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ORIGINAL STUDY

Intramedullary versus extra medullary fixation for basicervical femoral fractures : which is better?

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The basicervical femoral fracture (BCF) is rare and may be fixed with an intramedullary nail or an extramedullary device. The intramedullary nail is thought to cause an intraoperative wedge effect at the BCF, causing a fracture displacement. This study aims to compare the radiological and clinical outcomes of the use of intramedullary nail and extramedullary device for BCFs.

Patients with BCFs treated with an intramedullary nail or extramedullary device over 5 years were reviewed. The neck shaft angle (NSA) at before and after insertion of the implants were compared. The fracture reduction was also qualitatively reviewed by a fellowship-trained senior trauma surgeon. The Modified Barthel Index (MBI) and Modified Functional Ambulation Classification (MFAC) at pre-morbid and at 1 year post-operation were compared.

Thirty-one extramedullary device and 18 intra-medullary nail fixations were performed. Both groups had similar demographics. The NSA before the insertion of implants were similar (137.2°±5.1° vs. 134.8°±5.6°, *p*=0.191). After the insertion of the implants, the NSA in the extramedullary device group increased, while the NSA in the intramedullary nail group decreased (138.7°±5.1° vs. 133.6°±5.6°, *p*=0.003). The quality of reduction were similar in both groups. Both groups experienced similar declines in MBI over 1-year post-operation (-9.3±21.1 vs. -4.1±23.2, *p*=0.670). The median MFAC was indoor walker in both groups (*p*=0.328) with similar distribution in the change of MFAC over 1-year post-operation (*p*=0.863).

In basicervical femoral fractures, intramedullary nail fixation caused a wedge effect, but the short-term clinical outcomes were similar between intra- and extramedullary fixations.

Keywords : basicervical femoral fracture ; wedge effect ; intramedullary nailing ; extramedullary device.

INTRODUCTION

Hip fractures are an increasing problem with its global incidence estimated to rise from 1.66 million in 1990 to 6.26 million by 2050 *(1)*. A less common variant of the hip fracture is the basicervical femoral fracture (BCF) (AO classification 31B3), which is a fracture through the base of the femoral neck at its junction with the intertrochanteric region *(2-3)*. Surgical fixation may be performed using extramedullary or intramedullary devices *(4-7)*.

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Studies on the choice of fixation for BCFs has largely been biomechanical studies, *(8-10)* case series of one implant, *(4-7)* or studies involving older implants *(11-12)*.

The "wedge effect" has been previously described during the fixation of intertrochanteric fracture with intramedullary nailing, in which there is a distraction of the fracture site with resultant varus alignment as the nail passes through the fracture site *(13)*. The varus alignment is undesirable as it is associated with an increased risk of failure of the fixation *(14)*. While the BCF is a separate fracture entity from an intertrochanteric fracture, *(2)* the preferred entry point of intramedullary device in our institution is just slightly medial to the tip of the greater trochanter, *(15)* and therefore closer to the BCF region. This may produce a more pronounced wedge effect especially in this group of fractures.

Therefore, we aimed to investigate whether an extramedullary device or an intramedullary device would be better in the fixation of BCFs. We were interested in the presence or the absence of malreduction after the insertion of the fixation device. Secondly, we were interested in the outcomes of the patients following fixation with an extramedullary or an intramedullary device. We hypothesised that the intramedullary fixation device would create a varus malreduction, leading to poorer outcomes. The knowledge of this will elucidate the ideal choice of device for such a fracture configuration.

MATERIALS AND METHODS

Ethical approval was obtained from the Institutional Review Board prior to the commencement of the study.

Retrospective review of the institution's hip fracture registry between October 2011 and December 2016 was performed. Only BCFs that underwent surgical fixation with either the Dynamic Hip Screw (DHS ; Depuy Synthes, Oberdorf, Switzerland) or the Proximal Femoral Nail Anti-rotation (PFNA ; Depuy Synthes, Oberdorf, Switzerland) were included in the study. BCFs were identified via screening of the antero-posterior (AP) and the lateral views of plain radiographs on admission, as well as the intraoperative image-intensifier images. We diagnosed BCF fractures from the plain X-ray according to the parameters defined by Okano et al. *(16)*. The fracture line must be within an area medial to the intertrochanteric line, lateral to the base of the femoral head, with an intact lesser trochanter

Patients were excluded if the either the pre-implant or post-implant AP images were unavailable.

The DHS and the PFNA groups were compared in terms of age, gender, Charlson comorbidity index (CCI), *(17)* laterality, bone mineral density (BMD), Modified Barthel Index (MBI) *(18)* and Modified Functional Ambulation Classification (MFAC) *(19)* on admission and at 1 year post-operation.

The wedge effect was assessed quantitatively and qualitatively using the neck-shaft angle (NSA) and reviewing the intraoperative image-intensifier images respectively.

The NSA was measured using the institution's radiograph viewing software (Centricity Enterprise Web V3.0, GE Healthcare, US). Intraoperative image-intensifier images were used for measurements. The anterior-posterior (AP) view of the fractured hip before the insertion of the implant was used for the measurement of the pre-implant NSA. The final AP view of the fractured hip after the insertion of the implant was used for the measurement of the post-implant NSA. The NSA measurement was repeated by the second author to confirm inter-reader reliability. The images were taken while the patient was on a traction table. Once satisfactory reduction was obtained, the lower limb was immobilised throughout the surgery. This ensured that there was no rotation before and after the insertion of the implants, which may affect the NSA.

The intraoperative image-intensifier images were assessed by the senior author, a fellowship-trained senior trauma surgeon, to determine the adequacy of the initial reduction of the fractures and whether there was subsequent loss of reduction during the procedure. The entry position of the PFNA nail was also reviewed and categorised descriptively as standard (just medial to the greater trochanter tip), *(15)* or lateral (greater trochanter tip entry).

The MBI is a functional measure of patients' ability to perform daily activities and has been used to study the outcomes of patients after hip surgery for neck of femur fracture *(20)*. The score ranges from 0 to 100, whereby a higher score indicates that the patient is more independent in daily activities. In our centre, the scoring is routinely performed by qualified nurses on admission and at 1-year post operation via telephonic survey as part of a hip fracture registry. In the event of loss to follow up, the value was substituted with the average MBI score of the cohort at 1 year post operation.

The MFAC classifies the walking capacity of a patient into a 7-point Likert Scale , from I being someone who is unable to sit unsupported to VII being an outdoor walker. It has been validated as a tool to measure the ambulatory status in patients with hip fractures *(19)*. Incomplete follow up data was omitted and not adjusted.

Implant-related complications after the index surgery were recorded. Complications were defined as non-union, unexpected implant migration, or implant-related events which resulted in re-operation of the hip.

All patients were positioned supine on the traction table. Closed reduction was attempted first, failure of which required open reduction.

For the DHS, the 135º 38mm barrel with 2 or 4 hole-plate was inserted as per the technique guide. In some cases, antirotation wires were utilised, as well as cannulated partially threaded cancellous screws.

For the PFNA, the short PFNA with a blade-nail angle of 135º was inserted as per its surgical technique guide.

The choice of implant was decided by the surgeon, based on their personal practice.

All patients underwent standardised rehabilitation protocol whereby they were allowed full weight bearing as tolerated immediately post-op.

The Shapiro-Wilk test was performed to test the normality of the data distribution. The Student t-test was used to compare continuous parametric values, while the Mann-Whitney test was used to compare continuous non-parametric values. The paired t-test was used to compare the pre- and post-implant NSA. The chi-square test was used to compare categorical data. The intra-class correlation coefficient (ICC) was used to assess the inter-observer reliability of the NSA. All analyses were performed using SPSS Statistics (version 22 ; IBM, Armonk, NY). A p value of <0.05 was deemed as statistically significant.

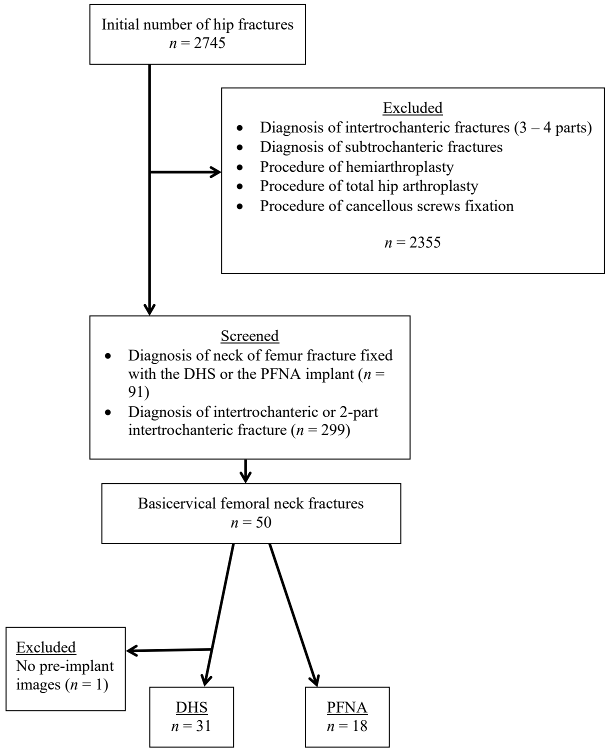

Figure 1. — Flowchart showing patient selection.

RESULTS

There were 2745 surgeries performed for hip fractures between October 2011 and December 2016. Following the exclusion criteria as seen in Figure 1, there were 31 patients remaining in the DHS group and 18 patients in the PFNA group. The prevalence of this fracture was 1.8%.

The patient demographics are represented in Table I. The patient groups were similar in terms of mean age (79.1 ± 9.4 vs. 81.3 ± 8.4, p=0.420), gender distribution (25 (81%) vs. 11 (61%) female, p=0.135), side of involvement (16 (52%) vs. 13 (72%) left side, p=0.157), distribution of CCI (p=0.058) and BMD (T-scores : -3.3 ± 1.0 vs. -3.4 ± 0.9, p=0.926). The BMD was measured on the average of 13 ± 124 days of the index admission.

Table I. — Demographics of patients

	DHS **n = 31**	**PFNA** **n = 18**	***p***
Mean age (years)	79.1 ± 9.4	81.3 ± 8.4	0.420
Female (%)	25 (81)	11 (61)	0.135
Charlson comorbidity index			0.058
≤2	28	12	
≥3	3	6	
Laterality (Left side) (%)	16 (52)	13 (72)	0.157
Mean BMD (T-score)	-3.3 ± 1.0	-3.4 ± 0.9	0.926

DHS – Dynamic Hip Screw. PFNA – Proximal Femur Nail Anti-rotation. BMD – Bone mineral density (total hip T-score).

Table II. — Mean neck-shaft angle (NSA) in the dynamic hip screw (DHS) and the Proximal Femur Nail Anti-rotation (PFNA) groups

	DHS (º)	**PFNA (º)**	***p***
Pre-implant	137.2 ± 5.1	134.8 ± 5.6	0.191
Post-implant	138.7 ± 5.1	133.6 ± 5.6	**0.003**
Overall change	1.6 ± 2.3	-1.2 ± 2.3	**<0.001**

DHS – Dynamic Hip Screw. PFNA – Proximal Femur Nail Anti-rotation.

Table III. — Qualitative analysis of the reduction and the change in neck-shaft angle (NSA)

	DHS (n = 31)	**PFNA** (n = 18)	***p***
Adequate reduction (%)	25 (80.6)	12 (66.7)	0.272
Loss of reduction intraoperatively (%)	8 (25.8)	7 (38.9)	0.338
Qualitative change in NSA after the insertion of implant (%)	3 (9.7)	0	0.288

DHS – Dynamic Hip Screw. PFNA – Proximal Femur Nail Anti-rotation

The mean duration of follow up for all patients was 330 ± 329 days.

The pre-implant NSA of the fractured hip was similar between the DHS and the PFNA groups (137.2˚ ± 5.1˚ vs. 134.8º ± 5.6º, p=0.191) (refer to Table II). At post-implantation, the NSA in the DHS group was significantly larger than the PFNA group (138.7º ± 5.1º vs. 133.6º ± 5.6º (p=0.003). From pre-implantation to post-implantation, the NSA in the DHS group had significantly increased by 1.6º ± 2.3º (p=0.001), while the NSA in the PFNA group significantly decreased by 1.2º ± 2.3º (p=0.035). The change in the NSA from pre-implantation to post-implantation was significantly different between the two groups (1.6º ± 2.3º vs. -1.2 ± 2.3º, p<0.001). The ICC values for the inter-observer reliability of the pre- and post-implant NSA were very good to excellent at 0.891 to 0.902.

Table IV. — Outcome measures of the patients

	DHS	**PFNA**	***p***
MBI	n = 31	n = 18	
Mean MBI on admission	92.8 ± 11.5	76.6 ± 31.6	**0.019**
Mean MBI at 1 year post operation	83.5 ± 21.4	72.5 ± 25.0	**0.025**
Mean change of MBI	-9.3 ± 21.1	-4.1 ± 23.2	0.670
MFAC	(n = 29)	(n = 16)	
Median MFAC on admission	6 [3, 7]	6 [2, 7]	0.126
Median MFAC at 1 year post operation	6 [1, 7]	5 [2, 7]	0.080
Change in MFAC			0.863
No change	9	4	
Deteriorated	16	9	
Improved	4	3	

DHS – Dynamic Hip Screw. PFNA – Proximal Femur Nail Anti-rotation. MBI – Modified Barthel Index. MFAC – Modified functional ambulatory classification

In the DHS group, K-wires alone were utilised in 22 cases for antirotation. A cannulated partially threaded screw in further 4 cases. In 5 cases, neither the K-wire nor the cannulated screw was utilised for antirotation. The 4-hole DHS plate was used in 12 cases, with 2-hole plates for the remaining 19 cases.

The proportion of patients who achieved adequate reduction before the insertion of the implants was similar (81% in DHS vs. 67% in PFNA, p=0.272) (see Table III). There were some cases of intraoperative loss of the fracture reduction but the proportion did not differ significantly between the DHS and the PFNA groups (26% in DHS vs. 39% in PFNA, p=0.338). In the DHS group, the loss of reduction occurred before the insertion of the implant in 2 cases, during the plate insertion in 1 case, before the DHS screw insertion in 1 case, and during the insertion of the DHS screw in 4 cases. In the PFNA group, the loss of reduction occurred during the reaming in 1 case, after the reaming in

2 cases, and during the nail insertion in 4 cases. Despite the above loss of reduction, there were only 3 cases of obvious change in the NSA in the DHS group, and none in the PFNA group. This was not significantly different between the two groups (*p*=0.288). There were equal numbers of standard and lateral entry points (9 each) in the PFNA group.

The DHS group had significantly greater MBI scores on admission (92.8 ± 11.5 vs. 76.6 ± 31.6, *p*=0.019) (Table IV). At 1 year post operation, 2 patients in each group were lost to follow up. The mean MBI was significantly lower at 1 year post-operation in both groups (*p*<0.001 for the DHS group, *p*=0.002 for the PFNA group). However, the extent of change was comparable between both groups (-9.3 ±21.1 vs. -4.1 ± 23.2, *p* = 0.670). The mean MBI of the DHS group remained higher than that of the PFNA group (83.5 ± 21.4 vs. 72.5 ± 25.0, *p* = 0.025).

The median ambulatory status was "indoor walker" in both groups (*p*=0.328). Each group lost 2 patients to follow up at 1 year post operation. The median ambulatory status remained "indoor walker" in the DHS group, but it decreased to "supervised walker" in the PFNA group (*p*=0.363). However, there was no significant difference in the distribution of patients with regards to the change in their MFAC class over the year (*p*=0.863).

One patient in the PFNA group had a peri-implant infection at 8 months post operation. Debridement and removal of the implant was performed, but the patient demised due to sepsis. There was no complications noted in the DHS group. None of the patients had mechanical failure or required revision surgery. Union of the fracture was noted in all patients. The proportion of patients with complications was not significantly different between the two groups (*p*=0.367).

DISCUSSION

The basicervical femoral fracture is an uncommon variant of hip fractures *(2)*. Several fixation options have been described in the literature. In cadaveric studies, Blair et al. *(8)* and Deneka et al. *(9)* compared the use of 3 parallel cannulated cancellous screws, against a sliding hip screw with an additional parallel antirotational screw. Both studies suggested that the use of a sliding hip screw provided better fixation strength. Blair et al suggested that the use of an additional parallel antirotational screw provided merely rotational control but did not confer additional strength to the fixation *(8)*. When the extramedullary device DHS was compared to the intramedullary device PFNA, Imren et al. *(10)* showed that there was no signicant difference in their fixation strength when tested in composite synthetic bones.

In clinical literature, Chen et al. *(4)* followed 269 patients with BCFs which were fixed with the DHS. The study reported 1.66% of nonunion and 0.83% of screw cutout *(4)*. Massoud[5] also had a series of 13 BCFs which were successfully treated with the DHS. These results are better than what was described by Kuokkanen *(11)* one to two decades earlier. Of the 14 BCFs performed, only 6 survived till follow up. Kuokkanen described 5 out of 6 had poor clinical outcome, and there was one pseudoarthrosis and deep infection *(11)*. With the PFNA, Hu et al. *(6)* achieved fair to good results in 30 BCFs. Similarly, Tasyikan et al. *(7)* and Okano et al. *(18)* achieved good results in 28 patients and 14 patients respectively, who were surgically treated with the PFNA.

More recently, Lee et al. *(21)* compared 40 patients treated with the PFNA to 29 patients treated with the DHS and found that the DHS construct was more likely to fail, requiring revision surgery. However, they did not study the clinical outcomes of these patients. Sharma et al. *(22)* compared 32 patients treated with the PFNA to 27 patients treated with the DHS and showed similar union rates, proportion of patients with complications, and clinical outcome scores. Notably, Sharma et al. *(22)* described techincal difficulties in treating the fracture with the PFNA, including "opening up of the fracture" and "varus angulation". These patients were excluded from their follow up.

To the best of our knowledge, this is the first clinical study to investigate the presence or the absence of malreduction after the insertion of the fixation device and their clinical outcomes. In our study, we found that the PFNA reduced the NSA after the initial reduction, with an example shown in

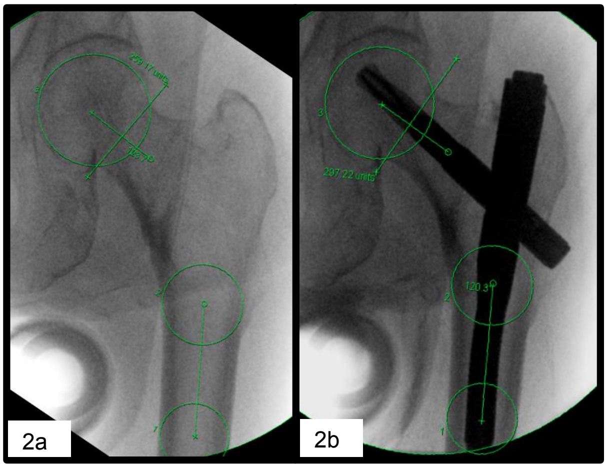

Figure 2. — X-rays demonstrating the wedge effect caused by the intramedullary nail. The neck-shaft angle measured before the insertion of the implant was 123º (2a). The neck-shaft angle measured after the insertion of the implant was 120º (2b).

Figure 2. This was similar to that reported by Hu et al. *(6)* and Sharma et al. *(22)* Hu et al. *(6)* described the "V effect" to be the cause, which was similar to the "wedge effect" originally described by O'Malley et al. *(15)*.

The "V" or "wedge effect" may be due to the superolateral base of the femoral neck, whereby its dense bone deflects the nail along with the femoral shaft as the nail passes through the fracture site to enter the femoral diaphysis *(23)*. The nail then becomes a physical block in the reduction of the fracture gap, making fracture site compression challenging.

With the DHS, there was an increase of the NSA following the insertion of the implant. While there is no existing report in the literature to explain this, we postulate this to be due to the fixed angle of the DHS and therefore, as the cortical screws are inserted across the plate, the femur gets pulled laterally towards the plate in a lag screw fashion, thus increasing the NSA.

The clinical significance of these changes in NSA were, however, doubtful. Firstly, the extent of change in the NSA was minimal. Although the mean NSA increase of 1.6º was statistically significant in the DHS group, only 3 appeared to have a change in the alignment upon qualitative assessment. Similarly in the PFNA group, upon qualitative assessment, the overall alignment of the fracture was similar between pre- and post- insertion of the PFNA despite a mean NSA decrease of 1.2º. A fracture fixation would be considered good if the NSA was within <10º of varus to <15º of valgus to the contralateral hip *(5)*. In our case, although there was no contralateral hip radiographs for comparison, the majority of our reduction were qualitatively adequate. The small change in the NSA values after the insertion of the implants were still within the normal NSA range for a hip *(24)*.

Secondly, both groups had a similar decline in their functional scores. Although the MBI score in the DHS group was significantly higher than the PFNA group at 1-year post operation, this was due to the higher score in the DHS group at pre-operation. Fitzgerald et al. *(25)* showed that patients with better baseline function, which in our case was indicated by the MBI, were more likely to achieve independent mobility soon after the incident of hip fracture. Similarly, Sylliaas et al. *(26)* showed that patients whom at prefracture required the use of walking aid and had a lower function of instrumental activities of daily living, both of which would negatively affect the MBI, were more likely to become dependent in basic activities of daily living. These would also explain the deterioration of the median MFAC in the PFNA group observed in our study.

We did not observe the need for revision surgery in our study compared to that reported by Lee et al. *(21)*. This may be due to the difference in the length of follow up.

Our study was limited, firstly due to our method for quantifying the wedge effect. O'Malley et al. *(15)* described the "wedge effect" as an increased perpendicular distance from the femoral head centre to the extended lateral femoral cortex and the decreased NSA. In our study, we only used the NSA as it is more reliable, reproducible, and has established significance *(27)*. We compared the post-implant NSA to the pre-implant NSA, instead of the contralateral hip because there may be a variation in left-right NSA that can be present even in normal hips *(28)*. Lastly, we did not replicate O'Malley et al.'s *(15)* measurement of the net lateralisation as that was based on an extended line from the inner lateral cortex which would be variable depending on the thickness of the cortex. As the foot of the patient is secured at a fix point by the traction table, and the groin is abutted by the post on the traction table, a lateral displacement of the femur shaft will invariably change the NSA. Hence we were of the opinion that the change in NSA was a sufficient indicator of the "wedge effect".

There was also no radiographic evaluation at 1 year post-operation to evaluate for further change in the NSA. We did not evaluate them because we felt that the position of the patient's limb will not be as consistent as that taken intraoperatively while the limb was secured on the traction table. Small changes in the attitude of the limb will affect the NSA and may therefore provide readings which were inaccurate for comparison with the immediate post operative images. We also felt that this was not necessary as both groups had final NSA readings which were within the normal range of a hip as discussed above.

Further limitations in our study included its retrospective nature. We were unable to ascertain the exact reason for the choice of implant used. Apart from the surgeon's preference, the frailty of the patient might influence the choice of implant used. As the MBI in the PFNA group was lower, these patients would comparatively be more frail, prompting the surgeons to consider the use of the PFNA in view of shorter operating time and blood loss *(29)*. Furthermore, our sample was small but this was a rare entity of femoral neck fracture with a rate previously reported at 1.8%, which was also reflected in our study population *(2)*.

Notwithstanding the above, there were strengths in our study. We believe we have answered an important clinical question using a well rationalised methodology that employed quantitative and qualitative measurement. Our radiological findings were also correlated with clinical outcomes for the interpretation of its clinical significance. Moving forward, we propose a prospective study utilising the original measuring technique as described by O'Malley et al, *(15)* with longer-term follow up.

Fixation of basicervical femoral fractures with an intramedullary device demonstrated the wedge effect. This was, however, subtle and difficult to identify intraoperatively. Moreover, it was not clinically significant as the short term outcomes were similar to fixation with an extramedullary device.

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