

## Standard plating vs. cortical strut and plating for periprosthetic knee fractures: a multicentre experience

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### ABSTRACT

**Aim** Periprosthetic fracture after knee arthroplasty occurs more frequently in the supracondylar area of femur, especially after low energy trauma associated with torsional or compressive forces. Several techniques have been described for the treatment of displaced fractures. The aim of this study is the evaluation of the outcomes and bone healing of periprosthetic femoral fractures managed by standard plate fixation compared to plating with bone grafting.

**Methods** Thirty-six periprosthetic fractures around the knee were selected. Eighteen patients underwent standard plate and screws fixation while other eighteen were treated by plating associated with a cortical strut. Knee Society Score (KSS) and Short Form 12 (SF12) with the UNION SCORE (RUS) were used for the evaluation of results.

**Results** After a minimum follow-up of 12 months, the results showed a statistically significant difference in SF-12, KSS, and RUS in favour of plating associated to bone graft with respect to the plating alone; four cases of non-union were recorded in the group of patients treated by standard plating.

**Conclusions** Our experience once again demonstrated that plating and bone grafting may ensure a mechanical and biological support for the healing of periprosthetic fracture of the knee more than simple plating.

**Keywords:** arthroplasty, cortical strut allograft, femoral fracture, internal fixation, knee, locking plate, periprosthetic fracture

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## INTRODUCTION

Total knee arthroplasty (TKA) procedures have been dramatically increasing worldwide in the last years, and consequently failures are expected in the very near future (1). Among the causes of failures, periprosthetic fractures are arising mostly related to the improvements of quality of life of elderly patients (1). Despite better health conditions, patients with a previous TKA may fall and in case of osteoporosis a fracture around the knee may realize. Periprosthetic fractures after TKA occurs more frequently in the femur, especially in the supracondylar area, with an incidence of 0.3% -2.5% and mostly 2 to 4 years after surgery (1,2). Majority of these fractures occur following a minor trauma, other causes include road-traffic accidents, seizures, and forced manipulation of a stiff knee (3). Osteoporosis is not the single risk factor of such injuries: anterior femoral notching, rheumatoid arthritis, steroid therapy, neurological diseases, previous revision arthroplasty, and local osteolysis and infection (3).

Whatever the cause, a fracture after TKA is a challenging complication and failure or suboptimal outcomes after any treatment are reported (4), and associated to an increased risk of mortality (5-6).

When operative intervention is chosen, the method will be guided by a variety of factors such as how well fixed the implant is, the fracture pattern (including presence or absence of comminution), the presence of infection, other implants proximal or distal to the TKA, periprosthetic bone stock, and bone quality (1-6). Operative strategies in this context include the use of retrograde intramedullary nailing, open reduction and internal fixation (ORIF) with non-locked or locked plates and the use of external fixation techniques (6). According Prins et al. (7) a revision of fixation and liberal use of bone grafting can lead to reliable healing in the majority of periprosthetic femoral non-unions.

The aim of the present study was the report of results of the management of periprosthetic femoral fractures by plating alone and plating plus cortical strut grafting in a series of patients operated at the authors' institution.

## PATIENTS AND METHODS

### Patients and study design

From January 2008 to December 2017, 64 consecutive femoral shaft fractures around the knee after TKA were treated. Inclusion criteria were: fractures caused by high or low energy, >65 years of age, patients completing a minimum follow-up of 12 months, Type 1 or Type 2 fractures according Rorabeck classification (8), ORIF with or without bone strut allograft.

Exclusion criteria were: fractures caused by haematological or oncological pathologies, <65 years of age, patients not completing a minimum follow-up of 12 months, fractures in loose implants (Rorabeck type 3), intramedullary nailing fixation.

A total of 36 patients were divided into two groups after being informed of the type of fracture, and the possibility of two different methods chosen by the method of sealed envelopes. Both treatments were performed respecting the ethical standards of the Helsinki Declaration.

Group 1 (Bio) was composed of 18 patients (6 males, 12 females) treated by plating, screws, and strut allografts, with a mean age of 78.64 (range: 67-89); 14 patients (77.78%) were operated for primary knee osteoarthritis, four (22.22%) for post-traumatic arthritis. Posterior-stabilized (PS) implants were applied in eight (44.44%), cruciate-retaining (CR) in four (22.22%), and mobile-bearing (MB) in five (27.78%) patients. The mean interval from TKA to trauma was 12.2 years (range: 7-20). Mechanisms of trauma were mainly falls (10 cases, 55.56%), daily activities (6 cases; 33.33%), sport (2; 11.11%). According to the classification of Rorabeck (8) fractures were classified as I or II type in nine cases each (Table 1). After admission in the ward, all patients were studied by DEXA and Non-Union Scoring System (NUSS) (14). The mean T-score was -3.2 ( $\pm 0.91$ ) with a Z-score of -1.67 ( $\pm 0.42$ ); the mean NUSS was 56.84 (range 35-70).

Group 2 (MET) included 18 patients (six males, 12 females) treated exclusively by plating, with a mean age of 78.66 (range: 65-88). Similarly to group 1, 14 (77.78%) and four (22.22%) patients were operated for primary and secondary arthritis, respectively. Posterior-stabilized TKA was present in nine (50%), cruciate-retaining in

five (27.78%), and mobile-bearing in other five (27.78%) patients. The interval between the index operation and periprosthetic fracture was 12.1 years (range: 7-20), with fall as the main cause of trauma in 11 (61.11%), daily activities in six (33.33%) and sport in one case (5.56%). According to Rorabeck classification (8) both type I and type II were found in nine (50%) patients. DEXA evaluation found a mean value of  $-3.2 (\pm 0.89)$  with a Z-score of  $-1.66 (\pm 0.43)$  and NUSS 56.9 (range: 35-70).

Surgery was performed by three of the authors in supine position using the direct lateral approach to the distal femur. After preservation of the vastus lateralis and its perforating arteries and exposure of the fracture site, plating or plating with fresh frozen allograft were positioned after reduction. All cases were managed by less invasive stabilization system (LISS) (Depuy Synthes, Oberdorf, Switzerland). Compression cortical screws were also applied to stabilize the strut bone, placed to reinforce the medial wall of the diaphysis and distal metaphysis. Furthermore, free spaces were filled with morcellized bone graft. Finally, the subcutaneous and cutaneous soft tissues were sutured (Figures 1, 2).

All patients were passively mobilized the day after surgery with prescription of articulated braces aiming to reach  $90^\circ$  of flexion as soon as possible. Also, isometric exercises for muscle strengthening of quadriceps and hamstring were proposed. Partial weight bearing was early prescribed with crutches or frame, depending on the age and functional ability of patients. Patients were encoura-

ged to achieve a full weight bearing after the first adequate x-ray check (one month after surgery).

Patients of both groups underwent the same follow-up conducted by clinical evaluations, a standard radiologic study, and the administration of Knee Society Score (KSS) (9) and Short Form 12 Health Survey (SF-12) (10). The NUSS was also used to assess the radiologic healing of fractures (11).

### Statistical analysis

Descriptive statistics were used to summarize the characteristics of the study group and subgroups, including means and standard deviations of all continuous variables. The t test was used to compare continuous outcomes. The Fisher exact test in the groups smaller than 10 patients, was used to compare categorical variables. The statistical significance was defined as  $p < 0.05$ . Pearson correlation coefficient (r) was used to compare the predictive score of outcomes and quality of life. Mean age (and standard deviations) of the patients was rounded at the closest year. The predictive score of outcomes and quality of life and their standard deviations were approximated at the first decimal while Pearson correlation coefficient (r) was approximated at the second decimal. The reliability and validity of the correlation between functional osteosynthesis and bone healing were determined by the Cohen's kappa (k).

### RESULTS

All the analysed data were homogeneous in the two study groups, reporting statistically signi-

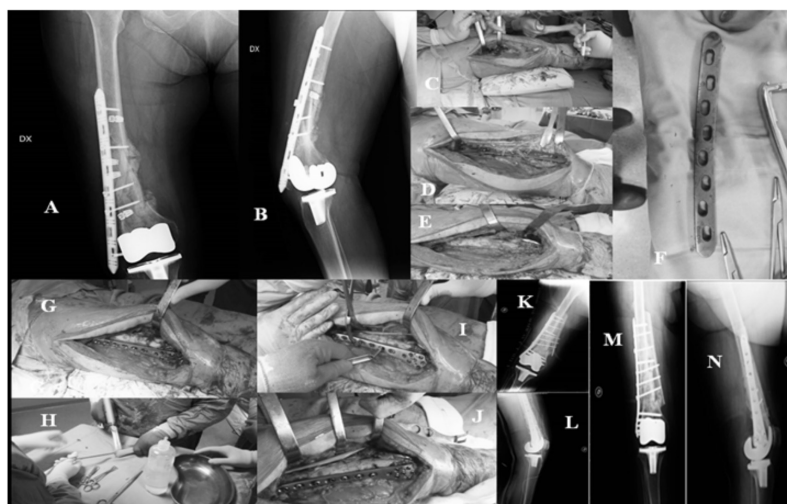


Figure 1. 85 year-old woman operated 4 years before by plate fixation and cerclages for a Rorabeck type II periprosthetic fracture. A, B) non-union and screws breakage; C-F) lateral access, hardware removal; G, H) temporary fixation by plate with bone strut allograft; K-L) final fixation; M, N) one-year of follow-up (Rollo G, 2017)



**Figure 2.** A-C) Rorabeck type II periprosthetic fracture in a 73-year old woman; D-F) inadequate reduction and plate fixation (D-F) (Bonura E, 2016)

ficant results with  $p > 0.05$ . The mean follow-up was 1.8 (range: 1-3) in the group 1 and 1.7 (range: 1-3) in the group 2 ( $p > 0.05$ ) (Table 1).

Knee function of Bio's life before the trauma, measured by Knee Society Score (KSS), was about 82.7 points (range 46-96), while the quality of life before the trauma, measured by KSS, was about 82.6 points (range 48-94) in MET ( $p > 0.05$ ). At the moment of trauma, in the Bio group the KSS was 16.6 (range 0-30) in the same moment MET, the KSS was 16.8 (range 0-30) ( $p > 0.05$ ). After 1 month from the revision surgery the KSS score was 34.6 (range 10-45) in Bio and 34.8 (range 10-45) in MET group ( $p > 0.05$ ). Also the third month after the surgery ( $p > 0.05$ ) difference at three KSS score was 50.8 in Bio (range 25-70) and 50.6 in MET (range 25-70), as well as the sixth month of follow-up.

At 6 months from the revision surgery, in Bio the KSS was 66.4 (range 30-85), while in MET it was 59.4 (range 30-85) ( $p > 0.05$ ). At twelve months after the surgery KSS score in Bio was 74.8 (range 30-90), while in MET it was 68.6 (range 30-90) ( $p > 0.05$ ).

The subjective quality and knee function of Bio's life before the trauma, measured by SF-12, was about 78.4 points (range 40-100), while the quality of life before the trauma, measured by SF-

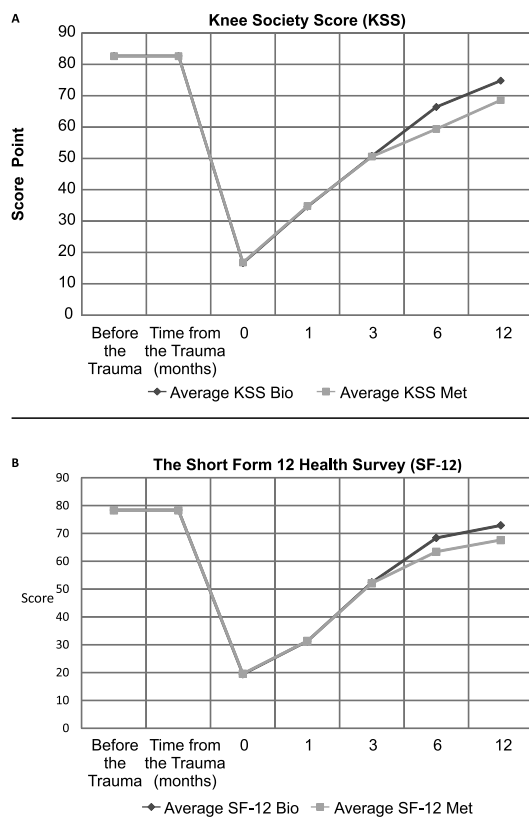
**Table 1. Demographic and clinical features of the patients in the Bio and Met groups**

Characteristic	Bio	Met	p
No of patients	18	18	>0.05
Mean age (range) (years)	78.64 (65-89)	78.66 (67-88)	>0.05
Gender Ratio (M:F)	0.5 (6:12)	0.5 (6:12)	>0.05
Diagnosis for TKA (No; % of patients)			
Trauma	4 (22.22)	4 (22.22)	>0.05
OA	14 (77.78)	14 (77.78)	>0.05
Type of TKA (No; % of patients)			
PS	8 (44.44)	9 (50)	>0.05
CR	4 (22.22)	5 (27.78)	>0.05
MB	5 (27.78)	5 (27.78)	>0.05
Mean interval between TKA and PPF (SD; range)	12.2 (±2.34; 7-20)	12.1 (±2.38; 7-20)	>0.05
Mechanism of PPF (No; % of patients)			
Accidental fall	10 (55.56)	11 (61.11)	>0.05
Daily activities	6 (33.33)	6 (33.33)	>0.05
Sport	2 (11.11)	1 (5.56)	>0.05
Rorabeck classification (No; % of patients)			
I	9 (50)	9 (50)	>0.05
II	9 (50)	9 (50)	>0.05
Mean T-score (ipsilateral Hip, SD)	-3.2 (±0.91)	-3.2 (±0.89)	>0.05
Mean Z-score (ipsilateral hip, SD)	-1.67 (±0.42)	-1.66 (±0.43)	>0.05
Mean Non Union Scoring System (range)	56.84 (35-70)	56.9 (35-70)	>0.05
Mean follow-up (range) (years)	1.8 (1-3)	1.7 (1-3)	>0.05
Mean surgical time (minutes)	116.2 (88 -192)	108.6 (79 -193)	>0.05
Mean time for radiographic bone healing (days)	140.4 (94 -156)	160.7 (95 -158)	<0.05
Cohen's kappa (k)	0.813±0.127	0.696±0.196	<0.05

TKA, total knee arthroplasty; OA, osteoarthritis; MB, mobile-bearing; PPF, periprosthetic fracture; SD, standard deviation;

12, was about 78.3 points (range 40-100) in MET ( $p>0.05$ ). At the moment of trauma, in Bio group the SF12 was 19.4 (range 0-24) and in the same moment MET, it was 19.6 (range 80-24) ( $p>0.05$ ). After 1 month from the revision surgery the SF-12 score was in 31.3 (range 5-40) in Bio and 31.4 (range 5-40) in MET ( $p>0.05$ ) group. Also, three months after the surgery ( $p>0.05$ ), difference at three SF12 scores was 52.4 in Bio (range 20-72) and 52.1 in MET (range 20-72) group, as well as in the sixth month of follow-up.

At 6 months from the revision surgery, in Bio group the SF-12 was 68.4 (range 24-82), while in MET it was 63.4 (range 24-80) ( $p>0.05$ ). At twelve months after the surgery SF-12 score in Bio of 72.9 (range 40-92) and in MET group of 67.6 (range 40-92) was noticed ( $p>0.05$ ) (Figure 3).



**Figure 3.** Knee Society Score (KSS) before and 1 year after fixation. **A)** At 6 and 12 months, there was a statistical difference ( $p<0.05$ ) for the group of patients undergoing plating with cortical struts; **B)** Short Form 12 Health Survey (SF-12) before and after surgery. At 6 and 12 months, there was a statistical difference ( $p<0.05$ ) for the group of patients undergoing plating with cortical struts

In the two groups, an average correlation between osteosynthesis and bone healing at the moment of X-rays callus was found. It was absolutely corre-

lated in Bio's clinical results with Cohen's kappa ( $k$ )=0.8138388±0.12772989 as in Met group with discrete correlation  $k=0.696211111±0.196643$  ( $p<0.05$ ) (Table 1).

At the endpoint the complications in Bio group were: postoperative blood loss of 723±186.03 mL; intra operative fracture in none, non-union in none, angular deviation in two (11.11%) patients; implant migration in none, limb shortening (>3 cm) in three (16.67) patients; loosening of the prosthesis in two (11.11%) patients; post-operative fracture in none; death after 1 year of follow up in two (11.11%) patients. At the endpoint the complications in Met group were: postoperative blood loss of 728±184.98 mL; intra operative fracture in none, non-union in four (22.22%) patients; angular deviation in six (33.33%) patients; implant migration in four (22.22%) patients; limb shortening (>3 cm) in seven (38.89%) patients; loosening of the prosthesis in six (33.33%) patients; post-operative fracture in none, death after 1 year of follow up in two (11.11%) patients. In comparison between the two groups, the major complications in the Met group were seen in non-union, angular deviation, implant migration, limb shortening and loosening of the prosthesis. In comparing the outcomes of the two groups there was a significant statistically difference ( $p<0.05$ ) in low complication rates for Bio (Table 2).

**Table 2. Results and complications of the patients in the Bio and Met groups**

Complications	No (%) of patients in the group		p
	Bio	Met	
Intra Operative Fracture	0	0	>0.05
Non union	0	4 (22.22)	<0.05
Angular deviation	2 (11.11)	6 (33.33)	<0.05
Implant migration	0	4 (22.22)	<0.05
Limb shortening (>3 cm)	3 (16.67)	7 (38.89)	<0.05
Implant loosening	2 (11.11)	6 (33.33)	<0.05
Post-op fracture	0	0	>0.05
Death at 1-year follow-up	2 (11.11)	2 (11.11)	>0.05

## DISCUSSION

Periprosthetic fractures of the distal femur are raising events in the general population. The treatment is generally challenging and the outcomes related to the choice of surgical strategy. If the implant is stable, open reduction and internal fixation is recommended. Such type of the procedure is mostly associated with high healing rates, but outcomes are variable.

Several authors have reported good results after open reduction and internal fixation of these fractures (12-14). Healy et al. treated 20 fractures with open reduction and internal fixation using a variety of different implants including blade plate, condylar screw and condylar buttress plates. They performed bone grafting in 15 patients and achieved union in 18 patients. Two patients, who did not have bone graft at the time of index surgery, needed reoperation with bone grafting to achieve union (15).

Some authors recommended primary bone grafting with internal fixation to increase the chances for union of these difficult fractures, to which blood supply had been compromised by previous total knee arthroplasty, the fracture itself and the operative fixation of the fracture (7,15). Moran et al. treated 15 patients with condylar screw and plates, blade plates and buttress plates. Of these 15 patients, 2 developed malunion and 3 non-union at the fracture site requiring further surgery (16). The possible varus angulation was managed with plate and screws (12-16).

Wang and Wang reported satisfactory results using combination of medial allograft struts and a compression plate for fractures above a total knee replacement with severe osteopenia or loss of bone stock and failure of initial open reduction and internal fixation (17).

Clinical studies have also reported good results using locking plates for the treatment of periprosthetic supracondylar femur fractures (3).

There are very few mechanical investigations of peri-prosthetic fracture fixation. The effect of allograft cortical strut length, strut configuration, cable number, cable tension and the use of wire or cable on periprosthetic fracture fixation was investigated (18-20).

The allograft struts essentially act as large onlay cortical allograft biological bone plates and they have the capacity to both augment the stability of a periprosthetic fracture fixation, and to increase the local bone stock at the fracture site. They can be customized to fit any femur, and they share the same modulus of elasticity as the host bone (21). In 1993 Chandler et al. recorded a series of 19 periprosthetic femoral fractures managed with massive cortical onlay graft; 84% of 19 patients united at a mean of 4.5 months. There were

two non-unions and one malunion that required further surgery (22). Emerson et al. reported that cortical strut allografts unite consistently and reliably by 8.4 months, with a union rate of 96.6% (23). Clinically, the use of one third circumference struts rather than a bivalve femur has the advantage of minimizing soft tissue stripping required for placement (24).

The use of a combination of fixation plate and cortical allograft is attractive. However, there are few reports of the use of a combination construct of fixation plate on one cortex and a cortical strut allograft on another cortex. Prins et al. reported a very high rate of fracture union in a multicenter study when cortical struts, either alone or in conjunction with a plate were used for the fixation of periprosthetic fractures non-union (7).

Nevertheless, when the femoral component is well fixed it is often retained with open reduction and internal fixation of the fracture. A number of alternatives are available for such treatment, some of which are associated with high failure rate. Cortical onlay strut allografting, as the primary method of fixation or as adjunctive fixation when a plate is used, has emerged as an attractive option for the treatment of periprosthetic femoral fractures around stable implants (24,25).

Chandler et al. reviewed the outcomes of treatment of nineteen fractures around well-fixed femoral hip or knee implants; they reported that seventeen had united by eighteen weeks and the patients had returned to their pre-morbid level of activity (22). The allograft struts confer stability to the fracture site, and they can incorporate and ultimately increase the femoral bone stock (7,20,21).

This study compares the degree of fracture fixation achieved with plate fixation (MET) and combined plate and strut allograft fixation (BIO). The combined plate and allograft fracture fixation demonstrate that early stability is enhanced in comparison to an isolated plate fixation. The plate provides protection to the allograft from excessive fracture motion and intuitively should enhance the ability of the graft to act as a bone stock replenisher. Stable fixation of fractures around well-fixed implants allows for fracture union in satisfactory alignment. Several factors make it more difficult to obtain satisfactory internal fixation. As well as conferring mechanical stability, they may enhance fracture-healing and increase bone stock (7,20,21). If appropriately selec-

ted and prepared, allograft struts can be customized to fit almost any femur. As the modulus of elasticity of allograft struts is similar to that of the host bone, there may be less stress-shielding of the host bone in comparison with that associated with other, more rigid forms of internal fixation (26).

There is a dynamic change in allograft biomechanics during the incorporation and re-modelling process (7,20,21,27,28). Previous studies have suggested that cortical struts predictably unite, remodel, and mature (20).

The duration of follow-up of the majority of our patients was insufficient to see maturation and re-modelling in all patients, but once graft-host union has occurred, the sequence of events described by the animal experiments and radiographic observations of humans would be expected to proceed (29,30).

The ideal length, position, and fixation of cortical struts have not been determined. Cortical strut allografting is a very useful option for periprosthetic femoral fractures around stable implants. Ideally, intramedullary fixation offers more rigid fixation especially when combined with rotational control. However, this is impractical in a well fixed implant since exchange of a stable implant may compromise the final construct. In that scenario as identified in the previous chapter, extramedullary fixation is preferred. An alternative to a cortical only graft is a metal plate (7).

Limits of the current study include the short-term follow-up, the limited number of patients, and the poor statistical power of the population due to the

low incidence of this type of fracture. Moreover, several variables as other risk factors related to each patient were not measured.

In conclusion, the combination of plating and strut grafts in our experience seems to be the most stable fixation method to treat femoral periprosthetic fractures around the knee, ensuring adequate healing time, stability, and rotational control of the fragments. However, no statistically significant differences in interfragmentary motion were observed within the two groups.

The data currently available, however, do not yet allow for definitive conclusions about the appropriate treatment and the best choice for periprosthetic femoral fractures around stable knee implants regarding complications and clinical outcomes. Furthermore, we need a larger number of patients and follow up at five years or more to provide more evidence for the type of treatment option that can be chosen with better clinical outcomes and decreased complications risk. Actually this is almost impossible due to the advanced age of the patients and related comorbidities being treated for this pathology. This RCT or meta-analysis is in this case useful to improve scientific evidence and give more information for the correct surgical treatment of periprosthetic fractures around the knee.

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## TRANSPARENCY DECLARATION

Conflicts of interest: None to declare.

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