

Fixation of supracondylar femoral fractures following total knee arthroplasty: is there any difference comparing angular stable plate fixation versus rigid interlocking nail fixation?

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Abstract

Introduction Literature does not provide any reliable comparison between angular stable plate fixation and rigid nail fixation for stabilization of supracondylar periprosthetic femoral fractures. Thus, the purpose of this study was to compare these two implants in clinical practice relating to fracture healing, functional results and treatment-related complications.

Patients and methods In this retrospective study (level IV), clinical and radiographic records of 86 patients (62 female and 24 male, average age: 75.6) with supracondylar periprosthetic femoral fractures between 1996 and 2010 were analyzed. 48 patients underwent lateral plate fixation by an angular stable plate system (LISS), whereas 38 patients were stabilized by a rigid interlocking nail device.

Results Sixty-four (76 %) patients returned to their pre-injury activity level and were satisfied with their clinical outcome. We had an overall Oxford outcome score of 2.21, with patients following angular stable plate fixation of 2.22, and patients after rigid nail fixation of 2.20. Successful fracture healing within 6 months was achieved in 74 (88 %) patients. Comparing between plate fixation and nail fixation, statistical analysis did not reveal any significant differences.

Summary Overall, we had a relatively high rate of fracture healing and a satisfactory functional outcome with both implants. Both methods of fixation showed similar results relating to the functional outcome and individual satisfaction of the patients. However, with regards to

fracture healing and treatment-related complications, intramedullary nail fixation showed slight advantages.

Keywords Total knee arthroplasty · Supracondylar periprosthetic fractures · Plate fixation versus nail fixation · Outcome

Introduction

Periprosthetic fractures associated with total knee arthroplasty (TKA) are continuously rising, as the ageing and more active population leads to a consistent increase of elderly patients with total joint replacements [1–3]. Several factors like osteoporosis, rheumatoid arthritis or the presence of local stress risers have been enumerated, enhancing the risk for these partly complex and challenging injuries [1, 2].

The majority of periprosthetic fractures following total knee joint replacement are supracondylar fractures originating either proximal to the femoral prosthetic component, or at the proximal aspect of the femoral component extending proximally [1, 2, 4–6]. Relating to recent reports in literature angular stable plate fixation and rigid interlocking nail fixation appear to be the most appropriate techniques for stabilization of these fracture types. For both implants, several authors have presented satisfactory results referring to the clinical and radiographic outcome of the patients, as well as in biomechanical testing [7–12]. However, there is no consensus or reliable data in literature, indicating superiority comparing these two different methods of fixation in clinical practice [8, 11, 12].

The purpose of this study was to compare the clinical and radiographic outcome after angular stable plate fixation and rigid interlocking nail fixation of supracondylar

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femoral fractures following TKA, with special emphasis on fracture healing, functional results and treatment-related complications.

Materials and methods

The authors reviewed the Trauma Database of Vienna General Hospital, Medical University of Vienna and identified all patients with periprosthetic fractures of the distal femur that were admitted to this level-I trauma centre between 1996 and 2010. The Trauma Database of Vienna General Hospital is a prospectively gathered database, which was established for registration of injury characteristics (type, mechanism, etc.) and demographic data of trauma patients. The study is a retrospective case series, according to level IV of evidence for primary research questions. It was approved by the Institutional Review Board.

Patients who had undergone surgical treatment of a supracondylar femoral fracture above total knee joint replacement were sorted and their dataset of follow-up monitoring was examined for completeness and accuracy. Depending on the type of implant (angular stable plate fixation vs. rigid interlocking nail fixation) used for stabilization of the periprosthetic fractures of the distal femur, the patients were separated into two study groups (A and B).

According to our inclusion criteria, patients with complete sets of collected data and a follow-up monitoring of at least 1 year after the injury were finally enrolled in this study. Collected data included variables, such as age, gender, mechanism of injury, methods of treatment (angular stable plate fixation or rigid nail fixation), clinical and radiographic outcome of the patients, as well as general and treatment-related complications. Exclusion criteria for this study contain patients with incomplete data set, patients with diacondylar periprosthetic fractures, as well as patients with pathological periprosthetic fractures of the distal femur. Pathological fractures were considered as fractures following a primary bony malignancy or a metastasis. Incomplete data set was determined, if pertinent clinical or radiographic data of follow-up monitoring (e.g. documents of clinical findings or functional results, radiographs, etc.) were missing.

From a database of 95 patients with periprosthetic fractures of the distal femur, we had 86 patients with supracondylar femoral fractures after TKA. Table 1 gives a detailed overview about TKA-related periprosthetic fractures at our department. All 86 patients met criteria for inclusion and were finally enrolled in this series. The patients showed an average of 75.6 (59–89) years with a vast majority of females ($n = 62$). Fifty-four patients

sustained a periprosthetic supracondylar femoral fracture of the right knee, in 32 cases the injury affected the left knee. Seventy-nine of the injured patients had a cruciate-retaining implant, six patients had a posterior stabilized prosthesis.

Mechanism of injury and fracture classification

Clinical records showed several mechanisms of injury: The injuries resulted from falls which were of low energy (fall from a chair or a standing position) in 62 patients, falls from a considerable height or down stairs in fourteen patients, sports-related injuries in nine patients and from motor-vehicle accidents in one patient.

For classification of supracondylar femoral fractures above TKA, we used the classification system of Su et al. [2], dividing periprosthetic fractures of the distal femur into three sub-types. The classification was based on conventional radiographs and CT-scan. Within our series, we had 32 patients with a Su type I fracture (proximal to the femoral prosthetic component), and 54 patients with a Su type II fracture (originating at the anterior flange of the femoral prosthetic component). Patients with Su type III ($n = 9$) fractures were excluded from our study, as these fractures involve the diacondylar region of the distal femur.

Methods of treatment and type of implant

Forty-eight of the patients with a supracondylar femoral fracture after TKA underwent lateral plate fixation and were included into study group A, whereas 38 patients were treated by intramedullary nail fixation and entered into study group B. For lateral plate fixation we used an angular stable plate device [Less Invasive Stabilization System (LISS), Synthes®] (Fig. 1) through a lateral approach. For intramedullary nail fixation, we performed retrograde nailing by a rigid supracondylar interlocking nail (Supracondylar Nail (SCN), Stryker®) (see Fig. 2).

The use of either the LISS by Synthes® or the SCN by Stryker® was depending on the surgeon's preference, as well as on the fracture type on design of the prosthesis. Thus, there is a selection bias for the chosen method of treatment. According to the literature, both techniques are

Table 1 TKA-related periprosthetic fractures: overview

| Region | Classification | Patients |
|----------------|----------------|----------|
| Distal femur | Su type I | 32 |
| | Su type II | 54 |
| | Su type III | 9 |
| Proximal tibia | / | 7 |
| Patella | / | 2 |



Fig. 1 Angular stable plate fixation using the LISS (Synthes®)



Fig. 2 Rigid interlocking nail fixation using the SCN (Stryker®)

well known and accepted for surgical stabilization of supracondylar femoral fractures as presented in our study, originating either proximal to the femoral prosthetic component, or at the proximal aspect of the femoral component extending proximally [7–12].

Operative techniques for insertion and fixation have been well described for both implants. All operative procedures were performed either under general or regional anaesthesia with the patients in supine position on the operating table.

Hospital course and follow up examination

All patients were routinely given prophylactic antibiotic therapy intra-operatively and for three to five days after the surgery. Postoperative rehabilitation was routinely begun on the second or third day after operation. In both study groups patients were mobilized with gradual weight bearing as being tolerated until a minimum of 6–8 weeks.

Follow-up monitoring included clinical and radiographic examination of the patients before discharge, and then at 6 and 12 weeks after the trauma. Further regular examinations were performed at 6 and 12 months after the injury. For radiographic assessment, accurate anteroposterior (AP) and lateral radiographs of the injured knee were obtained at each follow-up control. Changes in the position of the implants and the extent of the fracture union were noted. In cases of inadequate bony fusion on the standard radiographs, CT-scan was performed to confirm the diagnosis of delayed union or non-union.

To quantify the clinical results of the patients, we performed the Oxford Knee Score 1 year after surgery, obtaining the twelve items for patients' outcome assessment. For further clinical examination status of mobility, range of motion and presence of pain were routinely evaluated. Patients were assessed for limitations or impairments in activities of daily living, and if they had returned to their pre-injury activity level after the trauma. They were additionally asked to grade their clinical outcome from excellent [1] to poor [5]. Range of motion was determined by evaluation of flexion and extension using a goniometer. Flexion $>90^\circ$ and full extension was graded as 'excellent', flexion $>70^\circ$ and decrease of extension $<10^\circ$ were graded as 'satisfactory', flexion $<70^\circ$ and decrease of extension $>10^\circ$ were considered as 'poor'. Finally, all results were collected on the basis of patients records at 1 year.

Statistical analysis

Dichotomous variables were analyzed with χ^2 testing. An ANCOVA model was used with sex and age as covariates to analyze potential relationships between the independent variables type of implant (nail vs. plate) and Su classification (Su I vs. Su II), and the dependent variables fracture healing, subjective outcome, pain level, ROM classification, the Oxford Knee Score, procedure-related complications and the necessity for consecutive operations. Statistical significance was defined as $p < 0.05$.

Results

Eighty-six patients with an average of 75.6 years at the time of injury were finally included into this study. Two of

these patients (both after intramedullary nail fixation) died during hospital stay due to cardio-respiratory insufficiency and had to be excluded from analysis of clinical and radiographic outcome.

Radiographic results

Successful fracture healing within 6 months was achieved in 74 (88 %) of 84 patients. In the remaining ten patients adequate bony fusion could not be obtained and non-union was diagnosed between 6 and 8 months after the surgery. Seven of these patients had undergone angular stable plate fixation (group A), whereas three patients had been stabilized by rigid interlocking nail fixation (group B). All seven patients from study group A were suffering from severe motion pain and underwent revision surgery with supplementary bone grafting. In three of these patients we saw a plate breakage before revision surgery (see Fig. 3). Finally, the periprosthetic fracture had healed uneventfully in all cases. The remaining three patients (all of group B) were nearly free of pain symptoms and 12 months after the surgery radiographic findings finally showed an osseous union without revision surgery. Comparing between the two study groups, the incidence of inadequate bony union was higher following femoral plate fixation (14.6 %) than after intramedullary nail fixation (8.3 %). Moreover, all patients with non-union after plate fixation required revision surgery, whereas patients after nail fixation had no additional surgery due to inadequate bony fusion.

Failures of reduction and fixation were noted in 12 (14 %) of 84 patients. As standing long radiographs were not available in every patient, particularly in early post-

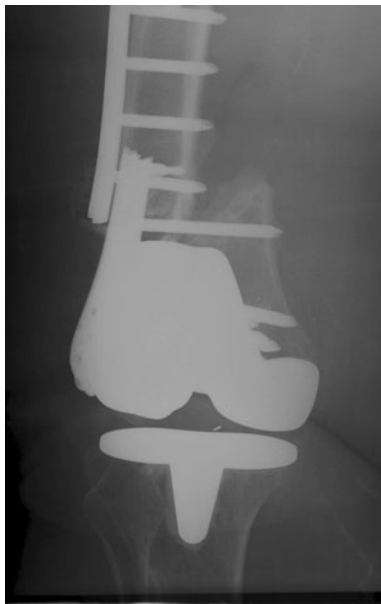


Fig. 3 Plate breakage 9 months after fixation

operative stages, there were some limits in correctly diagnosing mal-reduction or secondary loss of reduction, particularly relating to angular measurement. We failed to achieve adequate reduction of the fracture during the surgical procedure in five cases, and in another five patients we found a notable secondary loss of reduction after operative stabilization. Five of these patients had undergone rigid nail fixation (group B), indicating a higher incidence (17 %) for incomplete reduction as well as secondary loss of reduction compared to angular stable plate fixation (9 %) (group A). However, statistical analysis did not reveal a significant difference between the two study groups. Revision surgery in these cases of reduction and fixation failures was finally necessary in the four patients, all of them following angular stable plate fixation. In these patients fracture healing could not be obtained, leading to non-union with severe motion pain and immobility.

In a further patient we found a mal-positioning of the implant, as the angular stable plate device was fixed too far ventrally and cranially at the diacondylar region of the distal femur, and in another patient we noted an implant loosening, as one of the distal interlocking screws of the SCN migrated towards the skin. The patient with the loosened interlocking screw finally underwent revision surgery within the last two cases.

Clinical results

Using the Oxford Knee Score to quantify the clinical outcome of the patients by grading the twelve items from 1 to 5, we had an overall average outcome score of 2.21. Patients following angular stable plate fixation (group A) had an average outcome score of 2.22, whereas patients after rigid nail fixation had an average outcome score of 2.20, indicating no significant differences between the two study groups (see Table 2).

Relating to the subjective grading of the patients, 64 (76 %) of the 84 patients had achieved a satisfactory clinical outcome after rehabilitation. All of them nearly returned to their pre-injury activity level 1 year after surgery and were subjectively satisfied with their treatment by grading their outcome [1] excellent ($n = 13$), [2] good ($n = 26$), or [3] satisfactory ($n = 25$). The remaining twenty patients complained about relevant limitations and impairments in activities of daily living and were not satisfied with the functional outcome by grading it [4] acceptable ($n = 10$), or [5] poor ($n = 10$). Eleven of these patients were treated by angular stable plate fixation, the other nine patients were stabilized by rigid nail fixation, indicating no differences between the two methods of treatment (see Table 2).

Presence of persisting pain symptoms was noted in seventeen patients (20 %). Ten of them complained about occasional pain symptoms during long distance walking or

in the change of weather, seven patients about chronic pain, requiring analgesics regularly. Relating to the severity of the pain, we had fourteen patients with rather mild symptoms and three patients with severe symptoms. An ‘excellent’ or ‘satisfactory’ range of movement was maintained in 56 patients, whereas in 28 patients we had a ‘poor’ outcome in knee motion. Comparing patients after angular stable plate fixation (group A) to those after rigid nail fixation (group B) referring to mobility and pain symptoms, we did not see any significant differences. Patients with severe pain symptoms and notable limitations in knee movement were distributed similarly between the two study groups (see Table 2).

Morbidity, mortality and complications

Major general and treatment related complications finally occurred in eighteen of 86 patients, leading to an overall

Table 2 Clinical outcome: overview

| | Plate fixation (<i>n</i> = 48) | Nail fixation (<i>n</i> = 36) |
|--|------------------------------------|-----------------------------------|
| Activity level (related to pre-injury status) | | |
| No impairments | 14 | 12 |
| Limitations in certain activities (sports, profession, etc.) | 24 | 14 |
| Limitations in (nearly) all activities | 10 | 10 |
| Patients’ satisfaction (related to their outcome) | | |
| Excellent | 7 | 6 |
| Good | 14 | 12 |
| Satisfactory (moderate) | 16 | 9 |
| Acceptable | 5 | 5 |
| Poor | 6 | 4 |
| Range of motion | | |
| Flexion >90°, full extension (> excellent) | 14 | 8 |
| Flexion >70°, decrease of extension <10° (> satisfactory) | 20 | 14 |
| Flexion <70°, decrease of extension >10° (> poor) | 14 | 14 |
| Pain | | |
| Presence of pain | | |
| No relevant pain | 38 | 29 |
| Occasional pain | 6 | 4 |
| Regular pain | 4 | 3 |
| Severity of pain | | |
| Mild symptoms | 8 | 6 |
| Severe symptoms | 2 | 1 |
| Oxford Knee Score (modified) | | |
| Lower scores indicating a better outcome (1 pt. = best, 5pts. = worst) | 2.22 | 2.20 |

Table 3 Complications: overview

| | Patients | |
|--|----------------|---------------|
| | Plate fixation | Nail fixation |
| General complications | | |
| Respiratory failure | 2 | 0 |
| Pneumonia | 2 | 2 |
| Treatment-related complications | | |
| Non-union | 7 | 3 |
| No/incorrect reduction | 2 | 3 |
| Secondary loss of reduction | 3 | 2 |
| Wound infections | 1 | 0 |
| Implant failure (screw loosening, plate breakage) | 3 | 1 |
| Mal-positioning of the hardware (plate, screws) | 1 | 0 |
| Deaths | 0 | 2 |

complication rate of 21 %. Referring to general complications after surgical stabilization of supracondylar femoral fractures above TKA, two patients (of group A) were suffering from a respiratory failure postoperatively requiring prolonged mechanical ventilation, and another four patients (two of group A and of two group B) were suffering from pneumonia.

Specific complications relating to method of fixation were noted in 12 patients (27 %). We had ten patients with a delayed union or non-union after surgical stabilization, requiring revision surgery in seven of them. One patient developed a superficial wound infection after angular stable plate fixation, which was treated successfully with antibiotic therapy for several days, and in another patient after rigid nail fixation we saw a loosening of a distal interlocking screw which had to be replaced in a second operative procedure. Revision surgery was finally necessary in eight patients. Table 3 gives a detailed overview.

Two patients (of group B) died due to cardio-respiratory insufficiency related to the treatment, leading to a mortality rate of 2 %.

Comparing between the two methods of fixation, there was a insignificantly higher rate of treatment-related complications after angular stable plate fixation, including seven patients with inadequate bony fusion (leading to revision surgery) and one patient with wound infection (requiring antibiotic therapy).

Discussion

Relating to supracondylar femoral fractures following TKA, there is a wide variety of surgical devices that might

be used for fracture fixation. In recent years, angular stable plate devices have become a popular treatment option for stabilization of periprosthetic distal femoral fractures. Compared to a standard non-locking plate or a dynamic condylar screw, these constructs might reveal several advantages [1, 8, 13–16]. Fixed-angle devices are biomechanically stronger, allow better fixation in osteoporotic bones, and avoid extensive soft tissue exposure preserving a better blood supply for fracture healing [8, 15]. Using locking plates for stabilization of periprosthetic femoral fractures, several studies have presented lower complication rates and a minimized need for adjunctive structural bone grafting compared to conventional plate systems [11, 12, 16]. In our series, 53 % of the patients underwent fracture stabilization by an angular stable plate construct, in order to profit from this less invasive method of fixation. Nevertheless, a certain amount of soft tissue dissection with potential periosteal stripping is inevitable, even using a minimal invasive plate system. This fact might lead to an enhanced risk for delayed or inadequate bony fusion, as in seven cases within our study.

An also well-known method for fixation of supracondylar periprosthetic femoral fractures are intramedullary nail devices [1, 7, 9, 10]. While flexible nails have been abandoned because of their insufficiency to provide adequate stability, rigid interlocking femoral nails are commonly regarded as the preferred treatment method for stabilization of these fractures [11, 12, 16]. The most important advantages are the relative sparing of the fracture region and the minimal soft tissue dissection avoiding periosteal stripping. Concerning these benefits, the remaining 47 % of our patients underwent fracture fixation by using a rigid interlocking retrograde nail. However, intramedullary nail fixation performed in retrograde technique requires arthrotomy of the knee joint, an open box femoral component, and an adequate distal fracture fragment to allow insertion of the locking screws.

With particular regards to supracondylar femoral fractures following TKA, angular stable plate constructs and rigid interlocking nail devices are considered equally effective [1]. Some authors might favour angular stable plate fixation after showing excellent results in their series, whereas other surgeons have proposed a superior outcome by using intramedullary interlocking nails [4, 8–10]. However, literature does not provide any direct comparison of these two surgical techniques in clinical practice [1, 8, 11, 12]. In our series we had a similar number of patients who underwent lateral plate fixation ($n = 48$) with an angular stable plate construct (LISS, Synthes®) or intramedullary nailing ($n = 38$) using an interlocking SCN (Stryker®) for stabilization of these fractures. Comparing these two implants relating to the functional outcome (quantified by the Oxford Knee Score)

and individual satisfaction of the patients, we had similar results with both devices. Referring to successful fracture healing and treatment related complications, the technique of rigid nail fixation revealed slight advantages. The incidence of inadequate bony fusion and perioperative complications associated with the method of fixation was obviously higher following femoral plating. The 15 % non-union rate after angular stable plate fixation in our series might be attributed to an increased soft tissue exposure with potential devascularisation of the fracture region.

On the contrary, the technique of lateral plate fixation offered certain advantages in adequate fracture reduction and more sufficient fixation of the fragments with fixed angle screws. In our series, incorrect or incomplete primary reduction, as well as secondary loss of reduction was found more frequently after rigid nail fixation. As this technique requires a surgical approach away from the fracture region (knee joint arthrotomy for retrograde nailing), direct reduction as well as selective fixation of the fracture fragments is usually more demanding. This fact might have led to 17 % rate of incomplete or loss of reduction following rigid nail fixation.

Additionally, the use of either an intramedullary nail or an angular stable plate device might be depending on the fracture type and on the design of the prosthesis. Nail fixation, for example, requires an open box of the femoral component of the prosthesis and is more frequently seen in fracture types with a large distal fragment. Plate devices on the other hand are often preferred in more comminuted and distal fractures.

Relating to current data in literature, we had a relatively high rate of successful fracture healing and a satisfactory functional outcome after surgical management of supracondylar periprosthetic femoral fractures using either an angular stable plate system or an interlocking nail device [7, 11, 12]. Comparing these two implants, intramedullary nail fixation showed advantages relating to fracture healing and treatment-related complications, whereas angular stable plate fixation allowed a better reduction and fixation of the fragments. With regards to the functional outcome and individual satisfaction of the patients, we had similar results with both implants. Finally, none of these two techniques revealed universal superiority. We may be criticised for potential weaknesses linked to a retrospective design. Additionally, interpretation of functional outcome measures have to be regarded critically, as these results are severely influenced by the preoperative functional status after TKA. Nevertheless, we are the first to present a direct reliable comparison of the two most appropriate implants (angular stable plate fixation vs. rigid interlocking nail fixation) for the management of supracondylar periprosthetic fractures.

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