*Acta Orthop. Belg.*, 2020, **86**, 46-53

*ORIGINAL STUDY*

# Polyaxial locking plate fixation in periprosthetic, peri-implant and distal shaft fractures of the femur : a comparison of open and less invasive surgical approaches

Florian Hess, Christoph Knoth, JoEllen Welter, Ralph Zettl, Susanne Dörr

*From the Department of Orthopaedics and Traumatology, Cantonal Hospital, Frauenfeld, Switzerland*

**Polyaxial locking plate fixation is a widely performed treatment for femoral shaft, periprosthetic, and peri-implant fractures in elderly patients. This study's purpose was to compare patient outcomes following the open technique (OT) and less invasive techniques (LIT).**

**Data were gathered from 44 patients with 46 fractures treated with polyaxial locking plate between 2010-2015. Twenty fractures underwent the OT and 26 had a LIT. Long-term assessments for 83% of the fractures were done at a median of 23 months postoperatively.**

**Bone healing rates were 82% in the OT and 100% in the LIT group (p=0.0688). The difference in the median duration of the surgery (OT 120 minutes, LIT 73 minutes) (p< 0.001) was the main statistically significant finding.**

**Both surgical techniques resulted in similarly favourable outcomes. The LIT would be the preferred operating technique, especially when treating patients more susceptible to intra- and/or postoperative morbidity.**

**Keywords :** Periprosthetic fracture ; peri-implant fracture ; fragility fracture ; polyaxial locking plate ; femur fracture.

## INTRODUCTION

Total hip and knee arthroplasty are common procedures performed in elderly populations, and their use is expected to rise significantly in the future *(19)*. Given the high prevalence of co-morbidities, increased longevity, and poor bone quality of this population group, revision surgery is sometimes required. The incidence of periprosthetic fractures after primary total hip arthroplasty (THA) is approximately 0.1-6.0% (2,3,15), and 0.3-2.5% after primary total knee arthroplasty (TKA) *(2,20,23)*. The most common causes for revision surgery are instability (22%), mechanical loosening (20%), infection (15%), implant failure (10%), osteolysis (7%), periprosthetic fractures (6%), among others (20%) *(3)*.

Studies have found that polyaxial locking plate systems for the femur are more advantageous than conventional monoaxial locking systems *(7,13,16)*. However, it remains unclear which surgical approach for implantation is superior – open or less invasive techniques. Although studies reporting

*Competing interests : the authors declare that they have no conflict of interest.*
*Funding : There is no funding source.*

■ Florian Hess, MD,
■ Christoph Knoth, MD,
■ JoEllen Welter, MPH,
■ Ralph Zettl, MD,
■ Susanne Dörr, MD
*Department of Orthopaedics and Traumatology, Cantonal Hopistal, Frauenfeld, Switzerland.*
Correspondence : Dr. med. Florian Hess, Department of Orthopaedics and Traumatology, Cantonal Hopistal, Frauenfeld, Switzerland, Tel. +41-52-723-77-11. Fax +41- 52- 723-74-28.
E-mail : Florian.Hess@stgag.ch

complication and revision rates of less invasive techniques (LIT) *(8,9)* and open techniques (OT) *(5,10,18)* showed improved outcomes with the LIT *(4,5,6,11,25,26)*, no comparative study with adequate group sizes has been undertaken. Furthermore, the OT approach is most often referenced in the literature *(5,10,18,22)*, in spite of an upward trend in minimally invasive surgeries.

Our investigation's primary aim was to describe patient outcomes after osteosynthesis of periprosthetic femur fractures using a polyaxial locking plate system, and to compare these outcomes based on the surgical technique used. The study's secondary aim was to use these findings to determine if one of these approaches should be considered the preferred surgical technique.

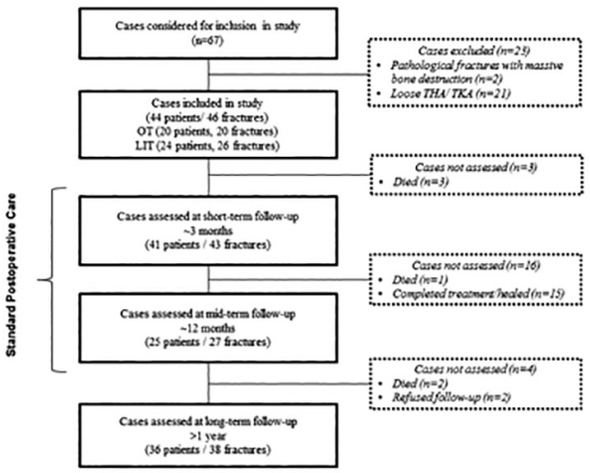


***Figure 1.*** — Flow diagram of patient assessments

## METHODS

Medical records of 67 consecutive patients treated for femoral shaft, periprosthetic and peri-implant fractures with polyaxial locking plate at our institution between 2010 and 2015 were assessed for inclusion. Of these 67, 44 patients with 46 fractures were analysed (Figure 1). One patient fractured both legs within two years (LIT, OT) ; another patient suffered bilateral fractures (two LIT) from a tractor accident. Included in the analysis were nine patients with distal femoral fractures, which did not require inlaying prosthesis or use of nails. The technique used on these nine patients did not differ from similar periprosthetic fractures. All nine fractures were located distally and appropriate treatment was with plating, not with nails.

Excluded from the study were pathological fractures with significant local bone destruction, implant failures, or preoperatively loose hip / knee prosthesis. Three Vancouver B2 fractures were included in the study because they were preoperatively classified as type B1 with a fixed stem. Cases of periprosthetic and peri-implant fractures that needed revision were also excluded. Table 1 presents a list of fracture types included in the analysis. With regard to patient selection and allocation to the operating techniques, this was largely influenced by the timing of the introduction of the NCB plate. At the time the plate was first put into use at our institution, we were exclusively using the open technique. We incrementally began performing less invasive techniques in addition to the open technique. The selection of the technique was

Table 1. — Fracture type by surgical technique

| Classification | Fracture type | Open technique (n=20) | Less invasive technique (n=26) | Total (n=46) |
|---|---|---|---|---|
| Vancouver[20] | A | 0 | 2 | 2 |
| | B1 | 9 | 5 | 14 |
| | B2 | 2 | 1 | 3 |
| | C | 1 | 5 | 6 |
| Rorabeck[21] | 1 | 0 | 2 | 2 |
| | 2 | 3 | 2 | 5 |
| | 3 | 0 | 0 | 0 |
| AO / OTA Class | Peri-implant | 2 | 3 | 5 |
| | Femoral fracture | 3 | 6 | 9 |

dependent on surgeon preference rather than patient characteristics or severity of the injury. Lastly, all patients provided written consent for participation and approval for the study was granted by the local ethics commission (01.53.01(2013/2006/KAP)013). Three operative techniques were used - minimally invasive *(20)*, mini-open *(6)*, and conventional open *(20)*. For the analysis, we combined the 'minimally invasive' and the 'mini-open' to form the 'less invasive technique' group *(21)*. Fractures were treated with the Non-Contact Bridging Plate (NCB®) polyaxial locking plate system (Zimmer Inc., Winterthur, Switzerland) : distal femur and periprosthetic fractures in patients with TKA received Non-Contact Bridging Plate - Distal Femur (NCB-DF®) ; periprosthetic fractures in patients with THA and peri-implant fractures received Non-Contact Bridging Plate - Periprosthetic Plate (NCB-PP®). At our institution, these plates are routinely used for such fractures. Therefore, other plates or monoaxial devices were not assessed in this study.

The *minimally invasive technique* was done to avoid opening the fracture zone and to preserve periosteal vascularisation in multi-fragmented and/or short oblique fractures (Figure 2). Reduction was achieved with ligamentotaxis and the plate during screw fixation. Once full reduction was achieved, manual traction and leg rotation maintained the position. Plate length was determined under fluoroscopy by positioning the implant on the skin. For proximal periprosthetic and femoral shaft fractures, the plate was inserted using an antero-grade approach through a small (3-4cm) lateral peritrochanteric space. This was done to position the metaphyseal part of the plate around the implant shaft. For periprosthetic distal or distal femur fractures, the plate was inserted using a distal approach lateral to the condyle. The plate was positioned under fluoroscopic view and temporarily fixed with proximal and distal K-wires. Before definitive screw fixation, the plate position was evaluated in the lateral view. The first screw was placed close to the fracture to improve reduction and pull the plate towards the femoral shaft. Screws were placed through the plate insertion approach or percutaneously. Finally, all screws were locked using caps.

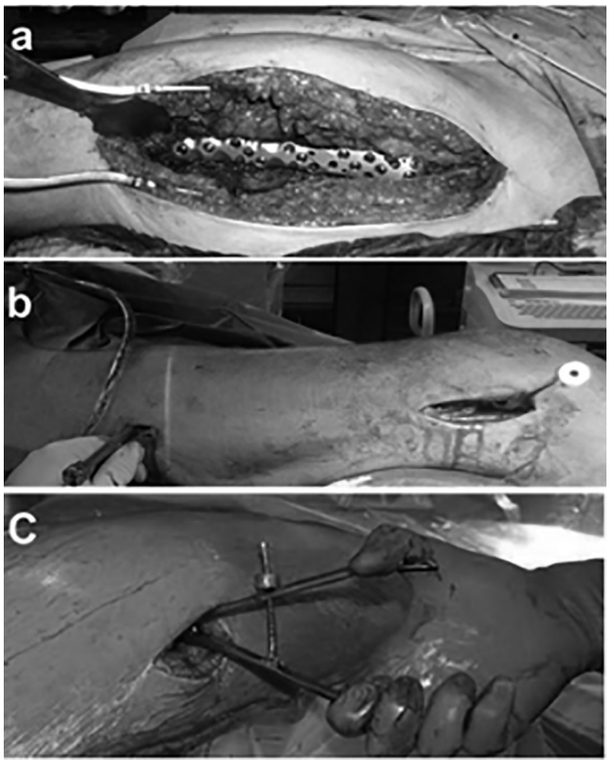


***Figure 2.*** — Example of the three different approaches
a: Open subvastus approach with inlaying NCB-PP®. b: Minimally invasive approach. The plate is inserted distally. A small incision proximally allows correct plate positioning and temporary fixation with two K-wires. c: Mini-open access. The middle incision is used to place cerclage, particularly useful in long spiral fractures

The *mini-open technique* was used to treat long periprosthetic oblique or spiral fractures (A0 32-A1 or 33-A1). A small (4-5cm) lateral subvastus approach was used to open the fracture region. The fracture was reduced manually and temporarily fixed with a reduction clamp. After fluoroscopic assessment of the axis and rotation, the clamp was replaced by 1-2 cerclages. If it was difficult to place the clamp due to the small exposure of the fracture region, the reduction was maintained by direct insertion of 1-2 cerclages. Anatomic reduction was achieved with extension and rotation while tightening the cerclages. Care was taken during this manoeuvre to avoid soft tissue interposition under the cerclage. The plate was then inserted as described above. It was temporarily fixed with distal and proximal K-wires. The screws were placed

through the incision and percutaneously. All screws were locked with caps.

In the minimally invasive and mini-open techniques, a targeting device to place the screws was not used. In patients with periprosthetic or peri-implant fractures, it is essential to pass the stem anteriorly or posteriorly. When using a targeting device, the direction is predetermined and cannot be modified. Consequently, we prefer to place the distal femoral screws under fluoroscopic control in order to choose the most suitable location for each screw.

When performing the *open technique*, we used a lateral subvastus approach with a 25-35cm incision (Figure 2). Care was taken to minimize dissection of the muscle coverage of the femoral shaft and avoid extensive damage to the blood supply. The periost was not removed. Moreover, interfragmentary compression was avoided to allow the plate to work as an internal fixator and accomplish a dynamic osteosynthesis. Temporary insertion of a reduction clamp or Dall-Miles cerclage was used to achieve anatomical reduction before plate fixation. The plate was fixed with proximal and distal K-wires before final screw placement. All screws were locked with caps. Figure 2 illustrates both minimally invasive and open plate insertions.

With all three techniques, the rotation and leg length were only assessed intraoperatively using fluoroscopy. No additional postoperative CT scan to exclude femoral malrotation was performed.

All patients were mobilized with the assistance of physiotherapists within two days after surgery. Given that half body weightbearing is often not feasible for elderly patients, full weightbearing using crutches for extra stability was allowed. Physical therapy was offered for a minimum of three months and could be extended up to a maximum of nine months in order to reach normal gait and full range of motion in the hip and knee. After three months or whenever visible consolidation of the fracture was observed, patients were encouraged to forgo crutches and/or use the walker they needed preoperatively.

Patients had preoperative clinical and radiologic assessments. Follow-up assessments were *scheduled* after 6 weeks, 12 weeks, and one year ; however, the precise timing of these visits depended on the patient's satisfaction and bone healing rate. Once fracture consolidation was demonstrated (antero-posterior and lateral views) and the patient was pain free, no additional radiological exams were performed. 'Non-union' was defined as no callus formation in two radiograph planes after nine months. For this investigation, patients were contacted for an additional long-term follow-up assessment using the SF12, Glasgow Outcome Scale *(14)* (GOS), and visual analogue scale (VAS) scores. Scores specifically targeting the hip or knee were not evaluated, and no comparisons were made to the preoperative status.

Descriptive statistics were used to analyse pre- and postoperative variables and clinical scores. The significance level for inferential statistics was set at alpha level of $< 0.05$. Two-tailed paired Student's t-test or Mann-Whitney U was used for continuous variables. Fisher's exact test was used to compare categorical variables. Multiple linear regression analyses were used to control for confounding factors. Included in the models were baseline demographic and clinical variables, such as age, gender, BMI, ASA, co-morbidities and concomitant injuries. All tests were conducted in IBM® SPSS® Statistics for Windows Version 21.0 (Armonk, NY).

## RESULTS

The only patient characteristic that differed between the groups (OT/LIT) was age (Table 2). There were no statistically significant differences in baseline characteristics of patients grouped together to create the LIT group. Upon discharge, 22 patients were referred to a rehabilitation clinic, 12 to a nursing home, and 8 returned home. Two patients died during hospitalisation.

Table 3 presents the surgical and patient outcomes by technique. For ten patients who were pain free and had fracture consolidation within three months, no additional radiological exams were done after this visit. Final radiological assessments were at a median of 11.5 months (IQR 6-19) for 40 fractures (OT n=17, LIT n= 23). Thirty-seven fractures achieved good and reliable callus formation and/or consolidation in the antero-posterior and lateral

Table 2. — Patient demographics according to surgical technique

| Characteristic | Open technique (n= 20) | Less invasive technique (n= 26) | P- value |
|---|---|---|---|
| Age in years[a] | 77 (64-84) | 84 (79-89) | 0.017[b] |
| Gender (female) | 11 (55%) | 18 (69%) | 0.369[c] |
| BMI (kg/m²)[a] | 23.8 (21-31) | 25.8 (22-30) | 0.685[b] |
| ASA ≥ 3 | 8 (40%) | 16 (62%) | 0.234[c] |
| ≥ 2 co-morbidities | 12 (60%) | 20 (77%) | 0.333[c] |

[a] Median and interquartile range; [b] Mann-Whitney U; [c] Fisher's exact test.

Table 3. — Surgical and patient outcomes according to surgical technique

| Outcome | Open technique (n= 20) | Less invasive technique (n= 26) | P- value |
|---|---|---|---|
| Number of screws (implant)[a] | 5 (4-6) | 5 (4-6) | 0.068[c] |
| Number of screws (diaphyseal side)[a] | 4 (4-5) | 4 (4-6) | 0.116[c] |
| Number of cerclages[a] | 2 (1-3) | 0 (0-1) | 0.001[c] |
| Operating time in minutes[a] | 120 (106-175) | 73 (60-103) | < 0.001[c] |
| Hospitalization in days[a] | 13.5 (11-14) | 9 (8-13) | 0.01[c] |
| ≥1 blood unit transfusion (450ml) | 35% (7/20) | 31% (8/26) | 0.999[e] |
| Preoperative haemoglobin (g/dl)[b] | 119.8 (±21) | 118.3 (±22) | 0.929[d] |
| Postoperative haemoglobin (g/dl) – 24 hours[b] | 87 (±12) | 90 (±13) | 0.946[d] |
| Number of patients who died during hospitalization | 0 | 2 | 0.6731[e] |
| Number of patients who died after discharge (≤ 3 months) | 1 | 0 | |
| Number of patients who died >3 months ≤ 1 year | 0 | 1 | |
| Number of patients who died > 1 year | 1 | 1 | |
| Surgery-related complications not requiring reoperation (≤ 12 months) | 5% (1/20) | 0% (0/26) | 0.4348[e] |
| Surgery-related complications requiring reoperation (≤ 12 months) | 15% (3/20) | 11.5% (3/26) | 0.999[e] |
| Bone healing rate (assessed ≤ 9 months) | 82% (14/17) | 100% (23/23) | 0.0688[e] |

[a] Median and interquartile range; [b] Mean and standard deviation; [c] Mann-Whitney U; [d] T-test; [e] Fisher's exact test

view, resulting in a 92.5% bone healing rate at nine months. Three patients in the OT group experienced pseudarthrosis without plate breakage (Figure 3). There were no cases of delayed or non-union in the LIT group.

Results of the multiple linear regression analysis indicated that, on average, the duration of the LIT procedure was 50 minutes shorter than the open technique ($p<0.001$), after controlling for age, gender, BMI, ASA ≥3, number of co-morbidities and number of concomitant injuries. When controlling for these same variables, the difference in the duration of the hospitalization between the groups was no longer significant ($p=0.142$).

In addition to the two patients who died during hospitalization, two died within one year. The median age of these patients was 90.5 years (IQR

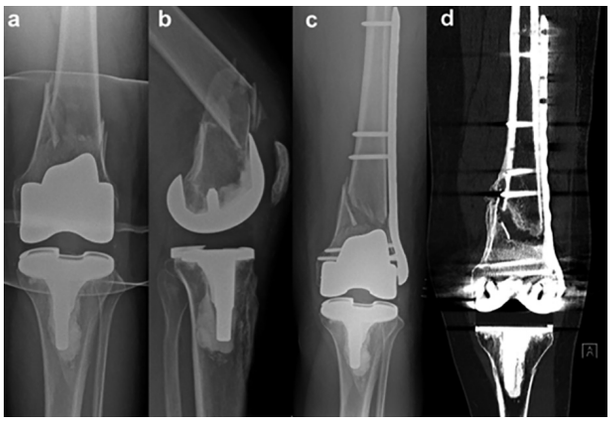


***Figure 3.*** — Examples of pseudarthrosis (9 months after osteosynthesis) of a Rorabeck 2 fracture. Preoperative radiographs (a : antero-posterior view, b : lateral view) present osteoporotic bone with thinned cortial bone. c : Postoperative radiograph. d : Coronar reconstruction of CT scan 9 months with avascular pseudarthrosis.

88-92.5), which was significantly older than the remaining cohort ($p<0.011$). One patient died during hospitalization (7 days) from acute abdomen and renal failure due to pre-existing renal deficiency. The second patient died of cardiac and renal failure (13 days). This patient also had a humerus fracture that was stabilised using LIT plating. A 92-year old patient (OT) died of pneumonia 46 days after surgery. Another patient (LIT) who died after 355 days had advanced renal cell carcinoma with multiple bone metastases. Two additional patients died 13 months (OT) and 18 months (LIT) postoperatively due to causes unrelated to surgery.

Within 12 months, one patient experienced minor complications (OT) and 13% (6/46) had complications requiring surgery (3 LIT, 3 OT). Conservative treatment was given to the patient (Rorabeck Type 2) who had a minor wound dehiscence that was successfully treated within three weeks.

In the LIT group, the complications needing revision were as follows : 1) one hematoma evacuation ; 2) one hematoma with secondary necrosis from oral anticoagulation required revision with necrosectomy (13 days) – fracture consolidated and fistula was stable with no sign of infection, however, the stem loosened four months after plating and a secondary stem exchange with a cemented Weber stem was necessary ; and 3) a patient with an initial Rorabeck 2 fracture involving the medial condyle was reportedly pain free and had an uneventful fracture consolidation, however, she began experiencing persistent instability due to medial collateral ligament insufficiency and progressive TKA loosening (16 months) – a TKA exchange and im-plantation of a rotating hinged arthroplasty was required.

In the OT group, the three major complications were 1) Rorabeck 2 fracture in which the plate osteosynthesis was done in a malrotated position of 15° of external rotation – seven days after surgery the femur was derotated and stabilised using the original plate ; 2) reosteosynthesis needed for patient with a well-fixed Rorabeck 2 fracture around a rotating hinged TKA who fell 48 days after surgery causing a secondary dislocation of the fracture ; and 3) patient had a secondary stem loosening after a Vancouver B1 fracture.

Thirty-six patients (38 fractures) were assessed at a median of 23 months (IQR 13-35) postoperatively. In addition to the six patients who died, two patients refused further evaluations. The median SF12 scores for the physical (OT = 39.4, IQR 27.5-52.6 ; LIT = 42.8, IQR 29.0-53.9 ; $p=0.633$) and mental health (OT = 57.1, IQR 49.6-59.2 ; LIT = 58.9, IQR 55.7-60.8 ; $p=0.276$) components were higher in the LIT group, although not statistically significant. The median GOS score for both groups was 4 (IQR 3-5 ; $p=0.646$). No significant difference in the median VAS scores was detected ($p=0.573$) – with a median pain score of 0 for both groups.

## DISCUSSION

Although our investigation showed most clinical outcomes did not differ significantly between the groups, findings were more favourable after surgery using a less invasive technique. Both groups had few complications and good bone healing rates, but the median operation time was significantly shorter when using the less invasive approach. These results, together with similarly encouraging findings of previous studies *(7,9,10,21)* should prompt a reassessment of the standard of care.

All bones treated with a LIT had healed nine months after surgery, yet three patients in the OT group had non-unions. In one of these three patients, two cerclages were used, which might have compromised blood supply and resulted in the non-union. When treating fractures in elderly patients with poor bone quality, stable fixation can be difficult and fracture healing delayed, especially in cases of periprosthetic fractures *(17)*. Use of the OT – with or without cerclages – often leads to destruction of the periosteal blood supply, which can cause bone necrosis and pseudarthrosis *(12,24)*. Consistent with findings from previous LIT studies *(1)*, percutaneously applied cerclages did not compromise bone healing in our study population. This technique is a viable option for long spiral or long oblique fractures.

Concerning complications requiring revision, one patient in the OT group experienced secondary stem loosening in a periprosthetic femur fracture. Since preoperative detection of a loose stem can be difficult

for certain fractures, CT scans can help differentiate between fracture types (e.g., Vancouver B2 and B1). In some cases, however, definitive classification can only be confirmed intraoperatively. Slight variations of stem rotation or differences in cranio-caudal stem position are signs of a loose stem and precaution should be taken to change the stem. In this study cohort, three patients with a Vancouver B2 fracture were preoperatively classified as B1 fractures with a fixed stem. Yet intraoperatively it became evident that the stem was loose and an additional stem exchange was done in all three cases.

Complications due to malrotation develop with LIT *(21)* when fracture reduction is done indirectly and assessed with fluoroscopy. Particularly challenging are cases of short oblique or multi-fragmented fractures lacking clear bony reference. One patient (OT group) who had a distal short oblique Rorabeck Type 2 fracture needed derotation after initial osteosynthesis. Even though this patient was still mobile, chronic malrotation could lead to painful TKA. Nevertheless, other studies have found that slight malrotation associated with previous immobility does not usually limit postoperative function *(21)*.

We used a mixed study design that combined retrospectively documented data with long-term follow-up of clinical outcomes. Since group allocation was not randomized, selection bias may have occurred. We do not believe, however, that the median age difference in the groups resulted from a bias in treatment allocation but rather annual fluctuations in patient age distribution. Nevertheless, we attempted to control for potentially confounding factors by using multivariate analyses. Although inclusion of a smaller range of fracture types could have strengthened our ability to draw conclusions, this restriction was not feasible given the size of our patient population and incidence of these fracture types. Moreover, we included all fracture types since invasiveness of the surgical procedure in both groups (OT and LIT) is similar - irrespective of the presence of an intramedullary implant - and monitoring of outcomes is comparable.

## CONCLUSIONS

We found that the conventional subvastus approach to treating periprosthetic, peri-implant and femoral fractures with a polyaxial locking plate leads to significantly longer operations than the less invasive technique. Although the open technique remains a viable option, we conclude that the LIT would be the preferred operating technique, especially in patients more susceptible to intra- and/or postoperative morbidity.

**List of abbreviations**

ASA - American Society of Anesthesiologists
BMI – body mass index
GOS - Glasgow Outcome Scale
IQR – interquartile range
LIT – less invasive technique
NCB – noncontact bridging
OT – open technique
SF-12 – 12-item short form survey
THA - total hip arthroplasty
TKA - total knee arthroplasty
VAS - visual analogue scale

**DECLARATIONS**

**Ethical approval and consent to participate** : All procedures performed in studies involving human participants 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 was obtained from all individual participants included in the study.

**Author's contributions :** FH - manuscript writing ; CK - data collection, manuscript editing ; JW - data analysis, manuscript editing ; RZ - manuscript editing ; SD - data collection and manuscript editing. All authors read and approved the final manuscript.

## REFERENCES

1. **Apivatthakakul T, Phornphutkul C, Bunmaprasert T, Sananpanich K, Fernandez Dell'Oca A.** Percutaneous cerclage wiring and minimally invasive plate osteosynthesis (MIPO) : a percutaneous reduction technique in the treatment of Vancouver type B1 periprosthetic femoral shaft fractures. *Arch Orthop Trauma Surg.* 2012 ; 132 : 813-22.
2. **Berry DJ.** Epidemiology: hip and knee. *Orthop Clin North Am.*. 1999 ; 30 : 183-90.

3. **Bozic KJ, Kurtz SM, Lau E, Ong K, Vail TP, Berry DJ.** The epidemiology of revision total hip arthroplasty in the United States. *J Bone Joint Surg Am vol*. 2009 ; 91 : 128-33.
4. **Chakravarthy J, Bansal R, Cooper J.** Locking plate osteosynthesis for Vancouver Type B1 and Type C periprosthetic fractures of femur: a report on 12 patients. *Injury.*. 2007 ; 38 : 725-33.
5. **Ebraheim NA, Liu J, Hashmi SZ, Sochacki KR, Moral MZ, Hirschfeld AG.** High complication rate in locking plate fixation of lower periprosthetic distal femur fractures in patients with total knee arthroplasties. *J Arthroplasty.* 2012 ; 27 : 809-13.
6. **Ehlinger M, Adam P, Abane L, Rahme M, Moor BK, Arlettaz Y, et al.** Treatment of periprosthetic femoral fractures of the knee. *Knee Surg Sports Traumatol Arthroscopy.* 2011 ; 19 : 1473-8.
7. **El-Zayat BF, Efe T, Ruchholtz S, Khatib S, Timmesfeld N, Kruger A, *et al.*** Mono- versus polyaxial locking plates in distal femur fractures - a biomechanical comparison of the Non-Contact-Bridging- (NCB) and the PERILOC-plate. *BMC musculoskeletal disorders.* 2014 ; 15 : 369.
8. **El-Zayat BF, Ruchholtz S, Efe T, Fuchs-Winkelmann S, Kruger A, Kreslo D, *et al.*** NCB-plating in the treatment of geriatric and periprosthetic femoral fractures. *Orthop & Traumatol, Surg & Res*. 2012 ; 98 : 765-72.
9. **El-Zayat BF, Zettl R, Efe T, Kruger A, Eisenberg F, Ruchholtz S.** [Minimally invasive treatment of geriatric and osteoporotic femur fractures with polyaxial locking implants (NCB-DF(R))]. *Der Unfallchirurg.* 2012 ; 115 : 134-44.
10. **Erhardt JB, Grob K, Roderer G, Hoffmann A, Forster TN, Kuster MS.** Treatment of periprosthetic femur fractures with the non-contact bridging plate: a new angular stable implant. *Arch Orthop Trauma Surg.* 2008 ; 128 : 409-16.
11. **Fulkerson E, Tejwani N, Stuchin S, Egol K.** Management of periprosthetic femur fractures with a first generation locking plate. *Injury*. 2007 ; 38 : 965-72.
12. **Habernek H.** Percutaneous cerclage wiring and interlocking nailing for treatment of torsional fractures of the tibia. *Clin Orthop Rel Res.* 1991 ; 267 : 164-8.
13. **Hanschen M, Aschenbrenner IM, Fehske K, Kirchhoff S, Keil L, Holzapfel BM, *et al.*** Mono- versus polyaxial locking plates in distal femur fractures: a prospective randomized multicentre clinical trial. *International orthopaedics.* 2014 ; 38 : 857-63.
14. **Jennett B, Bond M.** Assessment of outcome after severe brain damage. *Lancet.* 1975 ; 1 : 480-4.
15. **Lindahl H.** Epidemiology of periprosthetic femur fracture around a total hip arthroplasty. *Injury.* 2007 ; 38 : 651-4.
16. **Liu Y, Li H, Zhang Y.** Mono versus polyaxial locking plates in distal femur fractures: a prospective randomized multicentre clinical trial. *Int Orthop*. 2014 ; 38 : 1543.
17. **Nikolaou VS, Efstathopoulos N, Kontakis G, Kanakaris NK, Giannoudis PV.** The influence of osteoporosis in femoral fracture healing time. *Injury.* 2009 ; 40 : 663-8.
18. **Pascarella R, Bettuzzi C, Bosco G, Leonetti D, Dessi S, Forte P, *et al.*** Results in treatment of distal femur fractures using polyaxial locking plate. *Strategies Trauma Limb Reconstr.* 2014 ; 9 : 13-8.
19. **Pivec R, Johnson AJ, Mears SC, Mont MA.** Hip arthroplasty. *Lancet.* 2012 ; 380 : 1768-77.
20. **Ritter MA, Faris PM, Keating EM.** Anterior femoral notching and ipsilateral supracondylar femur fracture in total knee arthroplasty. *J Arthroplasty.* 1988 ; 3 : 185-7.
21. **Ruchholtz S, El-Zayat B, Kreslo D, Bucking B, Lewan U, Kruger A, *et al.*** Less invasive polyaxial locking plate fixation in periprosthetic and peri-implant fractures of the femur--a prospective study of 41 patients. *Injury.* 2013 ; 44 : 239-48.
22. **Speer KP, Lohnes J, Garrett WE, Jr.** Arthroscopic subacromial decompression: results in advanced impingement syndrome. *Arthroscopy* 1991 ; 7 : 291-6.
23. **Su ET, DeWal H, Di Cesare PE.** Periprosthetic femoral fractures above total knee replacements. *J Am Academy Orthop Surg.*. 2004 ; 12 : 12-20.
24. **van Steijn MJ, Verhaar JA.** Osteonecrosis caused by percutaneous cerclage wiring of a tibial fracture: case report. *J Trauma.* 1997 ; 43 : 521-2.
25. **Wood GC, Naudie DR, McAuley J, McCalden RW.** Locking compression plates for the treatment of periprosthetic femoral fractures around well-fixed total hip and knee implants. *J Arthroplasty.* 2011 ; 26 : 886-92.
26. **Xue H, Tu Y, Cai M, Yang A.** Locking compression plate and cerclage band for type B1 periprosthetic femoral fractures preliminary results at average 30-month follow-up. *J Arthroplasty.* 2011 ; 26 : 467-71 e1.