Offset nail fixation for intertrochanteric fractures improves reduction and lag screw position

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Abstract

Background: Surgery for intertrochanteric fractures using intramedullary hip nails (IHNs) is one of the most common surgeries in the orthopedic field. Although IHNs provide a good overall outcome, they sometimes cause complications (e.g. a loss of reduction and cut-out). We compared the usefulness of IHNs with an anterior offset (Best Fit Nail® [BFN]) in maintaining the reduction of fragments and ensuring proper lag screw positioning to that with conventional non-offset nails, using postoperative computed tomography (CT).

Methods: Fifty consecutive patients with intertrochanteric fractures who underwent surgery with BFNs (BFN group) and 50 patients who underwent surgery with conventional non-offset nails (control group) were retrospectively analyzed. Indices evaluated by postoperative CT comprised the displacement distance of proximal fragments relative to distal fragments, reduction status (intramedullary, anatomical, and extramedullary types), screw direction, and the angle between the screw and the femoral neck axis (deviation angle).

Results: The median displacement distance [interquartile range] was significantly smaller in the BFN group (0 [0, 0] mm) and in the control group (4.4 [3.1, 6.3] mm) ($p < 0.0001$). Additionally, the reduction status was significantly better in the BFN group (anatomical type in 40 cases, intramedullary type in 9 cases, and extramedullary type in 1 case) than in the control group (anatomical type in 6 cases, intramedullary type in 40 cases, and extramedullary type in 4 cases) ($p < 0.0001$). Deviation of the lag screw direction was observed in significantly fewer cases in the BFN group (20 cases; 40%) than in the control group (35 cases; 70%). The deviation angle of the lag screw was significantly smaller in the BFN group ($-0.71^\circ \pm 4.0^\circ$) than in the control group ($5.7^\circ \pm 5.3^\circ$). No adverse events related to surgery were observed in either group.

Conclusions: Intertrochanteric fracture surgeries using BFNs exhibited significantly smaller displacement distance, better reduction status, and higher frequency of no deviation, with central lag screw positioning, compared to those using conventional non-offset nails.

Introduction

Surgery for intertrochanteric fracture using intramedullary hip nails (IHNs) is one of the most common surgeries in the orthopedic field [1–3]. Although IHNs provide a good outcome overall, it sometimes causes complications, such as a loss of reduction and cut-out, and is associated with higher reoperation rates than the sliding hip screw [4–6]. To obtain good clinical results, proper reduction of fracture fragments and appropriate positioning of the lag screw are critical. Regarding the reduction, proximal fragments should not be located posterior to distal fragments, which is important for preventing excessive telescoping [7–10]. Regarding the position of lag screws, it is ideal that they are inserted parallel to the femoral neck axis on the lateral radiographic view, and the screw tip should be placed in the central third of the femoral head [11–16]. However, using computed tomography (CT), we previously

demonstrated that it is difficult to achieve both anatomical reduction and proper positioning of lag screws simultaneously in IHN surgeries using conventional nails (non-offset nails) [17]. Only 18.0% of cases showed anatomical reduction, and 12.0% showed proper lag screw positions. It was speculated that poor reduction and inappropriate lag screw positioning frequently observed in IHN surgeries are caused by an anterior offset of the femoral neck relative to the femoral shaft axis [17].

To overcome these limitations, we developed an IHN with an anterior offset (Best Fit Nail® [BFN]). The BFN has a lag screw hole with a selectable anterior offset to the nail axis, rendering it possible to compensate for the deviation between the femoral neck and femoral shaft axes (Fig. 1). The objective of this study was to evaluate the usefulness of BFNs in maintaining the reduction of fragments and ensuring proper lag screw positioning, compared to that with conventional non-offset nails, using postoperative CT.

Patients And Methods

Patients and surgical procedures

This retrospective study was conducted in two hospitals in Japan, with approval of the Ethics Review Board in the University of Tokyo (IRB# 2674). Fifty consecutive patients who underwent surgery for intertrochanteric fracture using BFNs (BFN group) from 2019 to 2021, and 50 patients who underwent surgery using conventional non-offset IHNs (control group) from 2016 to 2021 were included. The types of non-offset IHNs used were determined by the surgeon's preference or the hospital's policy. Patients requiring open reduction were excluded from the study. The AO classification was used to evaluate the fracture types.

Surgeries were performed in the supine position on a traction table, with the aid of an image intensifier system. Closed reduction was performed in a standard manner by traction and adduction of the leg, and the reduction was confirmed by anteroposterior and lateral images [4]. Following the insertion of the femoral nail from the tip of the greater trochanter, a lag screw was introduced. Postoperative CT images were obtained using a Canon Alexion TSX (Canon Medical Systems, Tokyo, Japan), with a slice thickness of 1 mm. Nails with a 4.0-mm anterior offset were used in the BFN group. In the control group, 32 cases were treated with PFNA® (Johnson & Johnson), 3 with INTERTAN® (Smith & Nephew), 10 with Gamma3® (Stryker), and 5 with CM nail® (Zimmer Biomet).

CT evaluations

The femoral neck was divided into three areas according to the CT axial plane (anterior, central, and posterior). The following indices were evaluated (Fig. 2): displacement distance, reduction status, and screw direction. Displacement distance was defined as the distance between proximal fragments relative to distal fragments on CT (Fig. 2A). A positive displacement distance represents posterior displacement of the proximal fragment. The postoperative reduction status was classified according to the classification by Ikuta et al. (Fig. 2B) [7, 8, 10, 18, 19]. The reduction status was classified as “anatomical

type” when there was no displacement of the anterior wall of the fragments, and “intramedullary type” or “extramedullary type” when the anterior wall of the proximal bone was displaced posteriorly or anteriorly relative to the anterior wall of the distal bone, respectively (Fig. 2B). The screw direction was categorized according to the insertion and tip of the lag screw as previously reported [17] (Fig. 2C). When both the insertion and tip of the screw were placed in the same area, the screw direction was considered to have no deviation, and was categorized according to position (anterior, central, or posterior). The screw direction was considered as deviated when the insertion and tip were placed in different areas, and was categorized as AP (from anterior to posterior) or PA (from posterior to anterior) according to its direction (Fig. 2C). The angle between the lag screw and the femoral neck axis (deviation angle) was also measured, with positive values reflecting the anterior direction of the screw.

Statistical analysis

Demographic data were evaluated using the Shapiro-Wilk test, as well as by observing the kurtosis and skewness of the histograms, to determine whether continuous data were normally distributed. The *t*-test was used to compare parameters with normal distribution, and the Wilcoxon's rank-sum test was used to compare parameters without normal distribution between the two groups. For categorical data, the Fisher's exact test was used.

The screw direction was first classified according to the presence or absence of deviation. Patients with deviation were subdivided into two groups: PA deviation and AP deviation. Patients without deviation were subdivided into three groups according to the screw position: anterior, central, and posterior. Therefore, five groups in total were analyzed. Since the values of the cells in the contingency table were expected to be less than 10, the Fisher's exact test was used to compare the deviation distribution between groups, rather than the chi-square test. Reduction status was categorized into three types: anatomical, intramedullary, and extramedullary, and distribution was compared between groups using the Fisher's exact test.

Statistical significance was defined as a two-sided *p*-value <0.05. All statistical analyses were conducted using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA) and JMP Pro 16.0 (SAS Institute Inc., Cary, NC, USA).

Results

Baseline Characteristics

Table 1 provides the demographic profiles of the patients in the BFN and control groups. The BFN group (age: mean±standard deviation, 87.0±8.9 years) included 39 female and 11 male patients, and the control group (age: 87.7±7.9 years) included 34 female and 16 male patients. There were no significant differences in age, sex, body height, body weight, or AO classification between the groups (Table 1). The neck shaft angle of the nails used in the BFN group was 130° in 49 cases and 125° in 1 case. In the

control group, the neck shaft angle was 130° in 16 cases and 125° in 34 cases. The percentage of patients treated with 125° shaft angle nails was higher in the control group than in the BFN group.

Table 1
Demographics of the patients in the BFN and control groups

		BFN group (N=50)	Control group (N=50)	P value
Age		87.0 ± 8.9	87.7 ± 7.9	0.71
Sex	Female:Male	39:11	34:16	0.37
Height		150.7 ± 9.2	151.0 ± 10.4	0.88
Weight		46.7 ± 11.5	47.2 ± 9.0	0.81
AO Classification	31-A1	10	7	0.57
	31-A2	39	40	
	31-A3	1	1	
	31-B2	0	2	
Continuous and categorical data were analyzed by the <i>t</i> -test and Fisher's exact test, respectively				
BFN, Best Fit Nail				

CT evaluation

Histograms were created to visualize the displacement distance distribution in both groups. In the BFN group, the median [interquartile ranges] displacement distance was 0 [0, 0] mm (Fig. 3A), and the reduction status was anatomical type in 40 cases, intramedullary type in 9 cases, and extramedullary type in 1 case (**Table 2**). In the control group, the displacement distance was 4.4 [3.1, 6.3] mm (Fig. 3B), and the reduction status was anatomical type in 6 cases, intramedullary type in 40 cases, and extramedullary type in 4 cases (**Table 2**). In the BFN group, deviation in the lag screw direction was observed in 20 cases (40%): PA in six cases and AP in 14 cases (**Table 2**). In the control group, deviation was observed in 35 cases (70%): PA in 31 cases and AP in 4 cases (**Table 2**). The deviation angle of the lag screw was $-0.71^{\circ} \pm 4.0^{\circ}$ in the BFN group and $5.7^{\circ} \pm 5.3^{\circ}$ in the control group. On statistical analysis, BFN group exhibited significantly less posterior displacement ($p < 0.0001$), better reduction status ($p < 0.0001$), higher frequency of no deviation and with central lag screw positioning ($p < 0.0001$), and smaller deviation angle ($p < 0.0001$) than those in the control group. No adverse events related to surgery were observed in either group.

Discussion

The simultaneous achievement of anatomical reduction and proper positioning of the lag screw is difficult in IHN surgeries using conventional non-offset nails [17]. Only 18.0% of cases achieve

anatomical reduction, and only 12.0% show proper lag screw positioning [17]. This may be due to an anterior offset of the femoral neck relative to the femoral shaft. In fact, Anastopoulos *et al.* [20] reported that the optimum entry point of intramedullary nails was 3.5 ± 1.5 mm behind the femoral neck axis in the sagittal plane, indicating that the femoral neck is located an average of 3.5 mm anterior to the femoral shaft axis, reflecting an anterior offset. Similarly, the anterior offset of the femoral neck relative to the femoral shaft averaged 4.6 mm on CT analysis in our previous study [17].

It has been reported that posterior displacement of the proximal fragment in the lateral radiographic view (intramedullary type) should be avoided in intertrochanteric fracture reduction because it increases the risk of excessive telescoping and cut-out [7, 8, 10, 20]. In conventional non-offset nail fixation, lag screws are frequently inserted from the posterior of the femoral neck axis because of the anterior offset of the femoral neck, and tend to interfere with the posterior wall of the proximal fragments, causing posterior displacement of the fragments (intramedullary type) when screws are inserted parallel to the femoral neck. To avoid interference, lag screws are inserted from posterior to anterior (PA deviation). In fact, PA deviation was observed in 64% of patients treated with conventional non-offset nails (control group, **Table 2**). However, the force applied by weight bearing may cause posterior displacement of proximal fragments, resulting in a loss of reduction.

TABLE 2

Reduction status and screw direction in the BFN and control groups

BFN group

		Screw direction				
		No deviation			Deviation (+)	
		A	C	P	PA deviation	AP deviation
Reduction status	Anatomical type	0	24	1	3	12
	Intramedullary type	0	3	1	3	2
	Extramedullary type	0	1	0	0	0

Control group

		Screw direction				
		No deviation			Deviation (+)	
		A	C	P	PA deviation	AP deviation
Reduction status	Anatomical type	0	0	1	5	0
	Intramedullary type	0	4	10	22	4
	Extramedullary type	0	0	0	4	0

The BFN group had higher frequencies of anatomical type as the reduction status ($p<0.0001$) and no deviation ($p<0.0001$) compared to those in the control group A: anterior position, C: central position, P: posterior position, AP: anterior to posterior, PA: posterior to anterior; BFN, Best Fit Nail

To overcome these difficulties, we developed IHNs with a selective anterior offset (BFNs). The anatomical offset between the femoral neck and femoral shaft axes was inherently determined. As mentioned above, previous studies reported average anterior offsets of the femoral neck of 3.5 mm and 4.6 mm [17, 20]. Based on these results, we adopted nails with a 4-mm anterior offset in all cases in the present study. We found that the BFN group exhibited significantly better reduction status, with a higher anatomical reduction rate (80%), than that in the control group (12%) (**Table 2**). PA deviation was observed in only 12% of the cases in the BFN group. Since BFN lag screws are inserted close to and parallel to the femoral neck axis on the lateral view, interference between the lag screw and posterior wall of the femoral neck is rare, resulting in a lower frequency of posterior displacement of the proximal fragments. The median displacement distance in the BFN group was 0 mm, which was significantly better than that in the control group (4.4 mm). The few outliers observed in the present study may be due to the fact that when the displacement of the fragments is large, it is difficult to reduce them with an intramedullary nail alone, and open reduction should have been considered in such cases.

The present study has some limitations. First, the sample size was small. Further studies with a larger number of patients should be performed to establish the advantages of BFNs over conventional nails. Second, the size of the anterior offset of the BFNs was fixed at 4 mm. It would be better if a patient-specific offset size could be selected. Third, we did not analyze the postoperative functional results. Although it has been reported that minimal posterior displacement and straight insertion of lag screws

are important, future studies should investigate whether the small posterior displacement and proper positioning of lag screws achieved by BFNs can reduce excessive telescoping and cut-off, resulting in better clinical outcomes. Furthermore, long-term follow-up of a larger number of patients is necessary. Finally, this was a retrospective observational study conducted in two hospitals, and prospective randomized studies should be performed to demonstrate the superiority of BFN over non-offset nails in a more precise manner.

In summary, IHN surgery for intertrochanteric fracture with anterior-offset nails (BFNs) exhibited significantly smaller displacement distance, better reduction status, and higher frequency of no deviation, with central lag screws positioning, compared to those with conventional non-offset nails. Future prospective studies are required to determine whether surgery using BFNs results in better clinical outcomes than those using non-offset nails.

Declarations

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Conception and design: TM, IY, ST; Analysis and interpretation of the data: TM, IY, HO, ST; Drafting of the article: IY, ST; Final approval of the article: All authors; Provision of study materials or patients: KS, IY, HF, JY; Statistical expertise: HO; Obtaining of funding: ST. The authors read and approved the final manuscript.

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Ethics declarations

The study was conducted in accordance with the Declaration of Helsinki and with the approval by the ethics committee of the University of Tokyo (IRB# 2674). Written informed consent was obtained from all the participants.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analysed during the current study are available in a supplementary file (Matsubara et al., raw data).

Competing interests

All authors declare no conflict of interests and disclose no financial or personal relationships with other people or organizations that could have an inappropriate effect on this work.

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Figures

Figure 1

Appearance of the Best Fit Nail

The best fit nail (BFN) has a lag screw hole with a selectable anterior offset to the nail axis. There is a 4-mm anterior offset; A: nail central axis, B: lag screw hole central axis.

Figure 2

Computed tomography indices

A) Displacement distance: The displacement distance of the proximal fragment with respect to the distal fragment was measured at the anterior wall of the fracture site.

B) Classification of reduction status: The reduction status was classified as “anatomical type” when there was no displacement of the anterior wall of the fracture site, and “intramedullary type” or “extramedullary type” when the anterior wall of proximal bone was displaced posteriorly or anteriorly relative to the anterior wall of distal bone, respectively.

C) Screw direction: The screw direction was categorized according to the insertion and tip of the lag screw as previously reported [17]. When both insertion and tip of a screw were placed in the same area, the screw direction was considered have no deviation, and was categorized according to its position (A: anterior, C: central, P: posterior). The screw was considered deviated when the insertion and tip placed in different areas, and was categorized into AP (from anterior to posterior direction) or PA (from posterior to anterior direction) according to its direction.

Figure 3

Distribution of the displacement distance

Distribution of the displacement distance in the BFN group (**A**) and control group (**B**) is shown in histograms. Histograms are used in descriptive epidemiological studies. There was a significant difference in displacement distance between the groups ($p < 0.0001$).

Supplementary Files

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