</th>
<th>Interprostatic fractures, hip- and knee-arthroplasty n = 5</th>
<th>Peri-implant fractures with implant in situ n = 13</th>
<th>Primary osteosynthesis n = 20 (acc. AO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 × Johansson 1</td>
<td>12 × Rorabeck 2</td>
<td>3 × Johansson 2 and Rorabeck 2</td>
<td>1 × Johansson 1</td>
<td></td>
</tr>
<tr>
<td>13 × Johansson 2</td>
<td>2 × Johansson 3 and Rorabeck 2</td>
<td>8 × Johansson 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 × Johansson 3</td>
<td></td>
<td>4 × Johansson 3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

AO: Arbeitsgemeinschaft Osteosynthese; PFN: proximal femoral nail.

### Table 3 GOS-course.

<table>
<thead>
<tr>
<th>GOS</th>
<th>Pre trauma = 72</th>
<th>6 weeks post OPn = 70</th>
<th>24 weeks post OPn = 70</th>
<th>52 weeks post OPn = 70</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (good recovery)</td>
<td>15</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>12</td>
<td>28</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td>17</td>
<td>54</td>
<td>35</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5 (death)</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>
internal fixation was performed antegrade via proximal approach in mini-open technique with additional cerclage wires. A prolonged wound healing in two patients healed conservatively with antibiotics and repeated dressings. Eighteen cases of urinary tract infection, nine of cardiac failure, four of pneumonia and pulmonary failure, two cases of cerebral ischemia, one heel and one sacral decubitus as well as one deep vein thrombosis treated conservatively were registered. In the follow-up period, one patient (86 years old) developed a deep vein thrombosis and lethal pulmonary embolism 10 days after surgery.

Discussion

Stable fixation of complex femoral fractures in geriatric patients can be very demanding, especially if associated with low bone quality and the presence of implants after arthroplasty or osteosynthesis. Complication rates reported after surgical treatment of these fractures range from 19 to 53% [2,16–18]. Immobilisation and general complications render conservative therapy obsolete, even in non-displaced fractures and stable arthroplasty [19]. However, even with modern techniques and locking implants, complication rates remain high [20–24].

An important feature of the NCB-DF®-system is the possibility of minimally invasive implantation. The fracture haematoma with proven importance for fracture healing [25] is not compromised. A formerly common bone grafting to fracture region is not necessary in primary surgery but could be useful in revision surgery for non-union [24].

The most important innovation of NCB-DF®-systems comparing conventional and available systems is the possibility of polyaxial locking fixation with angular stability, allowing bicortical plate fixation avoiding intramedullar implants. Biomechanical studies proved higher stability compared to monoaxial implants, which seems to be relevant especially in osteoporotic bones [26,27].

In this study, we present two minimal invasive techniques in addition to the open approach. Actual literature seems to be consistent that minimal invasive surgery especially in "biological osteosynthesis" should be favourable to conventional open surgery if the high learning curve is completed and avoidance of pitfalls is assured [28]. Ehlinger et al. recently presented a case series of 36 patients with periprosthetic femoral fractures of whom 26 patients were treated by a minimal invasive locked plating showing good results concerning union (35/36), refracture (n=0) and mechanical failure (3/36) [29]. Nevertheless, most authors does not describe the extent of "minimal invasive" approach, making it difficult to compare. In our series, maximum efforts were done to preserve fracture vitality. Clinical follow-up showed no compromising of fracture healing in additional cerclage wiring. Noticeable is that the only two implant breakages occurred at delayed union after open surgery for exchange arthroplasty, in which rules of biological osteosynthesis could not be applied. Discussing reasons of implant failure the open surgical approach with soft tissue trauma, denudation of bone as well as opening and resection of fracture haematoma must be taken into consideration. Furthermore, transverse fractures are inapplicable to plating and should be treated by intramedullary nailing.

To date, only a few studies dealing with NCB-DF® in clinical aspects are published: one presents the osteosynthesis of 24 periprosthetic fractures in 32 months showing a revision rate of 15% and a healing rate of 90% [11]. Pressmar et al. reported on 11 revision surgeries (26% subsequent hip arthroplasty and 42% subsequent knee arthroplasty) out of 31 NCB-DF® implantations with a total of 20% implant failures. Noticeable is an open surgical procedure at 84% of implantations in that collective [30]. In the present study, the rate of minimal invasive procedures was noticeably higher, possibly explaining the lower complication and implant failure rate.

The all over implant-related complication rate in the presented series is 17%. Surgical revisions were necessary in 10% of the patients, whereas three out of these seven surgeries were screw changes and classified as minor revisions. To avoid such revisions and to define the surgical strategy in often comminuted fractures, prior computer tomography assessment is highly recommended. No surgical revision caused death. The overall mortality of 11% in the 12-month follow-up period is a little higher than the normal death rate in the studied age group. General complications like cardiovascular or respiratory decompensations, cerebral ischemias as well as urinary tract infections demonstrate the low general condition, multimorbidity and sensitivity of this patient population but are comparable to patients with proximal hip fracture.

GOS-course showed that 56% of the presented patients reached the same mobility and activity level as prior trauma at 52 weeks follow up; 28% decreased in the scale at one point, meaning dependency on crutches or other technical support. These data are comparable to the series of Erhardt et al. [11] but are definitely better than the results of Pressmar et al. [30]. A possible explanation might be the surgical technique and smaller accompanying soft tissue trauma too.

However, the presented data shows definitely lower complication rates for NCB®-plating compared to conventional plate osteosynthesis [6,18,31,32]. Comparing it to analogue locking plate systems with monoaxial stability, a similar complication and revision rate between 5.2 and 27% is detected. Limitations of all these studies are low numbers of patients and short follow-up periods of partly only 3 months [20–24].

Limitations

The general disadvantage of plate osteosynthesis is the lacking possibility of full weight bearing due to the eccentric stabilisation. Especially in geriatric patients, a stable procedure allowing immediate full weight bearing is required. Actual biomechanical investigations show a less loading stability in femoral plating compared to intramedullary nailing [33]. Other authors recommend the immediate full "pain-adapted" loading on the limb [29] showing good intermediate results, but not knowing the real amount of loading in every patient. In our series, full weight-bearing was allowed after 6 weeks, due to the aged geriatric collective with high occurrence of osteoporosis/osteomalacia. Furthermore, most geriatric patients are not really able to control the amount of bearing on the affected extremity due to often associated lag of proprioception and instable gait.
The fear of fracture complications after an uncontrolled fall or a mechanical failure at poor stability seems to be higher than the possible benefit of immediate full weight bearing and leads to more caution in this population of fragile patients.

High intraoperative image intensifier time up to 5 minutes was due to the technique of the minimally invasive closed procedure at demanding reduction and is burden primarily the operation room staff and only secondary the (aged) patient. This disadvantage is well known in all minimally invasive orthopaedic procedures.

Concerning the implant, criticism includes that polyaxial insertion of screws is only possible without using the aiming device of the system. Especially in obese patients this could be difficult, resulting in even more X-ray and surgery time.

In this study, the follow-up period was limited to 1 year. This period seems to be satisfactory as bone healing and remodelling should be completed within 12 months. At old age, early complications and rapid reintegration into the homely environment are relevant. A longer observation period will additionally show mid- and long-term complications, but will have a huge lost for follow up due to the nature of the collective.

Moreover, heterogeneous patient groups, non-uniformed literature with partly low patient numbers and inconsistent rehabilitation programs must be criticised. An eligible real internal control group in that patient collective is not possible, due to fracture entity and comorbidities.

Conclusions

The polyaxial NCB-DF® locking plate represents a safe option in treatment of complex and periprosthetic femoral fractures in geriatric patients at a low complication rate. Compared to other systems with complication rates up to 40%, we found a surgical revision rate of only 10% at a high rate of union and low rate of mechanical failures or infections. The presented system provides the possibility of a minimally invasive percutaneous surgical technique and polyaxial fixation avoiding intramedullary implants. Concerning different surgical strategies, clear advantage to minimal invasive and mini-open techniques in fracture healing is shown. Most complications occurred following conventional open surgery. Not only the fracture type and implant but also the implantation technique plays a vital role. Open surgery should be kept as exceptional procedure if minimal invasive procedures are impossible.

The advantages of the minimally invasive technique combined with adequate surgical technique contribute to successful management of these demanding fractures.

Disclosure of interest

No benefits or funds were received in support of this study. There are no conflicts of interest in relation to this study from following authors: Bilal Farouk El-Zayat, Turgay Efe, Antonio Krüger, Dimitri Kreslo and Susanne Fuchs-Winkelmann.

Ralph Zettl and Steffen Ruchholtz are lecturers and course instructors at Zimmer Inc.

References


