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# Locking plates versus retrograde intramedullary nails in the treatment of periprosthetic supracondylar knee fractures. A retrospective multicenter comparative study

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ABSTRACT

*Introduction:* Biomechanical studies demonstrated the superiority of retrograde supracondylar intramedullary nails (RIN) against locking plates (LP) for the treatment of periprosthetic supracondylar femoral fractures (PSFs); however, clinical results are still conflicting. This study aimed to compare LP and RIN, as well as, cemented and uncemented nails in the treatment of PSFs regarding fracture healing, complications and functional results.

*Materials and methods:* A retrospective multicenter analysis of 60 PSFs classified as Rorabeck type I or II was performed. Thirty-one cases were treated with LP while in 29 cases RIN were used. Out of the latter, 14 had nailed cementoplasty, while 15 an uncemented nail.

*Results:* The two groups were comparable concerning gender, ASA score, operated side, follow-up time, fracture type and mechanism of injury. The LP was significantly younger than the RIN group. Forty-six cases had fracture union at an average of six months, 11 were healed between seven and twelve months (delayed unions), and three developed non-unions. There was no significant difference in the median union time between RIN and LP groups (six vs five months, $p = 0.707$) or cemented and uncemented nailing groups (5.5 vs six months, $p = 0.354$). The RIN group had fewer delayed unions or non-unions than LP group; however, not reaching significance (4 vs 10, $p = 0.190$). Complications were fewer but non-significantly different between cemented and uncemented nails (one vs five, $p = 0.481$). The mean postoperative flexion was comparable between RIN and LP groups (99.1° vs 94.9°, $p = 0.547$) or cemented and uncemented nails (102° vs 96.3°, $p = 0.4$). The mean Oxford Knee Score did not differ between LP and RIN groups (30.8 vs 31.3, $p = 0.93$) as well as between cemented and uncemented nails (31.5 vs 30.6, $p = 0.801$).

*Discussion:* PSFs with good bone stock can be treated equally with LP or RIN. Nails demonstrated advantages concerning the fracture healing potential. Orthopaedic surgeons need to be trained in both treatment options to manage PSFs. Cemented nails may increase stability and healing capacity in elderly osteoporotic patients; however, further studies are needed.



## Introduction

Periprosthetic knee fractures (PKFs) are relatively rare, but very demanding complications of total knee arthroplasty (TKA) [1]. They require special equipment, perioperative support and high surgical skills of both fracture fixation and revision arthroplasty techniques [2,3]. The incidence of PKFs varies in the literature; however, it is inevitably expected to increase in the future [4]. The upcoming raise of PFKs is related to the increase of population's life expectancy and the steady increase in the number of TKAs [5,6].

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Periprosthetic supracondylar femoral fractures (PSFs) are the most common among PFKs [6]. The incidence of PSFs ranges between 0,5% to 2,3% after primary TKA and is significantly higher after revision TKA [6,7]. The most common risk factors are the increasing age, female gender and other pathological conditions, like osteoporosis, rheumatoid arthritis, chronic use of steroids, neurologic disorders and revision TKA [3,5,8]. The management of this group of patients is further complicated by the stability and the type of the prosthesis, the quality and quantity of bone available for fracture fixation in the distal femoral metaphyseal region, the fracture pattern and degree of displacement and the clinical experience of surgeons [9,10].

The optimal treatment of PSFs is controversial. Among different treatment options, the fixed angle locking plates (LP) using less invasive techniques and retrograde intramedullary nails (RIN) have shown favourable results over non-operative treatment and non-locked plates [11,12]. Although biomechanical studies demonstrated the superiority of RIN against LP for the treatment of PSFs, the transfer of this supremacy to the clinical setting is still debated [11,13].

The aim of our study was to retrospectively compare the union rate, complications, range of motion (ROM) and functional scores between two groups of PSFs and well-fixed implants treated either with LP or RIN. We also aimed to compare the union rate, complications, ROM and functional scores within the nailing group between cemented and uncemented nails.

## Materials and methods

This multicenter retrospective study was performed in three academic institutions. The electronic database of the departments was retrospectively reviewed to identify patients treated for PSFs between January 2003 and December 2014. This study was conducted according to the World Medical Association Declaration of Helsinki of 1964 as revised in 1975 and 2000 and was approved by the Scientific Research Board of the Institutions. Patients gave informed consent.

### *Inclusion/exclusion criteria*

All adult patients who had undergone RIN or LP for closed PSFs with well-fixed implants without stem were included. They needed to have a minimum of six months' follow-up and a complete and accurate follow-up monitoring.

Patients that had been treated with other surgical methods, having less than six months or incomplete follow-up data were excluded. Exclusion criteria were also loose or infected prostheses, pathological (primary or metastatic malignancies) and open fractures.

### *Outcomes*

The primary outcomes were the mean difference in the time of fracture healing (union time) between LP and RIN groups as well as between cemented and uncemented nails. Secondary outcomes were the reported complications, namely delayed union and non-union, the knee ROM and functional outcomes between groups.

Clinical and follow-up data were collected via the electronic database of the academic orthopaedic departments. Demographics in the form of age, sex, American Society of Anaesthesiologists (ASA) score, side, mechanism of injury were collected. Besides, the location and type of the fracture, the surgical technique, the type of implant, as well as the rehabilitation protocol were recorded.

The PSFs were classified according to Rorabeck and Taylor's classification [14] based on simple lateral and anteroposterior radiographs or CT-scan. The presence of bridging callus, at least in one cortex, on both anteroposterior and lateral radiographs and no signs of hardware loosening or failure were the radiological criteria of fracture union. The ability of the patient to weight bearing without pain or tenderness at the fracture site was the clinical criterion of fracture healing. Delayed union was defined as the healing process that exceeded six months. A painful fracture after six postoperative months, without any radiological sign of healing in three subsequent months, was considered as non-union. Other complications in terms of infection, deep vein thrombosis, pulmonary embolism were also recorded. The postoperative range of the patients' motion was evaluated with a manual goniometer and the functional outcomes using the Oxford Knee Score (OKS) Questionnaire.

### *Statistical analysis*

The determination of the samples' necessary size was made according to the reported time of fracture healing of PSFs in previous studies [13] that ranged from 3.5 to 9.5 months. We also took into consideration that no Minimal Clinical Important Difference concerning the time of bone union had previously been published. Our statistical analysis (Lehr's formula) showed that with sufficient power of 0.8 and the $\alpha$ value of 0.05, to see a difference in healing time of 1 month between groups with a standard deviation of 1.5 months, at least 24 patients had to be enrolled in each group.

The normality of the data distribution was assessed according to the Kolmogorov-Smirnov and Shapiro-Wilk test. All statistical tests were two-tailed. The alpha level was set at 0.05. Standard statistical methods were used for descriptive statistics. Continuous variables normally distributed were compared using a two-sided independent sample t-test; not normally distributed with Mann-Whitney *U* test Categorical data were evaluated using the Chi-squared test. Statistical analysis was performed using the IBM SPSS statistics version 25 software (SPSS Inc., Chicago, IL, USA).

## Results

A total of 76 patients who underwent surgical treatment for 79 PSFs were identified. Out of them, 62 cases were eligible to participate in this study for further analysis. Seventeen patients were excluded based on our eligibility criteria with reasons for exclusion being an infection in five, less than six months of follow up in eight and pathological fractures in four cases. Two patients died during follow-up from causes unrelated to surgery and therefore were excluded from the subsequent analysis. Sixty cases were finally enrolled in the study (Fig. 1).

The two groups were comparable as far as the gender, ASA score, operated side, follow-up time, Rorabeck classification type and mechanism of injury were concerned (Table 1). The LP group was significantly younger than the RIN group (Table 1); the groups of cemented and uncemented nails were also comparable for age (Table 2).

The mean age of the study population was 79 ($\pm$ 9.1) years and the mean follow-up time 19.9 months (range 6–54). There were 45 females and 15 males. Fifty-seven fractures occurred after minor trauma, and only three happened after high-energy trauma. Among the 60 supracondylar fractures, two were of Type I and 58 were of Type II fractures according to Rorabeck and Taylor's classification. Thirty-one patients were treated by plate fixation with an angular stable locking plate [Less Invasive Stabilization System (LISS), Synthes®] through a lateral minimally invasive surgical approach (LC group). Twenty-nine were treated with a rigid retrograde supracondylar nail [Supracondylar Nail (SCN), Stryker®] using the previous skin incision and mini-arthrotomy (RIN group). Out of the latter, 14 had nailed cementoplasty, while 15 the standard uncemented retrograde intramedullary nail. In total three senior orthopaedic surgeons were involved; bone grafting was not

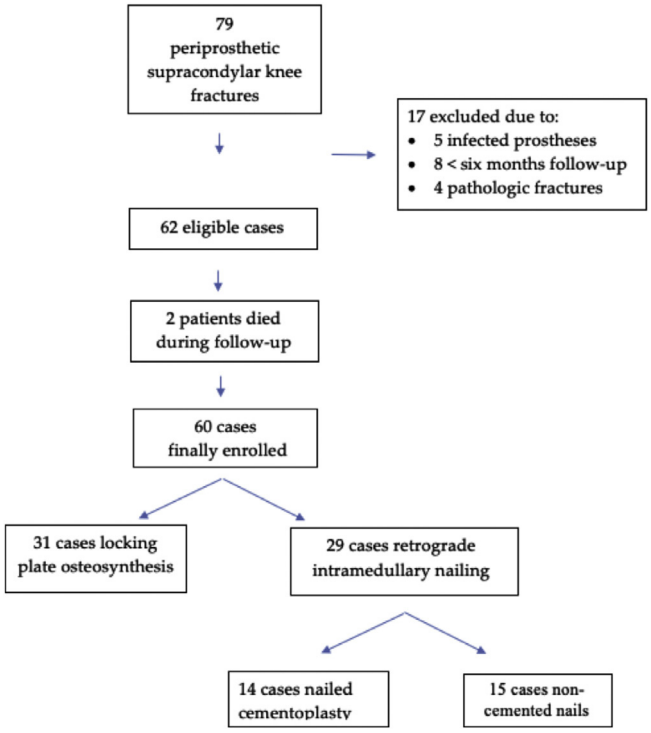


**Fig. 1.** Flowchart illustrating the search strategy.

used in any case. The primary TKAs involved thirty-five posterior stabilised knee prostheses, thirteen mobile bearing and twelve cruciate retaining prostheses. All patients were mobilised with partial and gradual weight bearing as being tolerated postoperatively.

Forty-six cases had fracture union at an average of six months, and 11 were healed after six months (range 7–12) and were classified as delayed unions. Three cases developed non-union, led to hardware failure and underwent revision TKA. There was no significant difference in the median union time between RIN and LP groups (six vs five months, p = 0.707) or cemented and uncemented nailing groups (5.5 vs six months, p = 0.354) (Tables 3, 4). The RIN group had fewer delayed unions or non-unions than the LP group; however, not reaching significance (4 vs 10, p = 0.190)

**Table 1**
The baseline characteristics, demographic and clinical data of LP and RIN groups.

| Variables | | Group LP (n = 31) | Group RIN (n = 29) | P-value |
|---|---|---|---|---|
| Age (years)* | | 76.1 (10.9) | 82.1 (5.5) | 0.01[@] |
| Gender** | Male | 8 | 7 | 0.881[&] |
| | Female | 23 | 22 | |
| Operated side** | Left | 12 | 13 | 0.631[&] |
| | Right | 19 | 16 | |
| Follow-up (months)* | | 22.3 (12.1) | 17.3 (9.6) | 0.104[$] |
| ASA grade** | II | 21 | 14 | 0.101[&] |
| | III | 6 | 13 | |
| | IV | 4 | 2 | |
| Mechanism of Injury** | High energy | 2 | 1 | 0.594[&] |
| | Low energy | 29 | 28 | |
| Rorabeck and Taylor classification** | I | 0 | 2 | 0.137[&] |
| | II | 31 | 27 | |

LP: locking plate, RIN: retrograde intramedullary nail.
The values are given as: * The mean with the standard deviation in parentheses.
** As raw numbers.
Tests performed using: [@] Independent Sample t-test, [$] Mann-Whitney test, [&] Chi-square ($x^2$) test.

**Table 2**
The baseline characteristics, demographic and clinical data of the cemented and uncemented nailing groups.

| Variables | | Uncemented Nails (n = 15) | Cemented Nails (n = 14) | P-value |
|---|---|---|---|---|
| Age (years)* | | 81.5 (4.4) | 82.7 (6.6) | 0.575[@] |
| Gender** | Male | 3 | 4 | 0.590[&] |
| | Female | 12 | 10 | |
| Operated side** | Left | 8 | 5 | 0.340[&] |
| | Right | 7 | 9 | |
| Follow-up (months)* | | 17.4 (11.2) | 17.2 (8.05) | 0.847[$] |
| ASA grade** | II | 5 | 9 | 0.149[&] |
| | III | 8 | 5 | |
| | IV | 2 | 0 | |
| Mechanism of Injury** | High energy | 0 | 1 | 0.292[&] |
| | Low energy | 15 | 13 | |
| Rorabeck and Taylor classification** | I | 2 | 0 | 0.157[&] |
| | II | 13 | 14 | |

The values are given as: * the mean with the standard deviation in parentheses.
** Raw numbers.
Tests performed using: [@] Independent Sample t-test, [$] Mann-Whitney test, [&] Chi-square ($x^2$) test.

(Table 3). Complications were fewer, but non-significantly different, between cemented and uncemented nails (one vs five, p = 0.481) (Table 4).

The mean postoperative flexion was not significantly different between the RIN and LP groups (99.1° vs 94.9°, p = 0.547) or the cemented and uncemented nails (102° vs 96.3°, p = 0.4) (Tables 3, 4). The mean OKS at last follow up for the whole group of patients was 30.9 (±8.7). The mean OKS was comparable between patients of the LP and RIN groups (30.8 vs 31.3, p = 0.93) as well as between the groups of cemented and uncemented nails (31.5 vs 30.6, p = 0.801) (Tables 3, 4).

## Discussion

Our study demonstrated that the mean union time, complications namely delayed union and non-union, functional scores and knee ROM did not differ significantly between two groups of PSFs treated either with LPs or RINs. Besides, comparable results were found between the subgroups of cemented and uncemented nails.

The strengths of this study include the quite large number of the cases and the comparable cohorts in several variables. To the best of our knowledge, this is the first study comparing cemented and uncemented RINs for the management of PSFs in the literature. In addition, the groups were compared based on clinical, radiological and functional scores.

**Table 3**
Comparative outcome data between LP and RIN groups.

| Outcome | | LP group | RIN group | P-value |
|---|---|---|---|---|
| Union time (months)* | | 5 (4-9) | 6 (4.5-6) | 0.707[$] |
| Complications** | Delayed Union | 8 (25.8) | 3 (10.3) | 0.190[&] |
| | Non-Union | 2 (6.5) | 1 (3.4) | |
| | DVT | 0 | 1 (3.4) | |
| | PE | 2 (6.5) | 0 | |
| Postoperative Oxford Knee Score*** | | 30.8 (8.1) | 31.03 (9.3) | 0.931[@] |
| Mean postoperative flexion*** | | 94.9 (21.4) | 99.1 (11.8) | 0.547[$] |

LP: locking plate, RIN: retrograde intramedullary nail.
The values are given as: * the median with the interquartile range in parentheses.
** Raw numbers with the percentages in parentheses.
*** The mean with standard deviation in parentheses.
Tests performed using: [@] Independent Sample t-test, [$] Mann-Whitney test, [&] Chi-square ($x^2$) test.

**Table 4**
Comparative outcome data between cemented and uncemented nailing groups.

| Outcome | | Uncemented nails | Cemented nails | P-value |
|---|---|---|---|---|
| Union time (months)* | | 6 (5-6) | 5.5 (4-6) | 0.354[$] |
| Complications** | Delayed | 2 (13.3) | 1 (7.1) | 0.481[&] |
| | Union | 1 (6.6) | 0 | |
| | Non-Union | 1 (6.6) | 0 | |
| | DVT | 0 | 0 | |
| | PE | | | |
| Postoperative Oxford Knee Score*** | | 30.6 (10.23) | 31.5 (8.6) | 0.801[@] |
| Mean postoperative flexion*** | | 96.3 (7.9) | 102 (14.6) | 0.400[$] |

The values are given as: * the median with the interquartile range in parentheses.
** raw numbers with the percentages in parentheses.
*** the mean with standard deviation in parentheses.
Tests performed using: [@] independent sample t-test, [$] Mann-Whitney test, [&] Chi-square ($x^2$) test.

In our study, the vast majority of patients were female that had a fracture following low energy trauma. Similar populations were documented in other published studies [15–18]. Aldrian et al. reported that 62 out of 86 patients in their series were women sustaining fracture after a fall from chair or standing position [11]. In another study, 95% of patients were women and the "slip fall" the most frequent mode of injury [15].

The treatment of PSFs remains challenging. A recent systematic analysis reported 10–15% non-union rate of PSFs, irrespectively of the treatment method [13]. In our series, 76.7% of the fractures were healed at six postoperative months and 95% at twelve months. Similar results were reported in other case-series [10,11]. Our study demonstrated no difference in time of fracture healing between the LP and RIN groups; however, the median union time of LP group was one month less compared to the RIN group. This may be attributed to the younger population of the LP group and the greater healing potential. Horneff et al. also supported that plating offers to the patients an improved time to full recovery and accelerated fracture healing, demonstrating significantly greater radiographic union rate for the LP group; however, the time to full weight bearing was similar between groups [9]. Our results are following the majority of published studies demonstrating no difference in fracture healing of PSFs between LP and RIN methods [13,19]. In a small study, Kilucoglu et al. showed similar mean healing time about four months for both treatments [20]. Gondalia et al. studied 24 PSFs treated with LPs and 18 with RINs [15]. Although there was a 10-week difference in mean fracture healing time favouring nails (38.3 vs 49.8 weeks), this was not statistically different [15].

Recent meta-analyses [13,21] also demonstrated no difference in the mean union time between LP and RIN groups for the treatment of SPFs. The main advantage of the nails is their ability to provide proper stability with minimal soft tissue stripping and preserve the local fracture biology enhancing healing [10,15]. Using fixed angle interlocking screws, they can efficiently add to the stability of the distal fracture fragment that is crucial for healing; however, their use for fractures below the flange of femoral prosthesis is questioned [22]. The co-axial implantation of nails augments the stiffness of the construct under axial loading and is considered a biomechanical advantage over LCP [23]. Despite the biomechanical and biological advantages of nails for fracture healing, practical issues restrict their use; they can be used only for an open-box design TKA, usually in small diameters to fit in the notch [13] and for non-stemmed femoral components. Comminution of the distal femoral component also precludes the use of nails. The faraway surgical approach to the fracture site, indirect reduction and the more demanding selective fixation are other disadvantages [11].

Our results do not support the theoretical advantage of RIN in the management of PSFs. The evolution of plates and the use of minimally invasive techniques may partly explain our results [13,24]. Compared to the standard non-locking plates, the LPs are biomechanically stronger and allow better fixation in osteoporotic bones [11]. A recent experimental and finite element analysis demonstrated that the LP/allograft construct exhibited the highest stiffness and the least micromotion for PSFs; it was recommended for a case with osteoporosis and loss of bone to achieve healing and improve alignment [25]. The direct surgical approach to the fracture site and the direct reduction of the fracture are also technical advantages. The plates are particularly useful to bypass an implant in the proximal femur to avoid the stress riser between the two implants [15]. The significant greater time of operation and the need for transfusion are disadvantages of the use of LPs [9,13,24].

Many complications, namely delayed union, nonunion, malunion, stiffness and infection have been reported in the treatment of periprosthetic fractures; generally attributed to the relatively older populations and low level of experience of surgeons [15]. In our study, the number of delayed unions or non-unions was fewer for RIN compared to LCP (115% vs 26.7%). Although this difference was not significant, it indeed demonstrates a better healing profile for the RIN group. Other complications as deep vein thrombosis and pulmonary embolism did not differ between groups. Recent meta-analyses [13,21] supported that the nonunion rate did not differ significantly between patients treated with LP or RIN for PSFs. However, several published studies demonstrated a higher but non-significant incidence of poor bone healing or non-union for plates [10,11,26]. In one of the largest comparatives published series, Meneghini et al. [10] reported 9% of non-unions or delayed unions in RIN group and 19% in the LP group; again, not reaching statistical significance. Eleven out of twelve non-unions in the LP group were observed in females and were not significantly related to comorbidities. The surgeons tended to use nails in older patients as in our study. This higher reported rate of inadequate bony fusion for plates may be ascribed to a certain amount of soft tissue dissection and periosteal stripping, even using a minimally invasive technique [11].

The inevitable mismatch between the diameter of a nail and metaphyseal flare may toggle of the nail in the metaphysis and puts at risk the stability of fixation, especially in osteoporotic patients [13]. In our study, we used cementoplasty of the distal femur to improve stability and the outcomes of the RIN in osteoporotic patients [27]. This a salvage procedure in octogenarians with advanced osteoporosis when standard nailing technique or plating is inadequate in maintaining the fracture. It is supported that the nail/cement construct bridges the femoral canal tightly and does not rupture the soft tissue envelope around the fracture site [27]. Besides, it is easy to perform, permits an immediate full range of movement and provides better initial stability to fasten healing [27]. To the best of our knowledge this is the first study comparing cemented and uncemented retrograde nails for the treatment of PSFs. Although the median union time of cemented nails was half a month less than uncemented, this difference was not statistically significant. Besides, the group of uncemented nails showed also a higher incidence of delayed unions and non-unions than the group of cemented nails; again, without reaching significance. Further studies are certainly needed to evaluate their efficacy.

A limited number of published studies reported on functional scores and ROM; they demonstrated similar to us results [15,28]. Gondalia et al. reported a mean of 95.8 degrees of flexion for the LP group and 100.7 degrees for the RIN group; this difference was no statistically significant [15]. Also, Althausen et al. found an average range of motion of 0–91 degrees for the locking plates and

0–110 degrees for the intramedullary nails [28]. No difference in functional scores also reported in other studies [11,20].

This study has limitations. It is a retrospective study lacking randomisation; however, the sample size equation strengthens our results. Furthermore, our study assembled data from three different departments and three different senior surgeons. The proportion of cases between institutions was not equal and nailed cementoplasty was used only in one of them. However, this was more than needed to increase the sample size of the study, given the small incidence of SKFs. Another limiting factor is that the clinical scores were estimated only postoperatively, making it impossible to compare with the preoperative ones.

## Conclusions

The management of PSFs is still challenging. The number of such fractures will inevitably increase in the future. Thus, the most effective treatment to avoid co-morbidities and support patients to reach their pre-injury functional status should be determined. Our study demonstrated that Rorabeck type I and II PSFs with good bone stock could be treated equally with LP or RIN. None of these two techniques presented universal superiority. RIN demonstrated advantages concerning the fracture healing potential. Both groups had similar results regarding functional scores and ROM. Orthopaedic surgeons need to be trained in both treatment options to manage PSFs. Nails augmented with cement may increase stability and healing capacity compared to uncemented nails especially in elderly osteoporotic patients; however, further studies are needed.

## Conflict of interest

The authors report no conflict of interest with regard to the content of this manuscript.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.injury.2019.04.019.

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