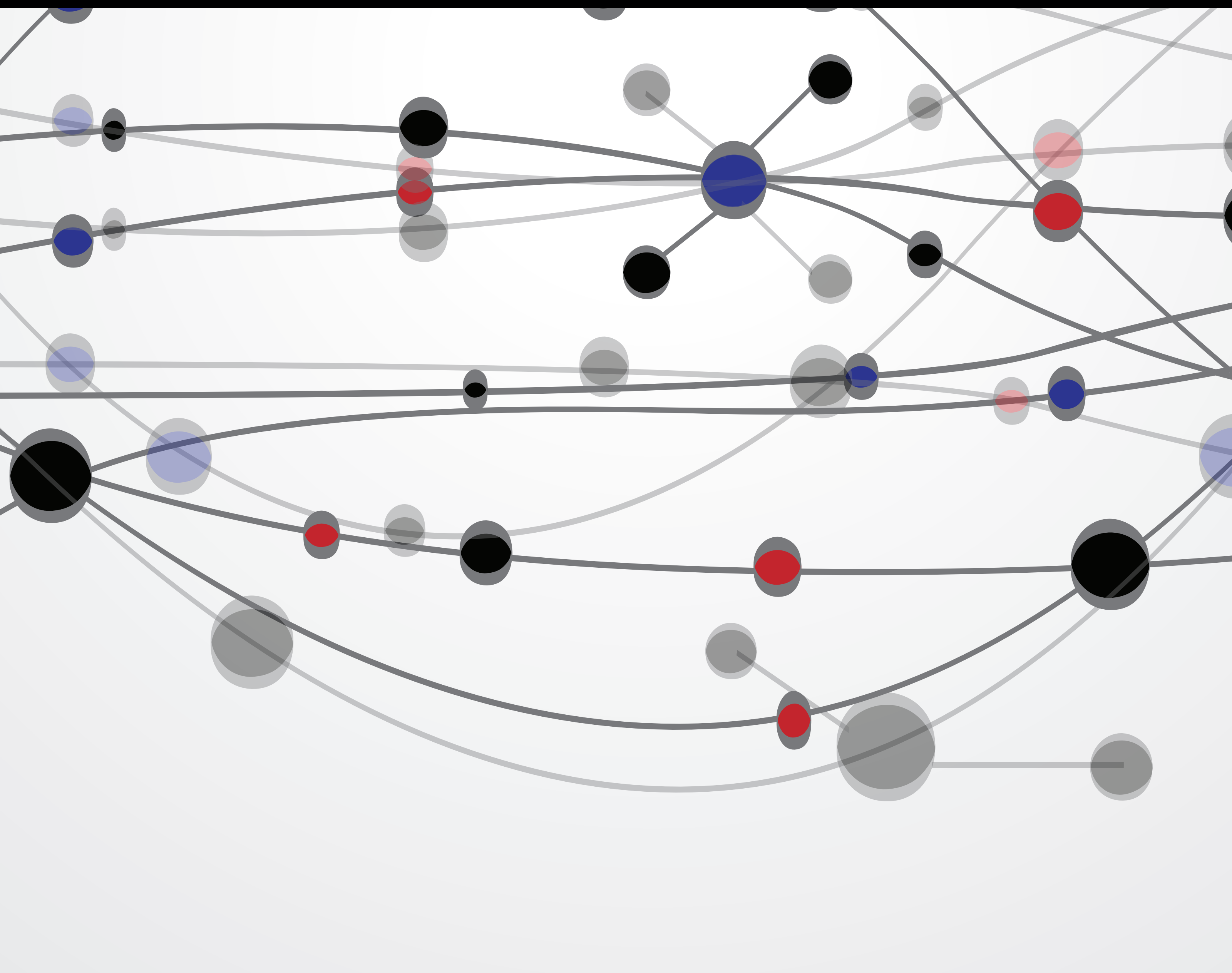
The Scientific World Journal

Osteoporotic Hip Fractures: Current Issues and Evolving Concepts of Surgical Management

Guest Editors: Frankie Leung, Fan Liu, Chris Morrey, and Chang-Wug Oh



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Editorial

Osteoporotic Hip Fractures: Current Issues and Evolving Concepts of Surgical Management

Frankie Leung,[1] Fan Liu,[2] Chris Morrey,[3] and Chang-Wug Oh[4]

[1] *Department of Orthopaedics & Traumatology, The University of Hong Kong, Hong Kong*
[2] *Department of Orthopaedics, Affiliated Hospital of NanTong University, NanTong, Jiangsu 226001, China*
[3] *Department of Orthopaedic, Cairns Orthopaedic Clinic, Cairns Base Hospital, Cairns, QLD 4870, Australia*
[4] *Department of Orthopedic Surgery, Kyungpook National University Hospital, Daegu 700-721, Republic of Korea*

Correspondence should be addressed to Frankie Leung; klleunga@hku.hk

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Osteoporotic hip fractures are the most severe kind of fragility fracture, with high risks of increased disability and mortality. Recent advances on surgical treatment have shed new light in the management of these fractures. Nevertheless, the poor bone quality sometimes renders the treatment unsuccessful and there remains a definite complication rate in its treatment. Up till now, there has been a continuous effort in improving the currently used implants and surgical techniques, ranging from joint replacements to various forms of internal fixation. In order to provide better care for these patients, there is an increasing need for better understanding of the factors responsible for determining a successful surgical outcome.

This special issue covers the important topic of osteoporotic hip fractures. Failure of management may be caused by a delay in diagnosis leading to delayed treatment, as highlighted by the two articles by S. Gill et al. and J. Harding et al. Since the fracture may occur with relatively small energy of trauma, a certain percentage of these injuries may not be clearly visible on radiographs and special imaging is required to make an early diagnosis. In this issue, J. Harding et al. reported on the use of Bristol hip view radiographs while S. Gill et al. suggested the use of multislice CT which had the same effectiveness as MRI.

Failure of management may also mean a poor choice of surgical fixation device. This is particularly common when surgeons need to find the best device for intertrochanteric fractures. Various methods have been used to investigate the effectiveness of different devices. S. Zhang et al. used three-dimensional computational modeling to check the geometrical fit of these implants in femur. R. Tao et al. compared the clinical outcomes of two fixation devices and X. Huang et al. reported on the meta-analysis of randomized comparative trials that used the two most commonly used devices.

To complicate the issue even more, it was found recently that some fractures are related to the bisphosphonates that the patients take as prophylaxis to osteoporotic fractures. Some of these atypical fractures are incomplete and C. W. Oh et al. reported the effectiveness of intramedullary nailing in the treatment of these fractures.

In summary, osteoporotic hip fractures are a big burden to modern health care system. Further efforts should be dedicated to seek the best treatment options to become available for these patients.

Frankie Leung
Fan Liu
Chris Morrey
Chang-Wug Oh

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Research Article

A Biomechanical Study Comparing Helical Blade with Screw Design for Sliding Hip Fixations of Unstable Intertrochanteric Fractures

Qiang Luo, Grace Yuen, Tak-Wing Lau, Kelvin Yeung, and Frankie Leung

Department of Orthopaedics and Traumatology, Queen Mary Hospital and The University of Hong Kong, Hong Kong

Correspondence should be addressed to Frankie Leung; klleunga@hku.hk

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Dynamic hip screw (DHS) is a well-established conventional implant for treating intertrochanteric fracture. However, revision surgery sometimes still occurs due to the cutting out of implants. A helical blade instead of threaded screw (DHS blade) was designed to improve the fixation power of the osteoporotic intertrochanteric fracture. In this study, the biomechanical properties of DHS blade compared to the conventional DHS were evaluated using an unstable AO/OTA 31-A2 intertrochanteric fracture model. Fifty synthetic proximal femoral bone models with such configuration were fixed with DHS and DHS blade in five different positions: centre-centre (CC), superior-centre (SC), inferior-center (IC), centre-anterior (CA), and centre-posterior (CP). All models had undergone mechanical compression test, and the vertical and rotational displacements were recorded. The results showed that DHS blade had less vertical or rotational displacement than the conventional DHS in CC, CA, and IC positions. The greatest vertical and rotational displacements were found at CP position in both groups. Overall speaking, DHS blade was superior in resisting vertical or rotational displacement in comparison to conventional DHS, and the centre-posterior position had the poorest performance in both groups.

1. Introduction

Sliding hip screw has been a well-established treatment for intertrochanteric fracture [1–3]. However, the revision rate of dynamic hip screw (DHS) was reported to be in the range of 4%–12% [4–6], and the complications of failed fixation led to the femoral head cutting out rates of 1.7% to 6.8% [7–9], especially in osteoporotic fractures.

In order to improve the fixation of unstable intertrochanteric fracture, a helical-shaped blade in dynamic hip fixation (DHS blade) with larger transverse area to resist cutting out was introduced in recent years. By inserting the blade into the femoral head, the surrounding trabecular structure would undergo a volumetric compaction. It offers the potential of resisting rotation and a better holding power in osteoporotic femoral head with more cancellous bones compaction and theoretically can decrease the rate of cutting out.

Besides the implant design, the position of the implant in the femoral head can also significantly influence the outcome of the fixation. Generally, one can describe the implant position in the femoral head as superior, central, and inferior in the anterior-posterior (AP) view, as well as anterior, central, and posterior in the lateral view. For screw placement, Parker found that cutting out occurred more frequently when screws were placed superiorly or posteriorly [10]. Davis et al. preferred the central position in both AP and lateral view [11], while Mainds and Newman and Thomas considered that central or inferior position in AP view was better in term of cutting out resistance [12, 13]. In addition, in order to improve clinical outcome of intertrochanteric fractures, tip apex distance (TAD) regarding adequate reduction was introduced by Baumgaertner in 1995 [14]. It is believed that less than 20–25 mm of TAD is acceptable for conventional DHS technique [15–17]. No such guidelines had been described for the blade design, and there is only little information in the literature about the performance of DHS blade.

There is a need to compare the fixation of DHS blade and DHS with different implant positions. Therefore, the aim of this study was to analyze the biomechanical properties of fixing femoral head with DHS blade in comparison to the

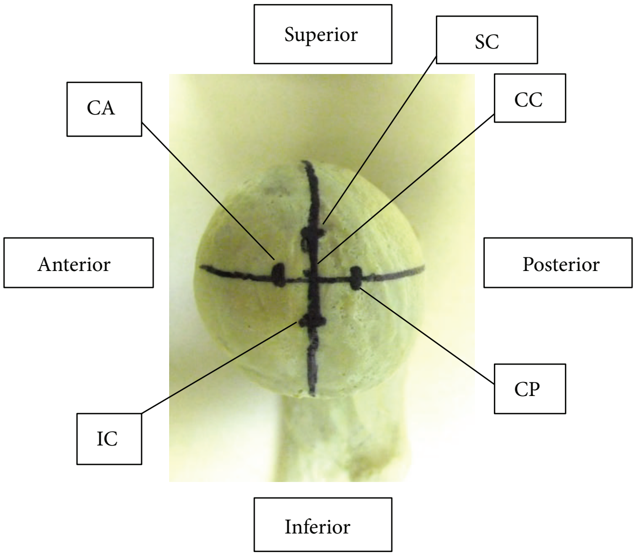


Figure 1: Different implants positions. 4 exit points were 8 mm away from the head center. (CC) AP view-center, lateral view-center, (SC) AP view-superior, lateral view-center, (CP) AP view-center, lateral view-posterior, (CA) AP view-center, lateral view-anterior, (IC) AP view-inferior, and lateral view-center.

conventional DHS in five different implants positions using an unstable intertrochanteric fracture model. The stability was analyzed by assessing vertical displacements and angles of rotation in anterior-posterior direction of the femoral head under vertical cycling loading.

2. Materials and Methods

2.1. Specimens. Fifty right synthetic proximal femoral bone models were used (Synbone model 2425, Synbone AG, Neugutstrasse 4, CH-7208 Malans, Switzerland). They had a length of 337 mm, neck shaft angle of 135°, anteversion of 15°, and a head diameter of 48 mm. All synthetic bones were coated with a synthetic cortical layer, and filled with dense inner foam, which were designed to simulate cancellous bone.

All sample models were divided into two groups and fixed by one of the two implant systems: dynamic hip screw blade system (DHS blade) (by Synthes, Inc., Oberdorf, Switzerland) or conventional dynamic hip screw (DHS). The lag screw or blade with a length of 100 mm, a long barrel 135° side plate, and four conventional bicortical screws were inserted as a complete set of fixation.

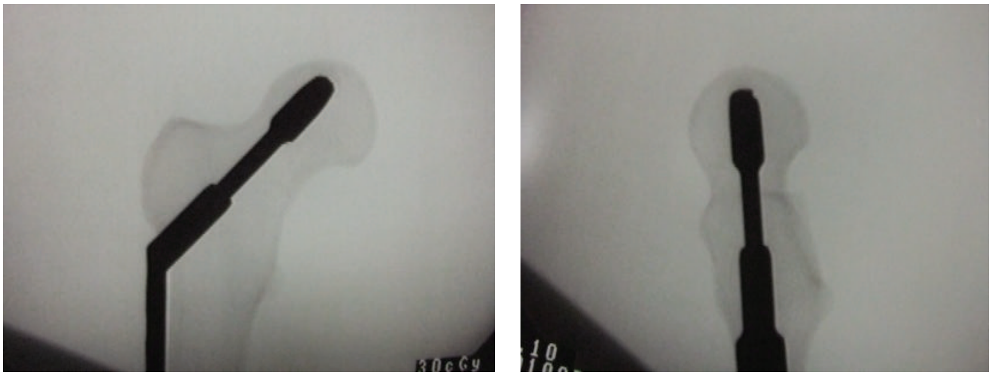
2.2. Model Establishment. The screws or blades were implanted in five different positions in femoral heads as shown in Figure 1: centre-centre (CC), superior-centre (SC), inferior-center (IC), centre-anterior (CA), and centre-posterior (CP). Five specimens were included in each of the five positions.

An AO/OTA A31-A2.2 unstable intertrochanteric fracture was created in every specimen, and only 2 cm of cortical support was left anteriorly. In order to implant screw lateral anteriorly or posteriorly in CA and CP models, the entry point was designed to be 4 mm anterior or posterior to the lateral raphe of femoral shaft [18], while the exit point of the guide pin for SC, IC, CA, and CP positions was at a point 8 mm away from the head center (Figure 1). All procedures were done according to the standard technical manual and under fluoroscopic guidance (Figure 2). Tip apex distance (TAD) was controlled to be within 10 to 20 mm, meaning a satisfactory implant position.

All samples were shortened 8 cm distally in order to decrease the elasticity of the synthetic bone with 6 cm distal end embedded into a cylindrical tray with Huntsman glue mixture (Araldite AW2104 + Hardener HW2934, USA). The fixation was allowed to polymerize for 24 hours at room temperature. The femoral shaft was physiologically tilted at 25° to the vertical.

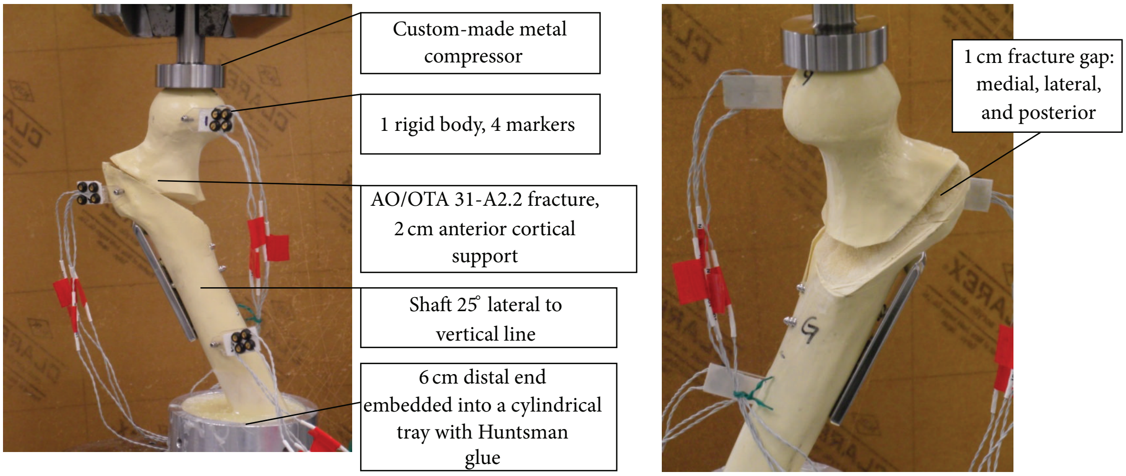
2.3. MTS Setup and Biomechanical Testing. The construct was placed in a servohydraulic grip of the mechanical testing machine (MTS 858 Mini Bionix, Minneapolis, USA) under a stainless steel-custom made spherical pressing shell. Then femoral shaft was oriented to make sure it was 25° to vertical line. Three rigid bodies were created each with 4 infrared ray receiving markers which were fixed to the tip of femoral head, greater trochanter and shaft (Figure 3) to capture 3-dimension linear and 3-dimension rotational motions up to 1/1000 mm precisely of each rigid bodies. The motion was captured at 100 frames per second throughout the test by the optical motion tracking system (NDI Optotrak Certus, Canada). Three pilot tests had been performed to determine the optimal testing time and vertical cyclic loading force to be applied on the synthetic bone models. 500 N and 900 N cyclic forces had been applied. For 500 N cyclic force, some critical anatomical sites had very limited displacement which would make the calculation difficult. Alternatively, for 900 N cyclic force, some shafts broke, or maximum displacement was reached in less than half cycles at some sites. Hence, 650 N was chosen as the peak load, and each specimen was tested with 500 vertical compression cycles at 1 Hz. Each cycle started at the peak load, and followed by minimal 65 N valley load prior to 90 seconds vertical loading to obtain equilibrium of the repair construct. The 3-dimension displacements of each rigid body were recorded throughout the test, and X-rays of the repair construct were taken before and after the test to confirm the displacements between the implant and femoral head.

2.4. Statistical Analysis. Repeated Mann-Whitney U test was employed to compare the stability, which included both the vertical and rotational displacements of two different implants in same position. In blade DHS group, ANOVA and Mann-Whitney U test were used to further confirm the stability of various implant positions. A P value of <0.05 was considered to be statistically significant for all analyses. All statistical calculations were performed by SPSS version 15 software (SPSS Inc., USA).



(a) (b)

Figure 2: Implant at SC position under fluoroscopic guidance instrumentation.



(a) (b)

Figure 3: (a) Unstable fracture AO/OTA 31-A2.2 with 2 cm anterior cortical support on MTS machine, 25° lateral to vertical, with 3 rigid bodies for motion tracking. (b) In posterior view, all fractures are with 1 cm gap over medial, lateral, and posterior.

3. Results

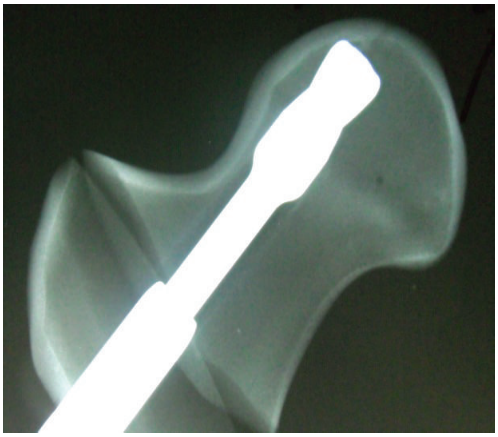
The mean and standard deviations of vertical and rotational displacements were shown in Table 1. The greatest vertical and rotational displacement was found at CP position in both groups. The vertical or rotational displacements in CP position were 2.39 and 2.19 times higher than that of CC position in DHS group and 12.17 times and 7.28 times higher in DHS blade group, respectively. With repeated ANOVA post hoc assessment within each group, CP position showed the lowest antirotation and antidisplacement ability in both groups (DHS: displacement $P = 0.00 \sim 0.01$; rotation $P = 0.009 \sim 0.023$; DHS blade: displacement and rotation $P < 0.001$). After mechanical compression tests, X-ray showed that DHS blade reached the top without cutting out, and no further displacement or rotation at SC position. While DHS screw at SC position touched the cortex with migration tract shadow inside femoral head (Figure 4).

Afterwards, the comparison between DHS and DHS blade in different implant positions was performed. As shown in Figure 5, CC and CA had lower vertical displacement ($P < 0.05$), IC showed lower rotation degree in DHS blade group than that of DHS group ($P < 0.05$). Overall speaking, the DHS blade group had a better performance in resisting rotational and translational displacement than DHS group.

Next, the biomechanical properties of five implant positions within DHS blade group were analyzed to determine the most stable implant position. Figure 5 showed that IC position had lower rotational and vertical displacements than other positions in both groups. When comparing the usually recommended CC position with IC position, the results showed no significant difference ($P < 0.754$) in antivertical displacement ability, but the antirotation property of IC position was greater than that of CC position ($P = 0.016$).

4. Discussion

Previous studies concluded that the choices of implants and their positions are the two important factors influencing



(a)

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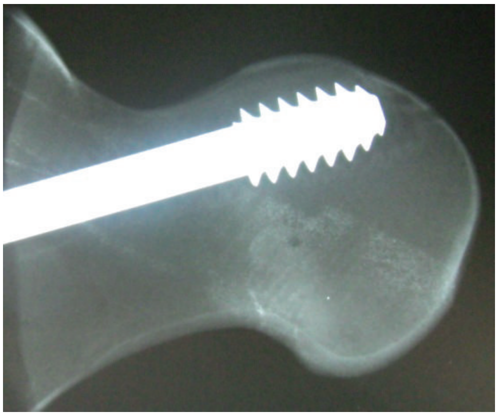

(c)

(d)

Figure 4: X-ray after compression testing at SC position in DHS blade and DHS group. In (a) and (b), blade DHS screw reached the top without cutting out. There was no further displacement or rotation. In (c) and (d), conventional DHS screw touched the cortex with migration tract shadow inside femoral head.

Table 1: The displacement and rotation degree among five positions both in DHS and DHS blade groups.

Positions	Displacement (mm)		Rotation degree (°)	
	DHS blade	DHS	DHS blade	DHS
CC	1.372 ± 1.0127	5.214 ± 3.0652	2.046 ± 0.99736	3.344 ± 1.1574
SC	4.198 ± 0.57334	4.65 ± 1.89662	1.676 ± 0.37334	1.45 ± 0.56285
CA	3.272 ± 1.18805	5.55 ± 1.53189	2.102 ± 0.35039	3.268 ± 3.37059
IC	1.246 ± 0.71339	2.3 ± 2.08868	0.37 ± 0.37895	2.554 ± 3.26475
CP	16.696 ± 4.15407	12.484 ± 4.24389	14.99 ± 4.74078	7.338 ± 3.21825

the outcome of the fixation of unstable intertrochanteric fractures [14, 19, 20]. Placement of lag screw at centre-centre or inferior-centre position is well accepted for conventional DHS techniques [18, 21].

There were some recent studies on the effectiveness of DHS blade. Windolf et al. had experimentally proved that DHS blade significantly enhanced cutting out resistance [22, 23]. O'Neil et al. found that DHS blade has greater rotational stability than DHS [24]. Leung et al. had also proven the effectiveness of DHS blade in a case series with 1% failure rate [25]. In this study, we found that DHS blade had better antidisplacement ability at CA and CC position and better antirotational ability at IC position than conventional DHS. There was no cutting out or crack observed at the anterior cortex of all samples during mechanical testing. This study showed that all screws were adjacent, approaching, or even contact with the head inner cortex in posttesting X-ray (Figure 5). A cut-out phenomenon similar to clinical setting could not be accurately reproduced in the synthetic bone model.

Besides, studies have shown that cuttingout occurred more frequent when the implants were placed superiorly or posteriorly, while the central or inferior position was the best [10, 11]. Parker observed that posterior to anterior obliquity

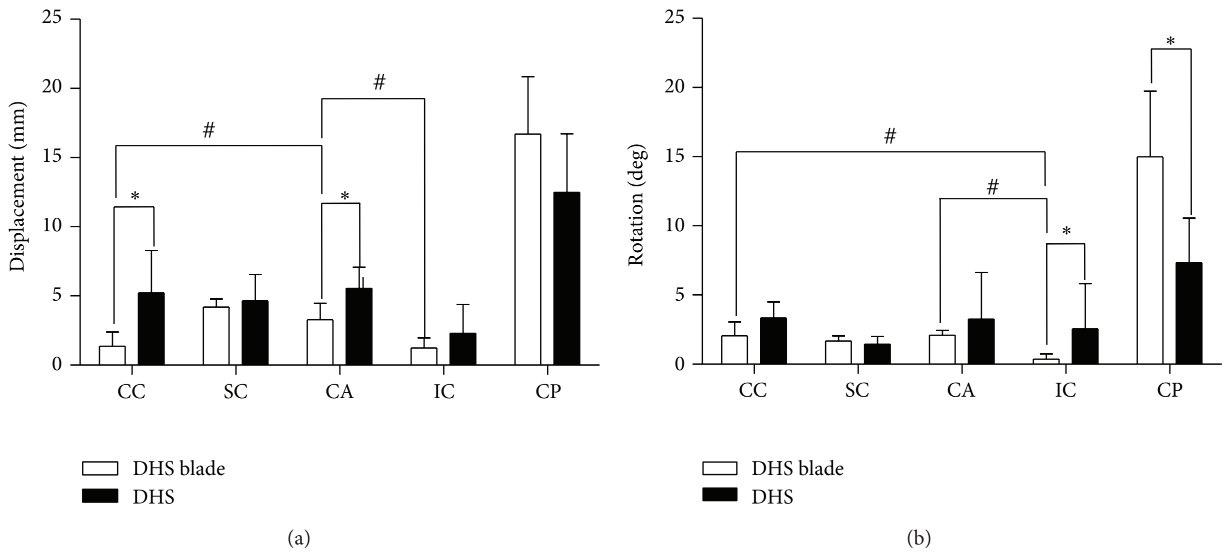

Figure 5: Results of comparing DHS blade (group 1) and conventional DHS (group 2) of five implant positions by Mann-Whitney U test with statistic significant $^{*}P < 0.05$ and results in comparing vertical displacement and rotation in 3 different implant positions in DHS blade group by Mann-Whitney U test with statistical significant $^{\#}P < 0.05$.

(equivalent to the CA position in this study) had a better rotational resistance than anterior to posterior obliquity (equivalent to the CP position in this current study) [10], which is consistent with the findings of our study.

When the positions of the implant in DHS blade group were studied, we found that the rotational displacement IC experienced was less than CC and CA, while vertical displacement was less than CA. These results were consistent with previous studies. Mainds and Newman as well as Thomas considered that central or inferior position in AP view was best in terms of cutting out rate [12, 13]. Their recommendation was consistent with our finding that the CC and IC position had greater stability than other positions in DHS blade group.

The material of the samples chosen was a synthetic bone substitute and made of rigid polyurethane foam with predetermined mechanical properties. Although it could not replicate the biomechanical properties of human bone, it provided consistent material properties similar to human cancellous bone [24]. In addition, using specimens of the same size was of great importance when determining the location of the implants. Hence, cadaveric bone could not serve this purpose. Furthermore, since all models had the same structure, and all fracture patterns were identical with minimal anterior cortical support, the vertical and angular femoral head displacements after the same cyclic loading and force were able to represent the migrations of implants at different positions of femoral head.

Although this experiment could not represent the true vital fracture fixation properties, it effectively provided information for comparing the relative stabilities at five different positions of two different implants.

In summary, this study demonstrated that DHS blade was superior in resisting vertical and rotational displacement as compared to conventional DHS in a synthetic bone model. It remains to be proven in clinical settings, and there is a need for further trials comparing the performance of these two devices in treating patients with intertrochanteric fractures.

Acknowledgment

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Research Article

Proximal Femoral Nail versus Dynamic Hip Screw Fixation for Trochanteric Fractures: A Meta-Analysis of Randomized Controlled Trials

Xiao Huang,[1] Frankie Leung,[2] Zhou Xiang,[1] Pei-Yong Tan,[1] Jing Yang,[1] Dai-Qing Wei,[1] and Xi Yu[1]

[1] *Department of Orthopaedics, West China Hospital, Sichuan University, No. 37 Guoxue Xiang, Chengdu, Sichuan 610041, China*
[2] *Department of Orthopaedics and Traumatology, Queen Mary Hospital, The University of Hong Kong, Hong Kong*

Correspondence should be addressed to Zhou Xiang; xiangzhou15@hotmail.com

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Background. The purpose of this meta-analysis was to find out whether the proximal femoral nail was better than the dynamic hip screw in the treatment of trochanteric fractures with respect to operation time, blood transfusion, hospital stay, wound complications, number of reoperation, and mortality rate. *Methods*. All randomized controlled trials comparing proximal femoral nail and dynamic hip screw in the treatment of trochanteric fractures were included. Articles and conference data were extracted by two authors independently. Data was analyzed using RevMan 5.1 version. Eight trials involving 1348 fractures were retrieved. *Results*. Compared with DHS fixation, PFN fixation had similar operation time (95% CI: −15.28–2.40, $P = 0.15$). Blood loss and transfusion during perioperative time were also comparable between the two fixations (95% CI: −301.39–28.11, $P = 0.10$; 95% CI: −356.02–107.20, $P = 0.29$, resp.). Outcomes of hospital stay (95% CI: −0.62–1.01, $P = 0.64$), wound complication (95% CI: 0.66–1.67, $P = 0.82$), mortality (95% CI: 0.83–1.30, $P = 0.72$), and reoperation (95% CI: 0.61–1.54, $P = 0.90$) were all similar between the two groups. *Conclusion*. PFN fixation shows the same effectiveness as DHS fixation in the parameters measured.

1. Introduction

The incidence of the hip fracture has been rising with an aging population in many parts of the world, and the number of hip fractures is expected to reach 512,000 in the year 2040 [1].

Hip fractures include mainly trochanteric and femoral neck fractures, and the former was reported with a mortality rate ranging from 15% to 30% in America [2]. Surgical treatment with stable fixation allows early mobilization and reduces complications. There are two main types of fixations for trochanteric fractures, which are plate fixation and intramedullary implants [3, 4]. Dynamic hip screw (DHS) or sliding hip screw (SHS) has been the standard implant in treating trochanteric fractures [5–10]. However, when compared with the intramedullary implants, it has a biomechanical disadvantage because of a wider distance between the weight bearing axis and the implants [11]. The proximal femoral nail (PFN) introduced by the AO/ASIF group in 1998 has become prevalent in treating trochanteric fractures in recent years [12–15]. Although there were several reports showing benefits of proximal femoral nail [16–18], it was still associated with technical failures [19, 20]. The cost of PFN is also much more than DHS.

Therefore, we conducted a meta-analysis to investigate whether there is a significant difference between PFN and DHS fixation in treating trochanteric fractures. The hypothesis is that PFN fixation is not more effective than DHS fixation in terms of decreasing operation time and blood transfusion, as well as reducing hospital stay, wound complication, reoperation, and mortality.

2. Methods

2.1. Search Strategies. The database for search included the Cochrane library, OVID, MEDLINE, EMBASE, and CNKI (China National Knowledge Infrastructure) from January

1998 to October 2012. Single or combinations of terms were searched as follows: dynamic hip screw, DHS, dynamic compression hip screw, sliding hip screw, SHS, proximal femoral nail, and PFN.

2.2. Inclusion and Exclusion Criteria. Only prospective, randomized controlled trials (RCTs) and quasi-randomized controlled trials which compared the PFN fixation with the DHS fixation were selected. These studies enrolled patients with hip fractures classified as pertrochanteric or intertrochanteric without subtrochanteric extension by AO/OTA classification [21, 22]. Patients with pathological fractures, fractures associated with polytrauma, or patients with previous ipsilateral hip or femur surgeries were excluded.

Targon PFN fixation was also included [25, 28], which offered a biaxial fixation of the proximal fragment [29], and was inserted in a similar method into the intramedullary cavity [10]. It was considered as a type of PFN implant.

If there were duplicates or multiple publications from the same study, which had overlap in original information, the most complete results should be chosen. If studies included had insufficient information, the authors were contacted for original data.

2.3. Data Extraction and Quality Assessment. Data were extracted by two experienced researchers independently. Different opinions were resolved by discussion. The assessment method which the Cochrane Handbook provided was used to assess the randomization, allocation concealment (according to whether allocation concealment was adequate, unclear, inadequate, or not used as a criterion to assess validity), blinding, and follow-up coverage of the studies included [30]. The three levels were assessed as follows: level A, all the criteria were adequate, which had a low risk of bias; level B, one or more of the criteria were not described, which had a moderate risk of bias; level C, one or more of the criteria were incorrect, inadequate, or not used, which had a high risk of bias.

2.4. Data Analysis. The weighted mean difference was calculated for continuous outcomes, and the relative risks (RRs) were calculated for dichotomous outcomes, with both adopted a 95% confidence interval (CI). The heterogeneity among studies was assessed using I-square (I^2) test, Chi-square (χ^2) test, and Tau-square (τ^2) test. When there was no statistical heterogeneity (as judged by χ^2 test $P \geq 0.1$ or $I^2 <$ 50%), a fixed effect model was adopted; otherwise, a random effect model was chosen. All analyses were performed by using the software Review Manager 5.1 [31]. A P value of less than 0.05 was considered statistically significant.

3. Results

A total of 489 potentially relevant articles were retrieved: 25 from Cochrane library, 60 from MEDLINE, 114 from OVID, 137 from EMBASE, and 153 from CNKI. After excluding nonrandomized control trials and studies not comparing the proper implants and/or reporting inadequate data, eight randomized or quasi-randomized controlled trials were included (Figure 1). There were a total of 1348 patients who were predominantly elderly with trochanteric fractures. Five trials targeted Caucasian patients, and the other three targeted Asian ones. There were 675 patients treated by PFN and 673 by DHS. The baseline characterizations like age and gender were comparable in two groups (Table 1). Most studies evaluated operation time, blood loss, blood transfusion, wound complication, mortality, and reoperation. The quality of six studies included was level B for the allocation concealment, or the blinding was unclear according to the evaluation criteria mentioned above. The other two studies, one was level A which met all the criteria and another was level C because patients' medical record numbers, were used for allocation, and the allocation concealment was inadequate (Table 2).

3.1. Operation Time. All eight studies provided data of operation time, but the data of five studies were eligible in the form of mean and standard deviation (SD). There were 1100 fractures included, 547 patients with the PFN fixation and 553 with the DHS fixation (Table 3). The heterogeneity test indicated a statistical evidence of heterogeneity ($\chi^2 = 50.13$, $P < 0.00001$, $I^2 = 92\%$). We pooled data by a random effect model which indicated that there was no statistical difference in operation time between the two groups. (mean difference: −6.44, 95% CI: −15.28–2.40, $P = 0.15$) (Figure 2).

3.2. Blood Loss and Transfusion. There were two articles involving 172 fractures which provided data of blood loss (Table 3). The heterogeneity test indicated there was a statistical heterogeneity ($\chi^2 = 3.76$, $P = 0.05$, $I^2 = 73\%$), and the outcome shows no significant difference of blood loss with PFN than with DHS (Mean Difference: −136.64, 95% CI: −301.39–28.11, $P = 0.10$) (Figure 3). There were four articles included with 978 fractures providing data for blood transfusion. No significant difference in the amount of blood transfusion between the PFN group and the DHS group was found (Mean Difference: −124.41, 95% CI: −356.02–107.20, $P = 0.29$) (Figure 4).

3.3. Hospital Stay. Five studies included data of hospital stay. There were a total of 608 patients, with 301 patients in the PFN group and 307 in the DHS group (Table 4). The heterogeneity test indicated no statistical heterogeneity ($\chi^2 = 3.96$, $P = 0.41$, $I^2 = 0\%$). Data pooled by a fixed effects model indicated that there was no statistical difference in hospital stay between the PFN group and DHS group (Mean Difference: 0.20, 95% CI: −0.62–1.01, $P = 0.64$) (Figure 5).

3.4. Wound Complication. Wound complications including wound infection, drainage, delayed healing, and hematoma were documented in seven studies while one showed no wound complication (Table 4). No statistical heterogeneity was presented by heterogeneity test ($\chi^2 = 3.54$, $P = 0.62$, $I^2 = 0\%$). Data pooled by a fixed effect model showed no statistical

Table 1: Characteristics of the included studies.

Studies	Ages (years)		Men (%)	Setting	Follow-up (months)	Fracture type (OTA, 31-)	Year
	PFN	DHS					
Saudan et al. [23]	83 ± 9.7	83.7 ± 10.1	22.3	Switzerland	12	A1, A2	2002
Pan et al. [24]	70 ± 6.8	69 ± 7.1	75	China	16 (12–28)	A1, A2, A3	2004
Pajarinen et al. [18]	80.9 ± 9.1	80.3 ± 10.8	25	Finland	4	A(1.1-1.2, 2.1-2.2, others)	2005
Giraud et al. [25]	81 ± 12.8	82 ± 9.8	23	France	3	A1, A2, A3	2005
Papasimos et al. [26]	79.4	81.4	38.8	Greece	12	A2, A3	2005
Liu et al. [27]	76 ± 4.3	78 ± 4.5	29.1	China	9	A1, A2	2009
Huang et al. [17]	75 ± 5	77 ± 5	26	China	9	A1, A2	2010
Parker et al. [28]	81.4 (27–104)	82.4 (26–104)	20.2	UK	12	A1, A2, A3, B2.1	2012

PFN: proximal femoral nail; DHS: dynamic hip screw; OTA: Orthopaedic Trauma Association.

Table 2: Methodological quality of included studies.

Studies	No. of fractures		Randomization	Allocation concealment	Blinding	Loss to follow-up	Level
	PFN	DHS					
Saudan et al. [23]	100	106	Adequate	Not described	Not described	Yes	B
Pan et al. [24]	30	34	Inadequate	Inadequate	Adequate	Yes	C
Pajarinen et al. [18]	54	54	Adequate	Adequate	Not described	Yes	B
Giraud et al. [25]	34	26	Adequate	Not described	Not described	Yes	B
Papasimos et al. [26]	40	40	Not described	Not described	Not described	Yes	B
Liu et al. [27]	69	65	Not described	Not described	Not described	Yes	B
Huang et al. [17]	48	48	Adequate	Adequate	Not described	Yes	B
Parker et al. [28]	300	300	Adequate	Adequate	Adequate	Yes	A

Loss to follow-up: reported patients loss to follow-up.

Table 3: Intraoperative outcomes of the two groups.

Studies	Operation time (min)		Blood loss (mL)		Blood transfusion (mL)[a]	
	PFN	DHS	PFN	DHS	PFN	DHS
Saudan et al. [23]	64 ± 33	65 ± 26	NA	NA	584 ± 720	692 ± 704
Pan et al. [24]	59.16 ± 16.92	87.35 ± 21.29	273.33 ± 120.8	480.88 ± 177.90	466.6 ± 137.19	833 ± 300
Pajarinen et al. [18]	55 (35–200)	45 (20–105)	320 ± 310	357 ± 495	1040 ± 960	1040 ± 800
Giraud et al. [25]	35	42	410	325	NA	NA
Papasimos et al. [26]	71.2 (60–240)	59.2 (40–100)	265	282.4	NA	NA
Liu et al. [27]	46.5 ± 20.5	53.4 ± 8.3	136	152	NA	NA
Huang et al. [17]	50.5 ± 20.2	52.4 ± 18.3	202.5	225	200	200
Parker et al. [28]	49 ± 12.7	46 ± 12.3	NA	NA	140 ± 220	128 ± 190

[a] Blood transfusion (mL) had a unit conversion from original articles; NA: not available.

Table 4: Postoperative outcomes of the two groups.

Studies	Hospital stay (days)		Wound complication[b]		Mortality[b]		Reoperation[b]	
	PFN	DHS	PFN	DHS	PFN	DHS	PFN	DHS
Saudan et al. [23]	13 ± 4	14 ± 10	11 (11%)	10 (9.43%)	21 (21%)	17 (16.04%)	11 (11%)	6 (5.66%)
Pan et al. [24]	24.73 ± 5.52	25.56 ± 5.32	2 (6.67%)	4 (11.76%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Pajarinen et al. [18]	6.1 ± 3.3	5.4 ± 3.0	0 (0%)	0 (0%)	10 (18.52%)	11 (20.37%)	8 (14.81%)	11 (20.37%)
Giraud et al. [25]	11	11	NA	NA	2 (5.89%)	1 (3.85%)	3 (8.82%)	0 (0%)
Papasimos et al. [26]	8.8	9.9	4 (10%)	5 (12.5%)	1 (2.5%)	1 (2.5%)	5 (12.5%)	3 (7.5%)
Liu et al. [27]	14 ± 8.1	15 ± 8.3	6 (8.70%)	2 (3.08%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Huang et al. [17]	12 ± 5.1	11 ± 4.3	5 (10.42%)	3 (6.25%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Parker et al. [28]	21.2 (1–408)	18.7 (1–141)	6 (2%)	9 (3%)	85 (28.33%)	85 (28.33%)	5 (1.67%)	13 (4.33%)

[b] The intention-to-treat analysis (ITT) was used in the analysis to reduce the withdrawal bias.
NA: not available.

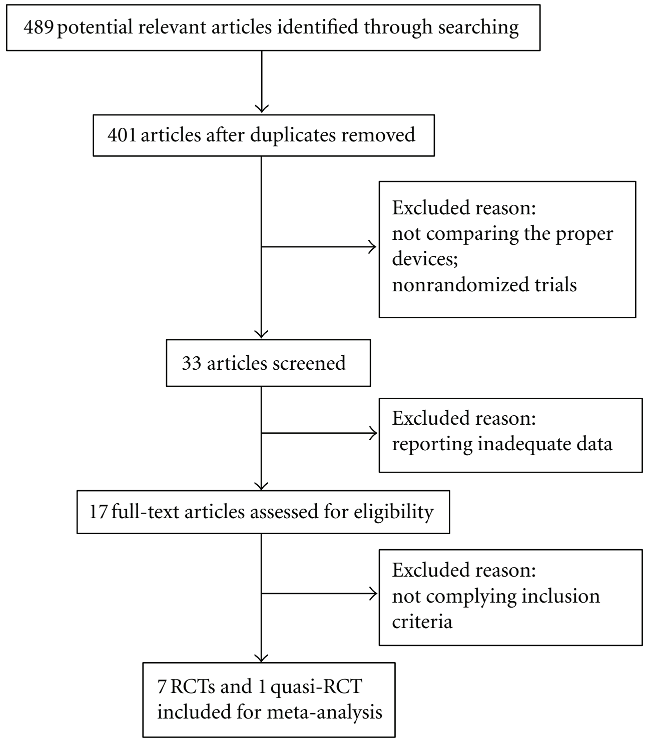

Figure 1: Flow diagram demonstrated methods for identification of studies and reasons for exclusion.

Study or subgroup	PFN Mean	PFN SD	PFN Total	DHS Mean	DHS SD	DHS Total	Weight	Mean difference IV, random, 95% CI
Huang et al. 2010	50.5	20.2	48	52.4	18.3	48	19.4%	−1.90 [−9.61, 5.81]
Liu et al. 2009	46.5	20.5	69	53.4	8.3	65	21.0%	−6.90 [−12.14, −1.66]
Saudan et al. 2002	64	33	100	65	26	106	19.0%	−1.00 [−9.14, 7.14]
Pan et al. 2004	59.16	16.92	30	87.35	21.29	34	18.1%	−28.19 [−37.56, −18.82]
Parker et al. 2012	49	12.7	300	46	12.3	300	22.5%	3.00 [1.00, 5.00]
Total (95% CI)			**547**			**553**	**100.0%**	**−6.44** [**−15.28, 2.40**]

Heterogeneity: $\tau^2 = 89.53$; $\chi^2 = 50.13$, df = 4 ($P < 0.00001$); $I^2 = 92\%$

Test for overall effect: $Z = 1.43$ ($P = 0.15$)

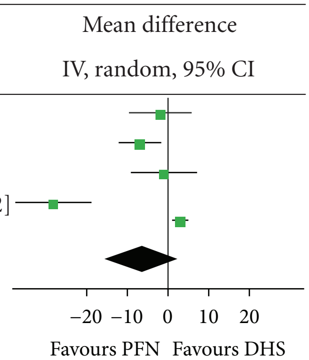

Figure 2: Comparison of operation time between PFN and DHS.

Study or subgroup	PFN Mean	PFN SD	PFN Total	DHS Mean	DHS SD	DHS Total	Weight	Mean difference IV, random, 95% CI
Pajarinen et al. 2005	320	310	54	357	495	54	41.6%	−37.00 [−192.78, 118.78]
Pan et al. 2004	273.33	120.8	30	480.88	177.9	34	58.4%	−207.55 [−281.34, −133.76]
Total (95% CI)			**84**			**88**	**100.0%**	**−136.64** [**−301.39, 28.11**]

Heterogeneity: $\tau^2 = 10676.46$; $\chi^2 = 3.76$, df = 1 ($P = 0.05$); $I^2 = 73\%$

Test for overall effect: $Z = 1.63$ ($P = 0.10$)

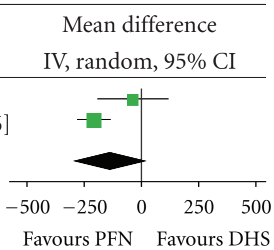

Figure 3: Comparison of blood loss between PFN and DHS.

Study or subgroup	PFN Mean	PFN SD	PFN Total	DHS Mean	DHS SD	DHS Total	Weight	Mean difference IV, random, 95% CI
Saudan et al. 2002	584	720	100	692	704	106	24.5%	−108.00 [−302.62, 86.62]
Pajarinen et al. 2005	1,040	960	54	1,040	800	54	18.4%	0.00 [−333.30, 333.30]
Pan et al. 2004	466.6	137.19	30	833	300	34	27.7%	−366.40 [−478.55, −254.25]
Parker et al. 2012	140	220	300	128	190	300	29.4%	12.00 [−20.89, 44.89]
Total (95% CI)			**484**			**494**	**100.0%**	**−124.41 [−356.02, 107.20]**

Heterogeneity: $\tau^2 = 47143.58$; $\chi^2 = 41.08$, df = 3 ($P < 0.00001$); $I^2 = 93\%$

Test for overall effect: $Z = 1.05$ ($P = 0.29$)

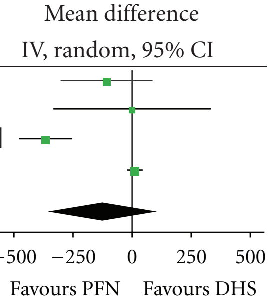

Figure 4: Comparison of blood transfusion between PFN and DHS.

Study or subgroup	PFN Mean	PFN SD	PFN Total	DHS Mean	DHS SD	DHS Total	Weight	Mean difference IV, fixed, 95% CI
Huang et al. 2010	12	5.1	48	11	4.3	48	18.8%	1.00 [−0.89, 2.89]
Liu et al. 2009	14	8.1	69	15	8.3	65	8.7%	−1.00 [−3.78, 1.78]
Saudan et al. 2002	13	4	100	14	10	106	15.8%	−1.00 [−3.06, 1.06]
Pajarinen et al. 2005	6.1	3.3	54	5.4	3	54	47.3%	0.70 [−0.49, 1.89]
Pan et al. 2004	24.73	5.52	30	25.56	5.32	34	9.4%	−0.83 [−3.49, 1.83]
Total (95% CI)			**301**			**307**	**100.0%**	**0.20 [−0.62, 1.01]**

Heterogeneity: $\chi^2 = 3.96$, df = 4 ($P = 0.41$); $I^2 = 0\%$

Test for overall effect: $Z = 0.47$ ($P = 0.64$)

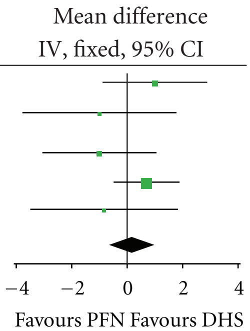

Figure 5: Comparison of hospital stay between PFN and DHS.

significant difference between the PFN group and the DHS group (RR: 1.05, 95% CI: 0.66–1.67, $P = 0.82$) (Figure 6).

3.5. Mortality. All eight studies provided data of mortality, with three of them observed no death in both groups during the period from operation to the last follow-up (Table 4). The average follow-up duration of these studies was 9.6 (3–28) months. The heterogeneity test indicated no statistical evidence of heterogeneity ($\chi^2 = 0.92$, $P = 0.92$, $I^2 = 0\%$), and data pooled by a fixed effect model indicated no statistical significant difference between the two groups (RR: 1.04, 95% CI: 0.83–1.30, $P = 0.72$) (Figure 7).

3.6. Reoperation. The reasons for reoperation mainly were cut-out of femoral head, redisplacement of the fractures, breakage of the implant, and nonunion. The average follow-up duration of these studies was 9.6 (3–28) months. All eight articles provided data of reoperation, with three of them had no case of reoperation before the last follow-up (Table 4). The heterogeneity test indicated no statistical heterogeneity ($\chi^2 = 7.59$, $P = 0.11$, $I^2 = 47\%$), and data pooled by a fixed effect model indicated the outcome of reoperation was similar between the PFN group and the DHS group (RR: 0.97, 95% CI: 0.61–1.54, $P = 0.90$) (Figure 8).

4. Discussion

The optimal fixation device for trochanteric fractures is still controversial at present. Jones et al. [32] compared the intramedullary nail (IMN), which involved gamma nail, intramedullary hip screw (IMHS), and PFN, with sliding hip screw for treatment of extracapsular proximal femoral fractures. They concluded that there was no statistically significant difference in the cut-out rate between the IMN and SHS while total failure rate and reoperation rate were greater with IMN. Parker and Handoll [10] also compared gamma and other cephalocondylic intramedullary nails with extramedullary implants for extracapsular hip fractures in adults. In their systematic review the authors enrolled four studies which included PFN and Targon PF nail compared with SHS. The authors concluded that there was no significant difference between the groups in outcomes of blood loss and transfusion, fixation complications, and post-operation complications and hospital stay.

This meta-analysis included eight RCTs, some of which were recently published and not included in previous meta-analysis and systematic review. We were able to show that PFN fixation and DHS fixation had similar effectiveness in the treatment of trochanteric fractures.

The analysis of operation time showed no significant difference between the two groups. But there was a notable heterogeneity, which could probably be explained by the

Study or subgroup	PFN Events	PFN Total	DHS Events	DHS Total	Weight	Risk ratio M-H, fixed, 95% CI
Huang et al. 2010	5	48	3	48	9.2%	1.67 [0.42, 6.59]
Liu et al. 2009	6	69	2	65	6.3%	2.83 [0.59, 13.50]
Saudan et al. 2002	11	100	10	106	29.9%	1.17 [0.52, 2.63]
Pajarinen et al. 2005	4	40	5	40	15.4%	0.80 [0.23, 2.76]
Pan et al. 2004	2	30	4	34	11.5%	0.57 [0.11, 2.88]
Papasimos et al. 2005	0	54	0	54		Not estimable
Parker et al. 2012	6	300	9	300	27.7%	0.67 [0.24, 1.85]
Total (95% CI)		**641**		**647**	**100.0%**	**1.05 [0.66, 1.67]**
Total events	34		33			

Heterogeneity: $\chi^2 = 3.54$, df = 5 ($P = 0.62$); $I^2 = 0\%$

Test for overall effect: $Z = 0.22$ ($P = 0.82$)

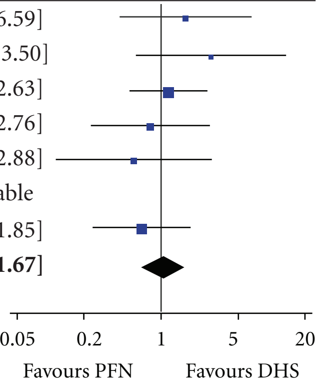

Figure 6: Comparison of wound complication between PFN and DHS.

Study or subgroup	PFN Events	PFN Total	DHS Events	DHS Total	Weight	Risk ratio M-H, fixed, 95% CI
Giraud et al. 2005	2	34	1	26	1.0%	1.53 [0.15, 15.97]
Huang et al. 2010	0	48	0	48		Not estimable
Liu et al. 2009	0	69	0	65		Not estimable
Saudan et al. 2002	21	100	17	106	14.4%	1.31 [0.73, 2.33]
Pajarinen et al. 2005	10	54	11	54	9.6%	0.91 [0.42, 1.96]
Pan et al. 2004	0	30	0	34		Not estimable
Papasimos et al. 2005	1	40	1	40	0.9%	1.00 [0.06, 15.44]
Parker et al. 2012	85	300	85	300	74.1%	1.00 [0.78, 1.29]
Total (95% CI)		**675**		**673**	**100.0%**	**1.04 [0.83, 1.30]**
Total events	119		115			

Heterogeneity: $\chi^2 = 0.92$, df = 4 ($P = 0.92$); $I^2 = 0\%$

Test for overall effect: $Z = 0.36$ ($P = 0.72$)

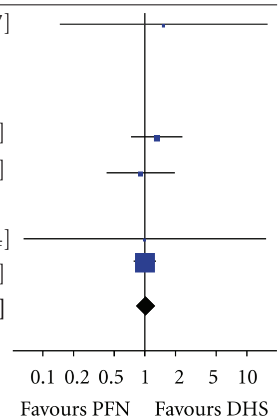

Figure 7: Comparison of mortality between PFN and DHS.

Study or subgroup	PFN Events	PFN Total	DHS Events	DHS Total	Weight	Risk ratio M-H, fixed, 95% CI
Giraud et al. 2005	3	34	0	26	1.7%	5.40 [0.29, 100.16]
Huang et al. 2010	0	48	0	48		Not estimable
Liu et al. 2009	0	69	0	65		Not estimable
Saudan et al. 2002	11	100	6	106	17.4%	1.94 [0.75, 5.06]
Pajarinen et al. 2005	8	54	11	54	32.9%	0.73 [0.32, 1.67]
Pan et al. 2004	0	30	0	34		Not estimable
Papasimos et al. 2005	5	40	3	40	9.0%	1.67 [0.43, 6.51]
Parker et al. 2012	5	300	13	300	38.9%	0.38 [0.14, 1.07]
Total (95% CI)		**675**		**673**	**100.0%**	**0.97 [0.61, 1.54]**
Total events	32		33			

Heterogeneity: $\chi^2 = 7.59$, df = 4 ($P = 0.11$); $I^2 = 47\%$

Test for overall effect: $Z = 0.13$ ($P = 0.90$)

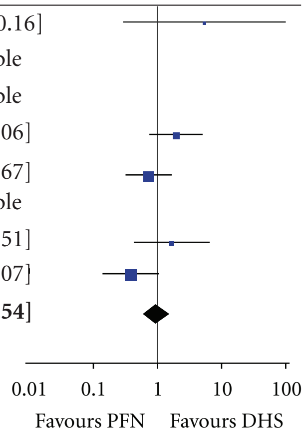

Figure 8: Comparison of reoperation between PFN and DHS.

different levels of experience of surgeons, and the duration of PFN fixation could be shortened as surgical skills improved.

This paper showed no significant difference of blood loss and blood transfusion between the two implants. We could only find detailed outcomes related to blood loss and blood transfusion of four randomized studies from which data could be extracted. We enrolled studies of Pan et al. [24] and Pajarinen et al. [18] for analyzing blood loss and studies of Pan et al. [24], Pajarinen et al. [18], Parker et al. [28], and Saudan et al. [23] for blood transfusion. A sensitivity test was performed, which showed that, in blood transfusion, the two groups were still similar. In practice, various counting methods of blood loss were used in different hospitals, and surgeons usually estimate the blood loss. That could explain the statistic significant difference of heterogeneity ($P = 0.01$, $I^2 = 77\%$), which made it hard to draw any conclusion.

The intention-to-treat analysis (ITT) was used in the analysis of mortality and reoperation to reduce the withdrawal bias [33–36]. Furthermore, we tried to contact the authors of these studies for additional information but only received one response for checking the data of their research. This paper listed three cases of hematoma, one case of superficial wound infection, and one case of delayed wood healing in wound complications, but the author added it up to four [26]. Nevertheless, the outcome was still similar between the two groups when we performed a sensitivity test. It would be desirable if all the data from the studies were fully reported in a standard format, so that a larger sample can be analyzed to reduce bias.

There were some limitations in this meta-analysis. The number of studies included was not so adequate which just had eight studies involving 1348 fractures, and the quality of the trials was generally low. We intended to perform a subgroup analysis based on AO/OTA classification of the trochanteric fracture initially. Unfortunately, not all the studies provided precise classification of patients and had inadequate outcome data for extraction. Furthermore, different follow-up duration of included studies also reduced the power of our research.

In summary, PFN and DHS are equally effective in the treatment of trochanteric fractures. With future modifications to these two types of implants, more high-quality randomized controlled trials and further studies are needed to investigate whether these changes can lead to different outcomes.

Conflict of Interests

Dr. F. Leung received a research grant from Synthes. The remaining authors declare that they have no conflict of interests.

Authors' Contribution

F. Leung and Z. Xiang have equally contributed to this study.

Acknowledgment

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Clinical Study

Internal Fixation of Intertrochanteric Hip Fractures: A Clinical Comparison of Two Implant Designs

Ran Tao, Yue Lu, Hua Xu, Zhen-Yu Zhou, You-Hua Wang, and Fan Liu

Department of Orthopaedics, Affiliated Hospital of Nantong University, 20 Xisi Road, Nantong, Jiangsu Province 226001, China

Correspondence should be addressed to Fan Liu; liufan19575@yahoo.com.cn

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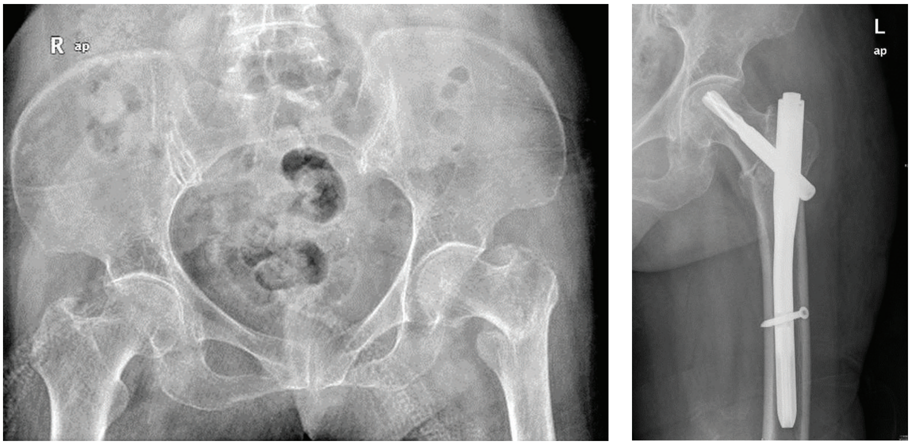
Objective. To compare two internal fixation devices clinically in stabilisation of intertrochanteric femur fractures. *Methods*. Eighty-seven patients were randomised upon their admission to the hospital using a sealed envelope method. Forty-five were treated with proximal femur nail antirotation (PFNA) and 42 with reverse less invasive stabilisation system (LISS). The perioperative data were recorded and compared in relation to fracture type. *Results*. In each type of fractures, no significant differences were found with respect to the blood loss, the quality of reduction, the time to bony healing, and the Harris hip score between the 2 groups. The mean duration of surgery was significantly longer in reverse LISS group than in PFNA group. *Conclusion*. Both the PFNA and the reversed LISS are effective in the treatment of different types of intertrochanteric femur fractures. PFNA is superior to reverse LISS in terms of surgical time, weight-bearing, and perhaps fluoroscopy time.

1. Introduction

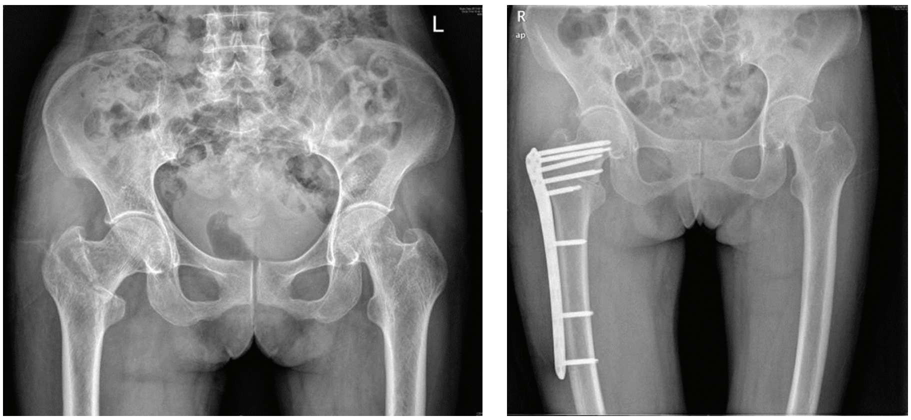
Numerous internal fixation devices have been used to stabilise intertrochanteric femur fractures, and they can be divided into 2 categories: extramedullary fixation devices and intramedullary fixation devices. It is generally accepted that dynamic hip screw (DHS) is the implant of choice in the treatment of stable intertrochanteric femur fractures (AO/OTA 31-A1) [1]. For unstable intertrochanteric femur fractures (AO/OTA 31-A2 and 31-A3), the commonly used extramedullary fixation devices, such as DHS, dynamic condylar screw (DCS), and angular blade plates are sometimes problematic [1–3]. The less invasive stabilisation system-distal femur (LISS-DF) was designed for stabilisation of distal femur fracture. Recently, quite a few reports have addressed its use in the treatment of proximal femur fracture, [2, 4, 5] and the clinical results are encouraging. As to intramedullary fixation devices, so far, proximal femur nail antirotation (PFNA) is one of the most effective methods in the treatment of intertrochanteric femur fractures [6–10]. The purpose of the present study was to compare reverse LISS with PFNA clinically and to determine the preferred method in stabilisation of intertrochanteric femur fractures.

2. Patients and Methods

Between September 2010 and August 2011, 100 patients with 100 intertrochanteric femoral fractures were randomised upon their admission to the hospital using a sealed envelope method. The inclusion criteria were ages above 65. Those with pathological fractures, osteoarthritis of the hips, and ASA [11] (American Society of Anesthesiologists scale) 4 or 5 were excluded from the study. Of the 100 patients, 7 died of different causes unrelated to implants within 1 year and six was lost to followup. The remaining 87 patients were available for analysis. There were 33 men and 54 women. Forty-five of them were treated with PFNA (group I) and 42 with reverse LISS (group II). The fractures were classified according to AO/OTA classification. GroupI consisted of 10 cases of type 31A1, 21 cases of 31A2 and 14 cases of 31A3 fractures and group II, 9 cases of type 31A1, 21 cases of 31A2, and 12 cases of 31A3



(a)



(b)

Figure 1: Patients with 31 A1 fractures. (a) PFNA: preoperative AP view and immediate postoperative AP view. (b) Reverse LISS: preoperative AP view and immediate postoperative AP view.

fractures. The perioperative data, such as operative time, the overall fluoroscopy time, and the blood loss were noted and compared among the groups (Table 1). Ethical approval was obtained from the hospital.

All patients were evaluated preoperatively with use of two standard plain radiographs, an anterior-posterior radiograph, and a medial-lateral radiograph. Surgical treatment was performed as soon as the patient's general medical condition allowed. Prophylactic intravenous first generation cephalosporin was administered half an hour before operation and discontinued 48–72 hours postoperatively. Internal fixation was performed by 3 orthopaedic consultants (Figures 1, 2, and 3). Close reduction was carried out first in all the cases with patient supine on a traction table. If failed, then semiopen or open reduction was performed. Reverse LISS was used in a similar way described by Ma H et al. [2]. The quality of reduction was graded as good, acceptable (5–10° varus/valgus and/or anteversion/retroversion), or poor (>10° varus/valgus and/or anteversion/retroversion) [12]. Fractures were judged to be healed radiographically if bridging callus was evident on three of four cortices as seen on two views [13]. Intraoperative time was recorded from the time that the close reduction was started to the time that the wound was sutured closed.

In group I, partial and full weight-bearing were allowed on third and sixth postoperative week, respectively. In group II, these were postponed to 6th and 12th postoperative week, respectively. A follow-up evaluation, which included a clinical and radiographic assessment, was performed at 6, 13, 26, and 52 weeks. Functional outcomes were assessed according to the Harris hip scoring system [14].

Statistical analysis was performed with SPSS Statistics 11.5, with use of the Student's t-test, the chi square test. Statististical significance was defined as $P < 0.05$.

3. Results

The results in relation to treatment group are shown in Table 1.

In each type of fractures, no significant differences were found with respect to the age, the sex, the time from injury to surgery, the quality of reduction, the blood loss, the time to bony healing, and the Harris hip score between the 2 groups.

Figure 2: Patients with 31 A2 fractures. (A) PFNA (A(a)) Preoperative AP view and lateral view. (A(b)) Immediate postoperative AP view and oblique view. (A(c)) Three months postoperatively. Callus formation can be seen in both AP view and oblique view. (B) Reverse LISS (B(a)) Preoperative AP view. (B(b)) Immediate postoperative AP view and lateral view.

The mean duration of surgery was significantly longer in group II than in groupI.

In type 31 A1 fractures, both the time to begin with partial weight-bearing ($P < 0.001$) and full weight-bearing ($P < 0.001$) were significant earlier in group I than in group II. The fluoroscopy time was significantly longer in group II than in group I. No significant difference was found with respect to the time of hospital stay.

In type 31 A2 fractures, no significant differences were found with respect to the fluoroscopy time and the time of hospital stay.

In type 31 A3 fractures, the patients in group I had significantly shorter time of hospital stay than in group II. No significant differences were found with respect to the fluoroscopy time.

In both 31 A2 and 31 A3 fractures, no significant differences were found regarding to the time to bony healing between the 2 groups. For most cases in group I, partial weight-bearing and full weight-bearing were began at 3 weeks and 6 weeks postoperatively, while in group II, most patients were allowed to start partial and full weight-bearing on 6th and 12th postoperative week, respectively.

Regardless of fracture types, no significant differences were found with respect to the age, the sex, the time from injury to surgery, the quality of reduction, the blood loss, the time of hospital stay, and the Harris hip score between the

(a) (a)

(b) (b)

(c) (c)

(A) (B)

Figure 3: Patients with 31 A3 fractures. (A) PFNA (A(a)) Preoperative AP view and lateral view. (A(b)) Immediate postoperative AP view and lateral view. (A(c)) Six weeks postoperatively. Callus formation can be seen in both AP view and oblique view. (B) Reverse LISS (B(a)) Preoperative AP view and lateral view. (B(b)) Immediate postoperative AP view and lateral view. (B(c)) Six months postoperatively. Reverse LISS successfully maintained the reduction till bony healing.

2 groups. The patients in group I had significantly shorter duration of surgery, less fluoroscopy time as well as less time to obtain bone healing compared with that of in group II.

There were altogether 9 postoperative complications, including 3 cases of pressure sore, 3 cases of urinary infection, 2 cases of pulmonary infection, and 1 case of deep venous thrombosis. Loss of reduction, implant failure, and nonunion were not found in any case.

4. Discussion

Controversy persists concerning the optimal internal fixation devices for stabilisation of intertrochanteric femur fractures. Recently, there is a tendency of increased use of intramedullary nails [15, 16]. Theoretically, intramedullary fixation offers advantages over plates, especially in its ability to ensure stability even in unstable fractures. This was

Table 1: Main demographic and clinical data of the fractures by treatment group.

	PFNA (n = 10)	Reverse LISS (n = 9)	P value
Type 31-A1 fractures (n = 19)			
Mean age (yr.)	80.1 ± 6.4	80.3 ± 8.1	0.945
Sex			
Male	6	2	0.096
Female	4	7	
Preoperative walking ability			
Independent walking	10	9	
Assisted walking	0	0	
Bedridden	0	0	
Mean duration from injury to surgery (day)	6.80 ± 3.3	6.11 ± 3.6	0.666
Mean duration of surgery (min.)	61.0 ± 9.4	87.2 ± 11.5	0.000
Mean fluoroscopy time (sec.)	109 ± 52.9	180 ± 70.8	0.024
Mean blood loss (mL)	210 ± 87.6	233 ± 82.9	0.560
Open reduction cases	0	0	
Quality of reduction			
Good	10	8	0.279
Acceptable	0	1	
Poor	0	0	
Mean time of hospital stay (day)	18.6 ± 3.1	21.3 ± 9.3	0.438
Mean time to bone healing (wk.)	17.4 ± 3.4	20.6 ± 3.2	0.054
Postoperative walking ability			
Independent walking	8	8	
Assisted walking	2	1	
Bedridden	0	0	
Harris hip score (pt.)	83.6 ± 5.8	85.2 ± 6.4	0.568
	PFNA (n = 21)	Reverse LISS (n = 21)	P value
Type 31-A2 fractures (n = 42)			
Mean age (yr.)	82.5 ± 7.9	80.7 ± 8.1	0.469
Sex			
Male	5	11	0.057
Female	16	10	
Preoperative walking ability			
Independent walking	17	19	
Assisted walking	3	2	
Bedridden	1	0	
Mean duration from injury to surgery (day)	6.57 ± 3.5	6.71 ± 4.8	0.912
Mean duration of surgery (min.)	65.5 ± 13.2	92.6 ± 17.1	0.000

Table 1: Continued.

	PFNA (n = 21)	Reverse LISS (n = 21)	P value
Mean fluoroscopy time (sec.)	153 ± 59.7	202 ± 91.1	0.050
Mean blood loss (mL)	231 ± 100.6	248 ± 152.9	0.679
Open reduction cases	2	3	
Quality of reduction			
Good	19	20	0.549
Acceptable	2	1	
Poor	0	0	
Mean time of hospital stay (day)	19.5 ± 5.2	19.8 ± 6.0	0.847
Mean time to bone healing (wk.)	22.2 ± 3.6	23.1 ± 4.3	0.440
Postoperative walking ability			
Independent walking	17	14	
Assisted walking	3	6	
Bedridden	1	1	
Harris hip score (pt.)	81.4 ± 10.0	78.1 ± 12.6	0.353
	PFNA (n = 14)	Reverse LISS (n = 12)	P value
Type 31-A3 fractures (n = 26)			
Mean age (yr.)	77.4 ± 6.3	77.2 ± 6.4	0.917
Sex			
Male	5	4	0.899
Female	9	8	
Preoperative walking ability			
Independent walking	14	12	
Assisted walking	0	0	
Bedridden	0	0	
Mean duration from injury to surgery (day)	4.50 ± 2.1	5.17 ± 2.2	0.430
Mean duration of surgery (min.)	73.2 ± 15.4	97.5 ± 18.4	0.001
Mean fluoroscopy time (sec.)	142 ± 72.3	199 ± 88.9	0.084
Mean blood loss (mL)	236 ± 111.7	238 ± 98.0	0.966
Open reduction cases	1	1	
Quality of reduction			
Good	12	11	0.636
Acceptable	2	1	
Poor	0	0	
Mean time of hospital stay (day)	16.6 ± 1.95	20.2 ± 3.86	0.005
Mean time to bone healing (wk.)	22.0 ± 4.31	24.8 ± 3.07	0.070

Table 1: Continued.

	PFNA ($n = 14$)	Reverse LISS ($n = 12$)	P value
Postoperative walking ability			
Independent walking	12	12	
Assisted walking	1	0	
Bedridden	1	0	
Harris hip score (pt.)	84.1 ± 11.3	86.2 ± 5.64	0.563
	PFNA ($n = 45$)	Reverse LISS ($n = 42$)	P value
All the fractures ($n = 87$)			
Mean age (yr.)	80.4 ± 7.3	79.6 ± 7.6	0.627
Sex			
Male	16	17	0.636
Female	29	25	
Preoperative walking ability			
Independent walking	41	40	
Assisted walking	3	2	
Bedridden	1	0	
Mean duration from injury to surgery (day)	5.98 ± 3.2	6.14 ± 3.9	0.828
Mean duration of surgery (min.)	66.9 ± 13.7	92.9 ± 16.5	0.000
Mean fluoroscopy time (sec.)	140 ± 63.5	196 ± 85.0	0.001
Mean blood loss (mL)	228 ± 100	242 ± 124	0.565
Open reduction cases	3	4	
Quality of reduction			
Good	41	40	0.765
Acceptable	4	2	
Poor	0	0	
Mean time of hospital stay (day)	18.4 ± 4.1	20.3 ± 6.3	0.101
Mean time to bone healing (wk.)	21.1 ± 4.2	23.1 ± 4.0	0.025
Postoperative walking ability			
Independent walking	37	34	
Assisted walking	6	7	
Bedridden	2	1	
Harris hip score (pt.)	82.8 ± 9.5	82.0 ± 10.4	0.717
Postoperative complications (cases)	4 (9%)	5 (12%)	
Pressure sore	1	2	
Urinary infection	1	2	
Pulmonary infection	1	1	
Deep venous thrombosis	1	0	
Death (cases)	4 (9%)	3 (7%)	

confirmed by the meta-analysis by Zeng et al. [17], who compared PFNA with DHS. However, the meta-analysis by Parker and Handoll of all prospective randomised trials comparing intramedullary to extramedullary devices does not support the perceived superiority of nails [1]. The purpose of the present study was to compare reverse LISS with PFNA in stabilisation of intertrochanteric femur fractures. To our knowledge, few authors [18, 19] compared these 2 devices clinically, and no published literatures made the comparison in relation to the fracture type.

The study population and the baseline data (age, sex, preoperative walking ability, and the duration from injury to surgery) were similar in each fracture type between the 2 groups. The most important finding of this study was that PFNA could significantly shorten surgical time compared with reverse LISS (31A1, $P < 0.001$; 31A2, $P < 0.001$; 31A3, $P = 0.001$; overall, $P < 0.001$). PFNA also shortened fluoroscopy time, but not statistically significant in unstable fractures (31A2 and 31A3). This can be explained that we are very familiar with PFNA [10] and lack of experience in reverse LISS. Before this study, only 4 intertrochanteric femur fractures (1 adolescent fracture, 3 pathological fractures) were treated by the contralateral reverse LISS-DF in our department. We found the correct positioning of reverse LISS to proximal femur was sometimes time consuming. There is no a so-called standard position concerning how proximal of the proximal end of LISS should be placed; however, two issues should be guaranteed. Firstly, at least 4 locking screws should be inserted in the proximal end of the LISS to effectively stabilise proximal fragment. Secondly, the LISS should be placed on the exact lateral aspect of the femur. PFNA shortened surgical time but did not reduce blood loss.

Good results were achieved with both the reverse LISS and PFNA in each fracture type, which was in accordance with the findings by Zhou et al. [19] and Han et al. [18]. Harris hip scores were comparable in both groups in relation to each fracture type. Another important finding of this study was that not a single mechanical failure was found in all the 87 fractures. This probably contributed to good quality of reduction, properly positioning of the internal fixation devices, as well as more conservative rehabilitation program. Every effort was made to obtain best reduction and ideal implants positioning. On rare occasions, close reduction was not satisfactory and open reduction was performed (3 cases in PFNA group, 4 cases in LISS group). As to postoperative treatment, joint movement was encouraged on second postoperative day for every patient in both groups. The time to start weight-bearing differed widely. In our opinion, the appropriate time to begin with weight-bearing depends not only on the implant used, but also on the fracture type, postoperative stability, osteoporosis, and body weight as well. Haidukewych [20] highlighted 4 classic intertrochanteric fracture patterns that signify instability. The unstable patterns include reverse obliquity fractures, transtrochanteric fractures, fractures with a large posteromedial fragment implying loss of the calcar buttress, and fractures with subtrochanteric extension. He suggested nailing for these fractures. In this study, weight-bearing was delayed in patients with these classic fracture patterns, regardless of treatment groups.

A weakness of this study is that we are familiar with PFNA but not with reverse LISS, for it is originally designed for distal femur. Another weakness is the relatively small patient group. Further studies are required concerning LISS application to proximal femur.

In conclusion, the results of the present study show that both the PFNA and the reverse LISS provide effective methods of treatment for intertrochanteric hip fractures. PFNA is superior to reverse LISS in terms of surgical time, weight-bearing, and perhaps fluoroscopy time. Mechanical failure can be minimized when the rehabilitation program is made based on individual characteristics.

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Research Article

Investigation of Occult Hip Fractures: The Use of CT and MRI

S. K. Gill, J. Smith, R. Fox, and T. J. S. Chesser

Trauma and Orthopaedic Department, Frenchay Hospital, North Bristol NHS Trust, Frenchay Park Road, Bristol BS16 1LE, UK

Correspondence should be addressed to S. K. Gill; sukhdeepgill@doctors.net.uk

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Aim. At present there is no data looking at modern multislice computerised tomography (CT) in the investigation of occult hip fracture. The aim of this study was to retrospectively compare the reports of patients sent for magnetic resonance imaging (MRI) or CT with negative radiographs and a clinical suspicion of a fractured neck of femur. *Methods*. All patients presenting to the hospital with a clinical suspicion of a hip fracture but initial negative radiographs over a three-year period were included. Patients were either investigated with an MRI scan or CT scan. The presence of a fracture, the requirement for surgery, and any further requirement for imaging were recorded. *Results*. Over three years 92 patients were included of which 61 were referred for a CT and 31 for an MRI. Thirty-four patients were found to have a fracture. Of these, MRI picked up a fracture in 36% and CT in 38% of referrals. *Discussion*. Up to 10% of proximal femur fractures may be missed on initial radiographs. Current guidelines state patients should be offered MRI if hip fracture is suspected despite negative hip radiographs. Our findings show that modern multislice CT may be comparable with MRI for detecting occult fracture.

1. Introduction

The early diagnosis and treatment of patients sustaining fractures of the proximal femur (hip fractures) has led to improved results both in terms of morbidity and mortality. Early treatment helps with pain control and well as reducing the length of hospital stay. However, it is recognized 2–10% of fractures may not be clearly visible on initial radiographs, and further imaging is required to make a definitive diagnosis [1–6]. These fractures have been termed occult hip fractures.

Current guidelines state patients should be offered magnetic resonance imaging (MRI) if hip fracture is suspected despite negative anteroposterior pelvis and lateral hip radiographs [1]. However, MRI may not be accessible in hospitals out of office hours, is more expensive than other imaging, and is contraindicated in some patients. One alternative is multislice computerised tomography (CT) which is more readily available, though there is no evidence of its sensitivity.

The aim of this study was to look at the sensitivity and results of suspected occult hip fractures (with negative radiographs) imaged with either MRI or CT.

2. Materials and Methods

A retrospective study of all patients presenting to a single hospital, over a three-year period with a clinical suspicion of a hip fracture, was performed. Patients presenting with clinical suspicion of a hip fracture (persistent hip pain after trauma, inability to bear weight, and pain on attempted straight leg raising, passive rotation, or axial loading tests), initially underwent both anteroposterior pelvis and lateral hip radiographs. If these were negative or inconclusive, further imaging was then arranged. All patients were subsequently sent for either MRI or CT scanning depending on accessibility. CT scans were used in those patients where MRI was contraindicated or where there was going to be more than a 24-hour wait.

The CT examinations were conducted by one of two multislice helical Siemens scanners with a ×4 quad slice and ×1 62 slice. The MRI examination was conducted using T1 weighted spine echo + STIR (Short Tau Inversion Recovery) axial and coronal scan, using a Philips 3T or a Philips 1.5T.

Table 1: Results.

	Total	CT	MRI
Number	92	61	31
Male	33	23	10
Female	59	38	21
Age range	52–100	52–100	61–95
Mean age	82	83	81
Fracture found	34 (37%)	23 (38%)	11 (36%)
Operated on	28	19	9
Intracapsular	17	14	6
Extracapsular	11	5	3

3. Results

The hospital treated 1353 hip fractures over the three-year period. During this time 92 patients were referred for further imaging for a diagnosis of an occult hip fracture of which 34 (37%) identified a fracture. This gave an occult fracture rate of 2.5%, with 7% of those presenting with a clinical suspicion of a hip fracture requiring further investigation after initial negative radiographs. When the radiographs were retrospectively reviewed by experienced musculoskeletal radiologists or trauma orthopaedic surgeons, 11 of the fractures were evident on the initial films, dropping the actual occult fracture rate to 1.7%.

CT scans were performed in 61 and MRI in 31 patients. Of those undergoing CT, 23 (38%) were diagnosed with a fracture compared with 11 who underwent MRI (36%). Of those who had a positive diagnosis 28 out of 34 underwent operative treatment with 17 sustaining intracapsular and 11 extracapsular injuries (see Table 1).

All patients who had scans for possible fractures were reviewed on the system to see if they had any further followup radiographs of their hips in the six weeks following their scans. Four patients who had a negative CT had further radiographs of their hip, which in all cases was negative.

Of the six people who were not operated on, one had an isolated greater trochanter fracture, two had scans which were suspicious of fracture, but the patients were mobilising comfortably, two had intracapsular fractures which were over three weeks old, the patients were mobilising comfortably, and one patient had an intertrochanteric fracture which was not operated on due to the patient having multiple medical problems and being bed bound due to end stage cancer.

4. Discussion

About 70–75,000 people fracture their proximal femur annually in the UK [1], and this number is expected to rise [2, 3]. It is quoted that up to 10% of these may be missed on initial radiographs and require further imaging if there is clinical suspicion of a hip fracture [2–6].

Occult fractures which are initially missed have implications for patients and clinicians. Delays in diagnosis can lead to AVN, nonunion and a greater risk of arthroplasty, unnecessary pain, increased mortality, and thromboembolic complications [2, 7–9]. The primary goal of fracture management is to return patients to prefracture level of function. Patients with a proximal femur fracture and a delay of greater than 48 hours from hospital admission to surgery have doubled the risk of dying before the end of the first postop year [10]. Early diagnosis of occult hip fractures would shorten hospitalisation by expediting definitive treatment, leading to reduced costs [6]. Kim et al., in a study looking at initially missed occult hip fractures, showed that there was an increased risk of need for operation in patients who were diagnosed on a subsequent occasion when they returned after discharge [4]. Patients who do not have a hip fracture do not necessarily need to be kept immobile or require a stay in hospital.

MRI is used to diagnose a multitude of all occult fractures, and the majority of papers reviewed on this subject felt that MRI was the most useful adjunct in the diagnosis of occult proximal femur fractures [2, 3, 11–21]. However, MRIs may not be readily available in all hospitals, is expensive, and is contraindicated in confused patients and patients with cardiac pacemakers [10, 12].

Our criteria for further imaging with MRI or CT were the same as previously published by Chana et al. [10]: negative plain radiographs (anteroposterior pelvic and lateral hip views) and a high clinical suspicion of fracture (persistent hip pain after trauma, inability to bear weight, and pain on attempted straight leg raising, passive rotation, or axial loading tests). Such patients underwent an urgent MRI or CT scan, within 48 hours where possible. The demographics of our two groups were similar, the indication for further imaging was the same, and the modality for which they were scanned was due solely to the availability of the MRI scanner or if there were any contraindications for using MRI. Our results showed that the proportion of scans in each modality that showed a fracture was similar (38% of CT scans, 36% of MRI scans). No MRI or CT scan missed an occult fracture which was then found when the initial X-rays were reported. No patients who underwent an MRI scan had their scans repeated or had further radiographs in the six weeks following their scans. Four patients who had a negative CT had a further radiograph of their hip with six weeks of their scans; these were all reported negative for a fracture.

Lubovsky et al. compared CT to MRI in the early diagnosis of occult hip fractures [6]. They scanned six patients with a possible fractured proximal femur with CT and then immediately after with MRI. Their findings showed that the CT images resulted in misdiagnosis in 66% of patients. Out of the four greater trochanteric fractures diagnosed by CT, three were rediagnosed as pertrochanteric and one as subcapital fractures after MRI. Lubovsky et al. felt that an MRI was more cost effective, as it gave a definitive diagnosis, including identifying soft tissue injuries, by one short examination [6]. However, their group for comparison was very small (only 13 patients in total, only six patients scanned by CT).

Cabarrus et al. compared CT with MRI for insufficiency fractures in the pelvis and reported 64 cases where MRI and CT could be compared side by side [7]. MRI identified 128/129 patients with pelvic fractures, CT identified 89/129. Only 2% of patients had fractures detected on CT but not on MRI, 52% had fractures detected on both, and 47% had fractures on MRI but not CT. CT only detected 70% of femoral neck fractures (90% on MRI) and 42.9% of femoral head fractures (100% on MRI). But the time lapse of up to 3 months between CT and MRI in some patients may have affected the results. Cabarrus et al. found that MRI did miss a fracture due to partial volume effects and adjacent joint effusion along with motion artefacts. This fracture was picked up by CT.

CT scanning was felt to be less useful than MRI by Pandey et al. due to the CT scanning only being available in the axial plane which may miss small impacted fractures or undisplaced fractures than run parallel to the axial plane [16]. However, this paper was written in 1995 before, the widespread usage of multislice helical scanners were available. Our results show that neither CT nor MRI missed a proximal hip fracture.

The majority of the papers in this field are over 10 years old [8, 9, 16, 19–27]. Advances in technology, such as 64-slice scanners and sophisticated 3-dimensional reconstruction algorithms, may have made the reliability of CT comparable to that of MRI. Perron et al. in 2005 thought CT was sensitive in depicting fracture lines and in the assessment of biomechanical stability [28]. Memarsadeghi et al. [29] in 2006 compared multidetector CT with MRI in detecting occult scaphoid fractures. In their study they demonstrated that multidetector CT was better than MRI for visualising the difference between a purely trabecular and cortical fracture, although MRI had better sensitivity overall for the visualisation of fractures [29]. They concluded that CT was useful diagnostically due to it being cheaper and more readily available. This finding was supported by a more recent paper by Mallee et al., who found that CT had comparable accuracy to MRI in diagnosing occult scaphoid fractures [30]. The cost for a CT scan (one area, no contrast) is £101. The cost of an MRI (one area, no contrast) is £206 [31]. If CT can be shown to be as reliable and accurate as MRI, this has considerable implications because of its widespread availability out of hours and lower cost.

Other imaging modalities previously described include bone scanning where it is reported high sensitivity at 72 hours; however, other studies have shown a false negative rate at 24 hours suggesting it is not as sensitive as MRI for an early diagnosis [11, 32].

As this is a retrospective study, we were unable to ensure every patient who had a negative CT or MRI scan had further imaging to rule out a fracture. However, our rate of 37% of patients with negative initial radiographs having a fracture on further imaging is comparable with results reported by other studies (range from 13% to 67%) [6–8, 11, 13, 16, 18, 20, 21, 23, 33]. We were unable to determine retrospectively what proportion of patients had a suspected fracture but did not undergo an MRI scan. However, it has been the policy at our institution to perform an MRI or a CT scan on all patients with a suspected fracture of the femoral neck but with normal plain radiographs, so we believe that this proportion would be negligible. Due to the retrospective nature of our study we were unable to perform both CT and MRI on all of our patients, so we are unable to directly compare the sensitivity of both modalities.

5. Conclusion

This is the first study reporting the use of multislice CT scanning and suggests it has a role to play in the investigation of occult hip fractures. CT scanning has widespread availability out of hours and lower cost when compared to MRI scanning. It can also be used in patients with confusion and cardiac pacemakers, where MRI is contraindicated. Whilst our study population was too small for statistical confirmation our findings show that CT may be considered as a useful adjunct. We feel that further prospective studies comparing CT and MRI for diagnosing occult fractures are needed to define their roles further.

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Review Article

Osteoporotic Hip Fractures: The Burden of Fixation Failure

J. M. Broderick,[1] R. Bruce-Brand,[1] E. Stanley,[1] and K. J. Mulhall[1,2,3]

[1] *Mater Misericordiae University Hospital, Dublin, Ireland*
[2] *Sports Surgery Clinic, Dublin, Ireland*
[3] *Cappagh National Orthopaedic Hospital, Dublin, Ireland*

Correspondence should be addressed to J. M. Broderick; jamesbrod@gmail.com

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Osteoporotic hip fractures are a major cause of morbidity and mortality in the elderly. Furthermore, reduced implant anchorage in osteoporotic bone predisposes towards fixation failure and with an ageing population, even low failure rates represent a significant challenge to healthcare systems. Fixation failure in fragility fractures of the hip ranges from 5% in peritrochanteric fractures through to 15% and 41% in undisplaced and displaced fractures of the femoral neck, respectively. Our findings, in general, support the view that failed internal fixation of these fragility fractures carries a poor prognosis: it leads to a twofold increase in the length of hospital stay and a doubling of healthcare costs. Patients are more likely to suffer a downgrade in their residential status upon discharge with a consequent increase in social dependency. Furthermore, the marked disability and reduction in quality of life evident before salvage procedures may persist at long-term followup. The risk, of course, for the elderly patient with a prolonged period of decreased functioning is that the disability becomes permanent. Despite this, however, no clear link between revision surgery and an increase in mortality has been demonstrated in the literature.

1. Introduction

Osteoporotic hip fractures are a substantial cause of morbidity and mortality in the elderly. That osteoporosis leads to fragility fractures is well known; however, underlying changes in bone mass and microarchitecture that manifest as fracture in the acute setting can also undermine subsequent attempts at fracture healing. Reduced implant anchorage in osteoporotic bone predisposes towards a failure of fixation [1] and with current projections estimating a worldwide increase in hip fractures from 1.7 million in 1990 to 6.3 million by 2050 [2], even low failure rates represent a significant challenge to healthcare systems. We have reviewed the incidence, the impact, and the additional economic cost of such fixation failures in osteoporotic fractures of the hip.

2. Review Methods

2.1. Defining Osteoporotic Fractures. The classic fragility fractures are those of the proximal femur, proximal humerus, distal radius, and vertebral fractures. There are, however, problems in determining what actually constitutes an osteoporotic fracture. The World Health Organization (WHO) defines osteoporosis as a bone mineral density (BMD) of 2.5 standard deviations (SDs) or more below the young normal mean [3]. However, this definition applies only to postmenopausal women assessed by dual-energy X-ray absorptiometry (DEXA) scan and no such definition exists for men. Previous attempts to estimate the degree of osteoporosis include the Singh index, which involves fitting the pattern of proximal femoral trabecular lines into six separate categories; however, this has been shown to have poor inter- and intraobserver reliability [4] and, moreover, it does not correlate with BMD as measured by DEXA scanning. Perhaps the most useful description of fragility fractures is that recently proposed by Kanis et al. [5] in defining osteoporotic fractures as those that occur at a site associated with low BMD and that increase in incidence over the age of 50 years. Indeed, hip fractures alone are regularly used as surrogate markers in determining the international burden of osteoporosis.

Table 1: Incidence of fixation failure and reoperation in undisplaced fractures of the femoral neck (Garden I and II). All patients >60 years.

Study	Year	Fixation method	Mean age	Followup (months)	*n*	Fixation failure *n* (%)	Revision surgery *n* (%)
Lee et al. [33]	2008	MIDHS, SHS, and CS	72.3	12	90	7 (7.8)	7 (7.8)
Bjørgul and Reikerås [12]	2007	CS	Nr	39	225	37 (16.4)	42 (18.7)
Yih-Shiunn et al. [34]	2007	SHS, CS	71.6	12	84	8 (9.5)	8 (9.5)
Chiu and Lo [35]	1996	Knowles pinning	73	74	250	42 (16.8)	42 (16.8)
Hui et al. [36]	1994	SHS	80	6	57	11 (19.2)	10 (17.5)
Total/average					706	105 (14.8)	109 (15.4)

Nr: not recorded; CS: cannulated screws; MIDHS: minimally invasive dynamic hip screw; SHS: sliding hip screw.

Table 2: Incidence of fixation failure and reoperation in displaced fractures of the femoral neck (Garden III and IV). All patients >60 years.

Study	Year	Fixation method	Mean age	Followup (months)	*n*	Fixation failure *n* (%)	Revision surgery *n* (%)
Parker et al. [37]	2010	CS	82.2	180	226	95 (42)	114 (50.4)
Leonardsson et al. [38]	2010	CS, HP	81.5	124	217	94 (43.3)	125 (57.6)
Frihagen et al. [14]	2007	CS	83.2	24	111	46 (41.4)	47 (42.3)
Johansson et al. [39]	2006	CS	84	24	78	37 (47.4)	34 (43.6)
Blomfeldt et al. [19]	2005	CS	81.4	48	53	22 (41.5)	25 (47.2)
Blomfeldt et al. [40]	2005	CS	84	24	30	9 (30)	10 (33.3)
Rödén et al. [41]	2003	von Bahr screws	81	60	53	34 (64.2)	31 (58.5)
Davison et al. [42]	2001	SHS	73	60	93	30 (32.3)	28 (30.1)
Neander et al. [43]	1997	CS	86	18	10	1 (10)	1 (10)
Jónsson et al. [44]	1996	HP	79	24	24	9 (37.5)	7 (29.2)
van Vugt et al. [45]	1993	SHS	75.3	36	21	6 (28.6)	6 (28.6)
Soreide et al. [46]	1979	von Bahr screws	78	12	51	13 (25.5)	11 (21.6)
Total/average					967	396 (41)	439 (45.4)

Nr: not recorded; CS: cannulated screws; HP: hook pin; SHS: sliding hip screw.

2.2. Determinants of the Incidence of Fixation Failure. With multiple fixation devices available and most studies concentrating on one implant versus another, we have included all fixation types in our review. Only studies reporting on patients aged 60 years and older were included.

Fixation failure was defined as

(i) nonunion (alternatively referred to in some studies as early, progressive, or redisplacement of the fracture or fracture collapse),

(ii) avascular necrosis of the femoral head,

(iii) cutout of the implant,

(iv) implant penetration of the femoral head,

(v) "Z-effect",

(vi) breakage of the implant,

(vii) detachment of the implant from the femur,

(viii) intraoperative fracture of the femur and,

(ix) later fracture of the femur.

Only excessive displacement necessitating revision surgery was classified as a fixation failure. Simple migration of the lag screw within the femoral head or a fracture that was noted to have united in "acceptable" varus, valgus, or rotation at routine followup was not classified as a fixation failure. Deep sepsis, despite being an important cause of patient morbidity and failed surgery, also fell outside our search criteria.

Where the number of patients providing data for any outcome was reported, we used these provided data. In studies in which the denominator was unclear, we used the numbers randomised or alive at followup.

2.3. Determinants of the Impact and Cost of Fixation Failure. We attempted to identify studies which specifically recorded final outcome measures in osteoporotic hip fracture patients who suffered a failed fixation. Data was extracted with regard to social and economic implications, namely, length of hospital stay, return to prefracture residential status, quality of life, and functioning as well as economic cost.

3. Results

3.1. Incidence of Fixation Failure. Undisplaced femoral neck fractures managed by internal fixation (IF) demonstrate an overall failure rate of 14.8% and a reoperation rate of 15.4% (Table 1).

A significantly higher failure rate, however, occurs in displaced fractures of the femoral neck. Randomized controlled trials (RCTs) demonstrate that, overall, a failure rate of 41% and reoperation rate of 45.4% can be expected (Table 2).

Table 3: Incidence of fixation failure and reoperation in peritrochanteric fractures of the femur. All patients >60 years.

Study	Year	Fixation method	Mean age	Followup (months)	n	Fixation failure n (%)	Revision surgery n (%)
de Grave* et al. [47]	2012	GN, ACE TN	74.9	12	112	4 (3.6)	4 (3.6)
Stern* et al. [48]	2011	SHS, GN, PFNA, and DHS Blade	86.4	12	269	11 (4.1)	13 (4.8)
Garg$^{\theta}$ et al. [49]	2011	SHS, PFNA	62.3	40	81	6 (7.4)	7 (7.4)
Varela-Egocheaga¥ et al. [6]	2009	PCP, GN	82	12	80	3 (3.8)	Nr
Pajarinen* et al. [50]	2005	SHS, PFN	81	4	108	4 (3.7)	4 (3.7)
Utrilla* et al. [51]	2005	SHS, TGN	80	12	163	10 (6.2)	5 (3.1)
Papasimos$^{\theta}$ et al. [52]	2005	SHS, PFN, and TGN	81.2	12	120	12 (10)	11 (9.2)
Miedel$^{\theta}$ et al. [53]	2005	GN, MSP	84	12	217	13 (6)	12 (5.5)
Saudan* et al. [54]	2002	SHS, PFN	83	12	168	4 (2.4)	8 (4.8)
Harrington$^{\theta}$ et al. [55]	2002	SHS, IMHS	83	12	102	6 (5.9)	Nr
Sadowski$^{\theta}$ et al. [7]	2002	95° DCS, PFN	79	12	35	8 (22.9)	8 (22.9)
Hoffman* and Lynskey [56]	1996	SHS, IMHS	82	3.7	110	4 (3.6)	2 (1.8)
Park* et al. [57]	1998	SHS, GN	73	18.5	60	3 (5)	1 (1.7)
Hardy* et al. [58]	1998	SHS, IMHS	81	12	100	5 (5)	7 (7)
Kukla* et al. [59]	1997	SHS, GN	83	6	89	0 (0)	2 (2.3)
Radford* et al. [60]	1993	SHS, GN	80	12	200	18 (9)	9 (4.5)
Leung* et al. [61]	1992	SHS, GN	80	7	186	13 (7)	6 (3.2)
Total/average					2200	97 (5)	99 (4.9)

Nr: not recorded; GN: Gamma Nail; TN: Trochanteric Nail; SHS: sliding hip screw; PFNA: Proximal Femoral Nail Antirotation; DHS Blade: Dynamic Hip System Blade; PCCP: Percutaneous Compression Plate; PFN: Proximal Femoral Nail; TGN: Trochanteric Gamma Nail; MSP: Medoff Sliding Plate; IMHS: Intramedullary Hip Screw; DCS: Dynamic Condylar Screw.
¥stable fractures only; *Stable and unstable fracture patterns; $^{\theta}$unstable fractures only.

With regard to peritrochanteric fractures of the femur, the results of RCTs demonstrate a failure rate of 5% and reoperation rate of 4.9% (Table 3). Failure rates will vary, however, depending on the stability of the fracture type. While most studies included both stable and unstable fracture patterns, Varela-Egocheaga [6] solely focused on stable fracture types noting a failure rate of 3.8%; this can be contrasted with the findings of Sadowski et al. [7] who investigated only the most unstable fracture patterns (reverse oblique and transverse intertrochanteric) and noted a significant increase in failure rate to 22.9%.

3.2. Impact of Fixation Failure. A hip fracture is probably the most devastating consequence of osteoporosis in our ageing population [8], with the concomitant increase in morbidity and mortality being well documented. Of particular interest, however, is the additional effect any fixation failure will have in this already frail population.

3.2.1. Length of Stay. On average, the failure of fixation results in a twofold increase in the length of hospital stay (Table 4). Thakar et al. [9] divided total hospital stay into acute—and community—stay periods and found that the majority of the 37-day difference in mean total time spent in NHS care for failed fixations was due to an increase in acute hospital bed days rather than community hospital days.

3.2.2. Return to Prefracture Residential Status. Several studies have noted a downgrade in patients' discharge destination following the failure of internal fixation compared to that of uncomplicated cases. Eastwood [10] noted that patients requiring revision surgery were 35 times more likely to be referred to continuing care, with a consequent increase in social dependency. Other studies support these findings with patients less likely to return to their own home and more likely to be referred for continuing rehabilitation [9, 11]. It appears, however, that this downgrade of residential status is limited to the short term and several authors have noted no difference at long-term followup [12, 13].

3.2.3. Quality of Life (QoL) and Functional Outcome. While all patients suffer a decrease in their quality of life after hip fracture, this is particularly evident in patients who have a failed fixation. Tidermark et al. [8] noted that mean quality of life (EQ-5D index score) was higher at each follow-up assessment for those with healing fractures than those who suffered a failure of fixation: at 4 months, 0.66 versus 0.49 ($P < 0.05$) and at 17 months, 0.62 versus 0.31 ($P < 0.005$). At

Table 4: Impact of fixation failure on length of stay (LOS).

Study	Year	LOS uncomplicated cases (days)	LOS revision cases (days)	Fold change
Thakar et al. [9]	2010	30	67.1	↑ 2.2
Foss et al. [24]	2007	12	55	↑ 3.2
Sipilä et al. [13]	2004	8	17	↑ 2.1
Tidermark et al. [62]	2003	17	31	↑ 1.8
Palmer et al. [11]	2000	29.2	54.4	↑ 1.8
Average				↑ 2.2

Table 5: Additional cost of fixation failure.

Study	Year	Cost uncomplicated cases	Cost revision cases	Net additional cost	Fold change
Thakar et al. [9]	2010	£ 8,976	£ 20,095	£ 11,119	↑ 2.2
Frihagen et al. [63]	2010	€ 33,301	€ 66,388	€ 33,087	↑ 2
Johansson et al. [39]	2006	€ 9,000	€ 18,300	€ 9,300	↑ 2
Rogmark et al. [30]	2003	$ 12,000	$ 29,000	$ 17,000	↑ 2.4
Palmer et al. [11]	2000	£ 5,215	£ 8,676	£ 3461	↑ 1.7
Average					↑ 2

inclusion, there had been no difference between the groups. They also noted a more profound decrease in body weight and lean body mass at 6 months in the fixation failure group. Other studies support this additional impact on quality of life in the short term, noting lower QoL scores and increased use of walking aids at 4–6-month followup [13–15].

With regard to long-term outcomes, studies reveal somewhat diverse findings. Frihagen et al. [14] noted that patients with failed IF requiring revision to hemiarthroplasty had worse QoL (Hip Score and Visual Analogue Score) at 4 months, but they did not differ from the healed IF group at 1- and 2-year followup. Similarly, Bjørgul and Reikerås [12] observed no difference at long-term followup in either pain scores or in the proportion of patients retaining their ability to be independent outdoor walkers. In contrast to this, however, several other studies have noted significantly impaired functional outcome and quality of life at one-to-five-year followup. Keating et al. [16], Magaziner et al. [17], and Tidermark [8], all observed that functional outcome for patients managed with IF who did not have subsequent surgery was clearly better than those who required revision surgery at 1-year followup, while Nilsson et al. [18], examining quality of life at 5-year followup via the Nottingham Health Profile (NHP Parts I and II), observed that patients with healed fractures had fewer problems with sleep, housework, and hobbies, and thus functioned better than patients who had required a secondary procedure.

Additionally, it is often assumed that the conversion of a failed IF for either femoral neck or peritrochanteric fractures is a straightforward solution to the problem. Studies, however, that have compared the outcome of primary arthroplasty (either for osteoarthritis or hip fracture) versus revision of failed fixation do not bear this out [14, 19–21]. There is increased surgical difficulty, more complications (with dislocation and infection rates approximately doubled). Functional outcome is also inferior and there is evidence that the survivorship of these revision prostheses is shorter. There are several reasons for this: patients frequently become profoundly disabled after failed IF leding to more muscle wasting and disuse osteoporosis. Previously operated sites may retain inflammatory tissue or act as a nidus for infection; removal of retained hardware can involve extensive dissection and further damage bone structure, while empty screw holes can lead to inadequate cement pressurisation; fracture collapse may also frustrate attempts at restoration of equal leg lengths.

3.2.4. Mortality. As hip fractures—and their surgical treatment—carry a well-documented increased mortality risk, it is of particular interest to examine the effect of additional surgery in the same patient group. While Thakar et al. [9] did note a significant increase in the probability of mortality following re-operation, other studies have observed only transient increases in mortality during either the initial period of hospitalisation [22] or during the first 6 months [23]. Revision procedures after this did not increase mortality risk and at long-term followup, several authors noted no overall difference in mortality between the groups [10–13, 24, 25]. It is likely, however, that patients passed fit to undergo a secondary operation are a subgroup within this population with a bias towards better survival.

3.2.5. Cost. Table 5 outlines the findings from several studies with regard to the additional cost of fixation failure. While the method of cost assessment and currency differ across studies, a clear trend can be seen with revision surgery for failed IF leading to an overall doubling of costs.

4. Discussion

Fragility fractures of the hip, with their well-documented impact on morbidity and mortality, probably represent the most devastating outcome of osteoporosis in the elderly. Further complicating management, however, is that weakened osteoporotic bone and vulnerable vascular supply predispose toward a failure of fixation. As our population becomes increasingly older and the incidence of hip fractures continues to rise, even low failure rates will constitute a major challenge to health care systems. Central then to planning for these changes is an understanding of both the incidence of such failures of fixation and the impact they can have.

Overall, the incidence of fixation failure in osteoporotic hip fractures ranges from 5% in peritrochanteric fractures to 15% and 41% in undisplaced and displaced fractures of the femoral neck, respectively. Our findings, in general, support the view that failed internal fixation of these fragility fractures carries a poor prognosis: it leads to a twofold increase in the length of hospital stay and a doubling of healthcare costs. Patients are more likely to suffer a downgrade in their residential status upon discharge with a consequent increase in social dependency. Furthermore, the marked disability and reduction in quality of life evident before salvage procedures may persist at long-term followup. The risk, of course, for the elderly patient with a prolonged period of decreased functioning is that the disability becomes permanent. Despite this, however, no clear link between revision surgery and an increase in mortality has been demonstrated in the literature.

In view of these findings, of particular relevance then is the discussion between IF and arthroplasty in the management of osteoporotic fractures of the hip. While there is a general consensus that elderly patients with an undisplaced (Garden I and II) fracture of the femoral neck can achieve good results after IF with regard to healing, function, and QoL [8, 26], the optimum management of displaced (Garden III and IV) fractures has previously been a source of debate. A recent meta-analysis examining this issue by Parker and Gurusamy [27] noted that although IF was associated with less initial operative trauma when compared to arthroplasty, there was a significantly higher re-operation rate of 40% versus 11%. Definitive conclusions could not be made regarding the length of hospital stay, return to prefracture residential status, or mortality, but pain and functional outcome did appear to be better for those undergoing a cemented arthroplasty in comparison with fixation. Similar findings were noted by Bhandari et al. in 2003 [28] and Rogmark and Johnell in 2006 [29]. The higher re-operation rate associated with IF is also reflected in studies reporting on financial cost which generally show fixation to be the more expensive option; although IF may have the advantage of a lower initial implant cost, this is outweighed by the high costs associated with repeat admissions and revision surgery [16, 30–32]. Reflecting the high failure and re-operation rates observed with IF, the majority of these fractures are managed by arthroplasty in modern orthopaedic practice. For peritrochanteric fractures of the femur, IF remains the mainstay of treatment, current controversy focusing on intra- versus extramedullary devices and cephalic fixation techniques.

In summary, our findings emphasise the importance of optimising patient surgery in order to reduce the incidence of fixation failure and the associated health and social costs. Furthermore, as arthroplasty has become the preferred treatment method for many of these patients, future studies should focus on which arthroplasty would best serve different patient groups.

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Research Article

Using Three-Dimensional Computational Modeling to Compare the Geometrical Fitness of Two Kinds of Proximal Femoral Intramedullary Nail for Chinese Femur

Sheng Zhang,[1] Kairui Zhang,[1] Yimin Wang,[1] Wei Feng,[2] Bowei Wang,[1] and Bin Yu[1]

[1] *Department of Orthopedics and Traumatology, Nanfang Hospital, Southern Medical University, Guangzhou 510515, China*
[2] *Department of Orthopedics, Second Affiliated Hospital to Inner Mongolia Medical University, Hohhot 10020, China*

Correspondence should be addressed to Bin Yu; 280219927@qq.com

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Objective. The aim of this study was to use three-dimensional (3D) computational modeling to compare the geometric fitness of these two kinds of proximal femoral intramedullary nails in the Chinese femurs. Computed tomography (CT) scans of a total of 120 normal adult Chinese cadaveric femurs were collected for analysis. With the three-dimensional (3D) computational technology, the anatomical fitness between the nail and bone was quantified according to the impingement incidence, maximum thicknesses and lengths by which the nail was protruding into the cortex in the virtual bone model, respectively, at the proximal, middle, and distal portions of the implant in the femur. The results showed that PFNA-II may fit better for the Chinese proximal femurs than InterTan, and the distal portion of InterTan may perform better than that of PFNA-II; the anatomic fitness of both nails for Chinese patients may not be very satisfactory. As a result, both implants need further modifications to meet the needs of the Chinese population.

1. Introduction

Intramedullary fixation device has advantages from the biomechanical point of view and has become increasingly popular in treating unstable trochanteric fractures [1, 2], but serious implant-related complications have been reported, such as femoral shaft fracture [3], cutting out [4], lateral migration of the femoral neck screw [4, 5], and distal locking [6, 7]. In 2003, the AO/ASIF group developed the Proximal Femoral Nail Antirotation (PFNA) to improve the rotational and angular stability with a helical blade which can avoid bone loss that occurs during the drilling and insertion of a standard sliding hip screw [8]. Biomechanical tests also demonstrated a significantly higher cut out resistance in the osteoporotic bone compared to commonly used screw systems [9, 10]. However, lots of intra- and postoperative complications were reported since it was used in Asians, such as pain around the hip and the thigh, femoral shaft fracture, lateral blade migration, and lateral cortex splitting during operation [9, 11, 12]. In response, AO/ASIF developed the PFNA-II, which was developed specifically for Asians. The flat lateral shape at the proximal portion of PFNA-II made it easier to be inserted intraoperatively, and its shortened proximal tip significantly reduced the postoperative hip pain [13, 14], but some Asian patients still complained about thigh pain after operation.

Similarly, a new device has been developed which uses 2 cephalocervical screws in an integrated mechanism allowing linear intraoperative compression and rotational stability of the head/neck fragment (InterTan) [15]. Biomechanical study shows the InterTan possesses some biomechanical benefits in internal fixation of unstable femoral neck fractures compared with DHS and CS [16]. Meanwhile, clinical outcomes support that the InterTan device appears to be a reliable implant for the treatment of intertrochanteric femoral fracture [15]. But few studies have reported the use of these two implants in Asians. The geometrical fitness between these two implants and Chinese femurs is still uncertain.

The purpose of this study was to compare the geometrical fitness of PFNA-II and InterTan for Chinese femurs and to discuss possible improvements needed for these two implants used in the Chinese population. We used three-dimensional (3D) computational modeling, because it has been well demonstrated that a 3D modeling is more precise than 2D

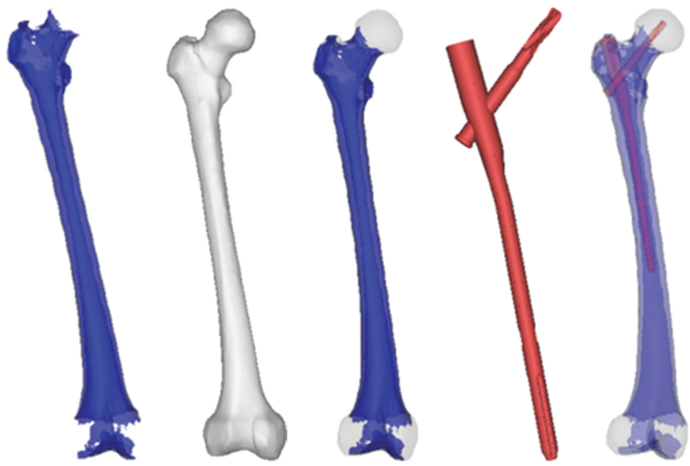

Figure 1: The femur and implant models were reconstructed with software and assembled according to the paper guidelines. (a) The femoral cortex model; (b) the intact femur model. (c) The femoral cortex differentiated from the intact femur model. (d) The PFNA-II model; (e) the implant assembled with the femoral model.

methods by Budge et al. as it is less influenced by body position [17].

2. Methods

A total of 120 cadaveric specimens of full length femur were selected and CT scanned at Nanfang Hospital, Southern Medical University, Guangzhou, China. The scanning region was set from the top of the great trochanter at 0.75 mm intervals to the distal femoral joint surface.

The characteristics of the GE 16 row spiral CT scanner were as follows: 120 KV, 300 MA, thickness of 0.75 mm, pitch of 0.75 mm, scan time of 200 ms each (10–12 s total scan time), and window diameter of 360 mm. All CT data were saved in ".dicom" format and imported into reverse engineering software Mimics 10.01 (Materialise, Belgium) for 3D reconstructions. 3D femoral models were established via masks creating, region growing, calculation, and remeshing of 3D objects.

According to the PFNA-II morphological parameters provided by Synthes and the InterTan morphological parameters provided by Smith & Nephew, 3D models of the two implants were reconstructed with Pro E 4.0 (PTC, MA, USA) software. Then the models of both implants were assembled into the femoral models to compare the geometrical fitness between the implants and the femur (Figure 1).

2.1. Position of Implants. The specific location of the whole implant was adjusted until it was in full compliance with the manufacturer's operational guidelines. The antirotation screw was placed in the middle of the femoral head, and the depth of insertion of the intramedullary nail was determined according to the position of the antirotation nail.

2.2. Insertion Point. The entry point for the nail was defined according to the manufacturer's guidelines. In the anteroposterior position (AP) view, the entry point was at the vertex of the great trochanter. In the lateral view, the entry point was at the anterior 1/3 of the vertex of the great trochanter.

In an ideal case, an anatomically shaped nail fits entirely the inside medullary cavity of the bone, indicating that the bone-nail construct stability is optimal, and the axial anatomical alignment of the bone is preserved. Therefore, in this study, the anatomical fitness between nail and bone was assessed by the extent the nail model was impinging or deviating from the medullary cavity of a particular intact (or nonfractured) femoral model. Once an impingement occurred, its incidence, thickness, and length were recorded precisely.

The following geometrical fitness parameters were precisely measured (Figures 2 and 3):

(A) The greatest thickness an implant impinged on the inner cortex of proximal femoral medullary cavity.

(B) The average length of an impingement area in proximal femur.

(C) The distance from the center of an impingement area (proximal) to the top of the great trochanter.

(D) The length of an implant protruding beyond the top of the great trochanter.

(E) The length and maximum thickness of a nail impinging the femoral shaft.

(F) The distance from the center of an impingement area to the top of the great trochanter (middle).

(G) The maximum distance between the inner cortex and an implant in the middle of femoral shaft.

(H) The length of an impingement area at the distal part of an implant.

2.3. Statistical Analysis. SPSS 16.0 (IBM, USA) was used for statistical analysis. Measurement data are shown in the form of mean $(\overline{X}) \pm$ SD. The repeated measures test was used to

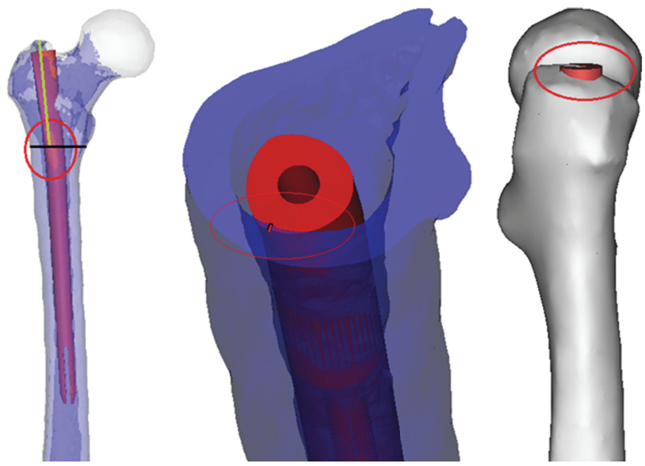

FIGURE 2: Proximal fitness of the implant with the femoral model. (a) The InterTan assembled with femoral model; the region within the red circle was the region of interest, the model was cut along the black line, and the distance between the top of the great trochanter and the center of the impingement region was depicted in green line. (b) The red line indicated the maximum thickness of the impingement area. (c) Within region the red circle was the proximal end of the implant protruding from the top of the great trochanter.

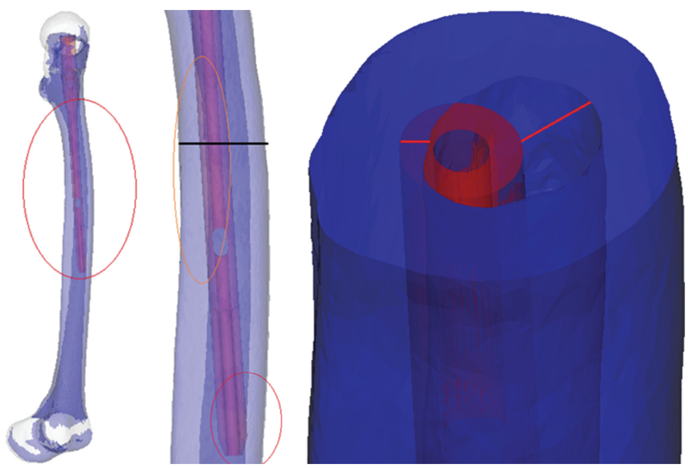

FIGURE 3: The model was assembled by PFNA-II and femur. (a) The region within the red circle was the region of interest. (b) The impingement area can be easily distinguished within the red circle, and the model was cut along the black line; (c) after the cut of the model, the maximum thickness of the impingement area and the distance from the inner cortex can be measured according to the direction of the red line.

assess the statistical significance of the measurement data. For all tests, $P < 0.05$ was considered significant. Categorical variables were analyzed by the chi-square test or Fisher exact test where appropriate.

3. Results

3.1. Proximal Fitness. At the proximal part of the nail, the anatomical fitness of these two implants was assessed by criteria (A), (B), (C), and (D). The impingement occurred in 24.2% ($n = 29$) of the InterTan models with an average thickness of 2.53 mm and an average length of 8.61 mm, including 26 cases on the anterior side of the proximal femur and 3 on the lateral. In contrast, the impingement occurred only in 5.8% ($n = 7$) of the PFNA-II models with an average thickness of 1.27 mm and an average length of 10.62 mm, all on the lateral side of the proximal femur. There was a significant difference regarding the impingement incidence between the two models ($P = 0.003$). The average distance from the top of the great trochanter to the center of the impingement area was 57.31 mm in InterTan nails and 62.82 mm in PFNA-II (Table 1).

The incidence of the implants protruding beyond the top of the great trochanter was 5.8% ($n = 7$) in InterTan nails and 7.5% ($n = 9$) in PFNA-II, the average protruding lenths being 1.05 mm and 1.48 mm, respectively.

3.2. Middle Fitness. The fitness at the middle portion of the implant for the femur was analyzed by the values (E), (F) and (G). The impingement occurred in 53.3% ($n = 64$) of

Table 1: The average fitness value of impingement on the proximal portion of the implant (mm).

	InterTan (n = 29)	PFNA-II (n = 7)	P value
Thickness	2.53 ± 0.58	1.27 ± 0.15	0.017
Length	8.61 ± 1.84	10.62 ± 2.26	0.183
Distance from the top of the great trochanter	57.31 ± 5.42	62.82 ± 5.87	0.213

Table 2: The average fitness value on the middle and distal portion of the implant (mm).

	InterTan (n = 64)	PFNA-II (n = 52)	P value
Impingement thickness on the middle shaft of the femur	2.11 ± 0.36	1.62 ± 0.38	0.073
Impingement length on the middle shaft of the femur	60.62 ± 8.37	58.48 ± 7.38	0.361
Distance from the top of the great trochanter to the central of the impingement area	154.43 ± 7.72	148.74 ± 8.87	0.652
Distance between the nail and the inner cortex in the lateral view	4.17 ± 0.35 (n = 120)	6.95 ± 0.68 (n = 120)	0.035

the InterTan models and 43.4% (n = 52) of the PFNA-II models, and the incidences were comparable (P = 0.087). The parameters related to the impingement area were recorded in Table 2.

The maximum space between the implant and the inner cortex was larger in PFNA-II models than that in InterTan models. The average maximum space was 6.95 mm (SD: 0.68 mm) in the PFNA-II models, much larger than in the InterTan models (4.17 mm ± 0.35 mm) (P = 0.035). In the lateral view, for all the models the maximum distance was located at the anterior edge of the nail (Figure 3).

3.3. Distal Fitness. At the distal part of the implant, impingement occurred in 31.7% (n = 38) of the InterTan models, significantly lower than 52.5% in the PFNA-II models (n = 63) (P = 0.007). The average length of impingement area was significantly shorter in the InterTan models (8.5 ± 2.13 mm) than in the PFNA-II models (17.6 ± 4.37 mm) (P = 0.001).

4. Discussion

Intraoperative and postoperative complications associated with intramedullary nails in the treatment of intertrochanteric fracture can result from imperfect fitness of an internal implant with specific morphology of the human bone. Design of anatomically fitting nails requires morphologic data of the bone that are representative of a specific population. It is well known that fixation devices based on the geometrical proportions of Caucasians do not adequately fit Asian patients, leading to such device-related complications as reported for the Gamma nail [18] and ETN [19].

It has been well demonstrated that the PFNA with a bending angle of 6° and a proximal diameter of 17 mm would cause a fracture of the proximal femur during inserting the nail. Otherwise, a larger femoral cannel should be prepared to benefit the nail insert more smoothly [12, 20]. The PFNA-II for Asians was designed to have a bending angle of 5° and a proximal diameter of 16.5 mm. Additionally, the proximal lateral surface was made flat to facilitate insertion and to lower the pressure on the lateral cortex [13]. The present study has demonstrated that the modified nail has a considerably better anatomic fitness for Chinese proximal femur. On the contrary, in this study the InterTan performed worse in the geometrical fitness with Chinese proximal femur, with an impingement incidence of 24.2%. Most impingements occurred on the anterior side of the proximal femur, indicating the anteroposterior diameter of the InterTan may not match well Chinese proximal femurs. Additionally, it is not easy to insert an InterTan nail with a trapezoidal proximal end into a poorly reduced marrow cavity. Consequently, repeated reduction and manipulation may increase both operative and fluoroscopy time and blood loss as well.

Hip and thigh pain [10, 21] seemed to be very common complications in previous reports and could occur in 90.1% of the cases during the follow-up period. One explanation comes to the chronic muscle injury caused by the overlong proximal end of the nail protruding beyond the great trochanter. In this study, both implants matched well the proximal tip of the great trochanter. Clinical results also supported that few patients experienced tenderness following either PFNA-II or InterTan implantation [10, 15].

It is known that Chinese women have a shorter femoral neck, smaller femoral neck angles, and increased anterior bowing of the shaft than white American women [18, 19]. It is also acknowledged that the overall stability of the bone-implant construct is important for significant improvements in decreasing postoperative pain and increasing postoperative walking ability. In this study, however, both nails impinged frequently upon the posterior side of the femur at the middle portion of the implant but deviated a lot from the anterior inner cortex from the lateral view. Moreover, both nails did not contact very well the inner cortex at the middle shaft of the femur, due to the Asian characteristic anterior bowing of the femoral shaft. As a result, stress can be concentrated on this region, especially around the locking screw, making the femoral shaft more vulnerable to fracture or leading to long-term thigh pain that cannot be explained. It is suggested that the morphology of the Chinese anterior bowing of the femoral shaft should be taken into consideration when these two nails are used in Asians, especially for those shorter elderly female patients. Furthermore, moderate modification is needed for both implants.

Furthermore, in the present study both implants were biased to the anterior inner cortex at the distal portion from the lateral view. The length of the impingement area was longer in PFNA-II models than in InterTan models. In a similar way, stress may be usually concentrated on this area. It is advised that a shorter PFNA-II should be chosen in treatment of short elderly female patients.

In this study, the impinged areas were mostly located in three regions of the femur. The first region was about 60 mm below the top of the great trochanter and on the anterolateral side of the proximal femur. The second one was located on the posterior side of the femoral shaft, about 155 mm below the top of the great trochanter. The third region was around the distal tip of the nail. In order to design a proximal femoral intramedullary nail fit for Chinese population, the three above regions should also be taken into consideration.

The impressive strength of the present study lies in the simplicity, efficiency, and low cost of the methodology we used to compare the fitness of two implants for a given population, compared with clinical trials.

In conclusion, although PFNA-II may fit better for the Chinese proximal femurs than InterTan and the distal portion of InterTan may perform better than that of PFNA-II, the anatomic fitness of both nails for Chinese patients may not be very satisfactory. Further clinical results are needed to test the findings of the present 3D computational modeling. In addition, multicenter CT data are also needed to build a database of Chinese bones for 3D modeling which will serve as the basis necessary for the research and development of orthopedic devices for the Chinese population.

Conflict of Interests

The authors declare that they have no conflict of interests.

Authors Contribution

S. Zhang, K. Zhang, and Y. Wang contributed equally to this work.

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Clinical Study

Prophylactic Nailing of Incomplete Atypical Femoral Fractures

Chang-Wug Oh,[1] Jong-Keon Oh,[2] Ki-Chul Park,[3] Joon-Woo Kim,[1] and Yong-Cheol Yoon[2]

[1] *Department of Orthopedic Surgery, Kyungpook National University Hospital, 50, 2-Ga, Samdok, Chung-gu, Daegu 700-721, Republic of Korea*
[2] *Department of Orthopedic Surgery, Korea University Guro Hospital, 148, Guro-dong, Guro-gu, Seoul 152-703, Republic of Korea*
[3] *Department of Orthopedic Surgery, Hanyang University Guri Hospital, 153, Gyeongchun-ro, Guri, Gyeonggi-do 471-701, Republic of Korea*

Correspondence should be addressed to Joon-Woo Kim; orthopedics@naver.com

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Introduction. Recent reports have described the occurrence of low-energy subtrochanteric and femoral shaft fractures associated with long-term bisphosphonate use. Although information regarding the surgical treatment of these atypical femoral fractures is increasing, it is unclear if the preventive operation is useful in incomplete fractures. This study examined the results of preventive intramedullary nailing for incomplete atypical femoral fractures. *Material and Methods*. A retrospective search was conducted for patients older than 50 years receiving bisphosphonate therapy, with incomplete, nondisplaced fractures in either the subtrochanteric or diaphyseal area of the femur. Seventeen patients with a total of 20 incomplete, non-displaced lesions were included. The mean duration of bisphosphonate use was 50.5 months. Eleven of the 17 (64.7%) patients had complete or incomplete fractures on the contralateral femur. All were treated with prophylactic fixation of an intramedullary (IM) nail. The minimum followup was 12 months. *Results*. All cases healed with a mean period of 14.3 weeks. Nineteen of the 20 cases healed with the dissolution of incomplete fractures of the lateral aspect. A complete fracture developed at the time of nailing in one patient, but it healed with callus bridging. *Conclusion*. IM nailing appears to be a reliable way of preventing the progress of incomplete atypical femoral fractures.

1. Introduction

Bisphosphonate (BP) medication has been the mainstay treatment of postmenopausal osteoporosis and metastatic diseases to the skeleton [1–4]. Although its efficacy is well known, several reports have described the bisphosphonate-associated insufficiency fractures of the femur among patients associated with long-term BP use [5]. Some studies have suggested that chronic suppression of bone turnover may produce hypermineralized bone, which is more brittle. These fractures differ from the typical proximal femoral fracture associated with osteoporosis. They are caused by low-energy mechanisms, with the typical radiographic features of unicortical beaking and hypertrophy of the diaphyseal cortex, appearing as insufficiency fractures [6, 7]. The prefracture radiographs of atypical femoral fractures have been described and include cortical thickening or beaking as well as a transverse line in the femoral cortex [8]. Several studies have reported that MR may find an incomplete lesion of atypical femoral fractures. These lesions have the potential to progress to complete fractures with associated thigh pain.

The decision to treat incomplete atypical femoral fractures nonsurgically or surgically is controversial. Although activity modification with partial weight bearing on the affected extremity is an option, it does not appear to be a reliable way of treating these fractures because the majority progress to fracture completion [9, 10]. Prophylactic fixation may prevent the fracture from progressing and the related morbidity. On the other hand, few studies have reported the results and risks of prophylactic fixation [11]. This study describes the ultimate outcomes of patients with incomplete atypical femoral fractures treated with intramedullary nailing.

2. Patients and Methods

A search of the fracture databases from three trauma centers was performed to identify patients older than 50 years with incomplete, non-displaced stress fractures in either the subtrochanteric or diaphyseal area of the femur between January 2008 and August 2010. Of these, 17 patients (20 fractures) with fractures radiographically characteristic of a bisphosphonate-associated incomplete stress femoral fracture were included in this study. The study design and protocol were approved by the Institutional Review Board. The inclusion criteria were as follows: (1) incomplete atypical femur fracture, as defined on the radiographs, (2) prophylactic IM nailing for incomplete fractures, and (3) clinical followup for at least one year after the index operation.

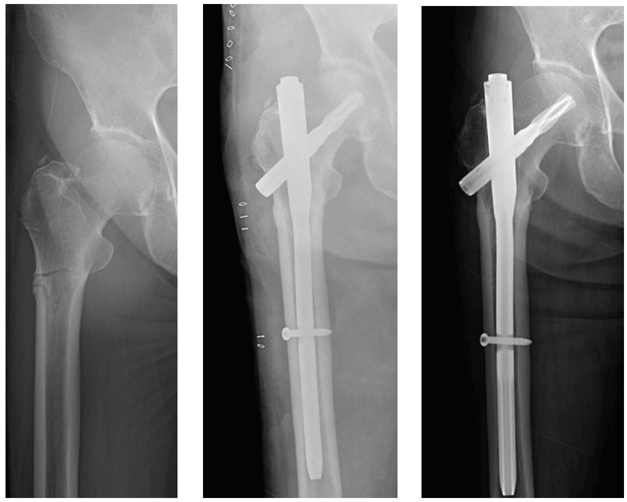
Eleven of the 17 (64.7%) patients (14 fractures) had complete or incomplete fractures of the contralateral femur. The other 6 patients did not show these lesions up to the latest followup. All except for three had a documented history of bisphosphonate use at the time of presentation. All patients were female with a mean age of 68.3 years (range, 54~83). The bone mineral density was evaluated in all cases by dual-energy X-ray absorptiometry (DEXA), which showed a mean T-score of −2.97 (range, −1.7~ −5.2). Eleven of the 14 patients (78.6%) had been treated with alendronate, two patients were treated with risedronate, and one patient was treated with ibandronate. The average length of treatment with bisphosphonates was 50.5 months (range, 6~102). All patients had a minimum followup of 12 months (mean, 20.1; range, 12~33). All patients were recalled specifically for this study to assess the current physical status. The data was also obtained from medical records and radiographs.

Six fractures were located in the subtrochanteric area and 14 were located in the femoral shaft. All except one fracture lines located within lateral cortex only, whereas one fracture at subtrochanteric region involved more than 2/3 cortical width without displacement (Figure 1). All patients were treated with prophylactic fixation of an intramedullary nail. Eleven patients with incomplete contralateral femoral fractures were also nailed simultaneously or after primary operation. Closed IM nailing with static mode was performed in all cases. The entries of the nail were piriformis fossa in 3 patients and the tip of the greater trochanter in 17 cases. In the types of IM nail, a standard interlocking nail was used in 9 cases, and a cephalomedullary or reconstruction type nail was used in 11 cases.

All patients began hip and knee motion exercises, and weight bearing as tolerated was allowed immediately after surgery. Routine follow-up radiographs were obtained every 6~8 weeks until the fracture line vanished. Radiographic healing was documented as a loss of fracture lucency on the standard anteroposterior and lateral femoral radiographs taken at the standard follow-up intervals, whereas clinical healing was documented as an absence of pain (in those who presented without fracture lucency) and/or a loss of fracture lucency on the radiographs.

3. Results

All cases healed with a mean period of 14.3 weeks (Figure 1). None of the patients showed any limited motion of the hip and knee joints, and they could perform their normal daily activities. All could walk without crutches after a mean of 6 months (4~8 months).



(a) (b) (c)

Figure 1: (a) A 72-year-old woman had pain in her right thigh with a transverse fracture line and thickening of the lateral cortex in the subtrochanteric area. (b) She underwent internal fixation using a proximal femoral nail. (c) At 13 weeks postoperatively, she had no pain with a dissolution of the fracture line at the lateral cortex.

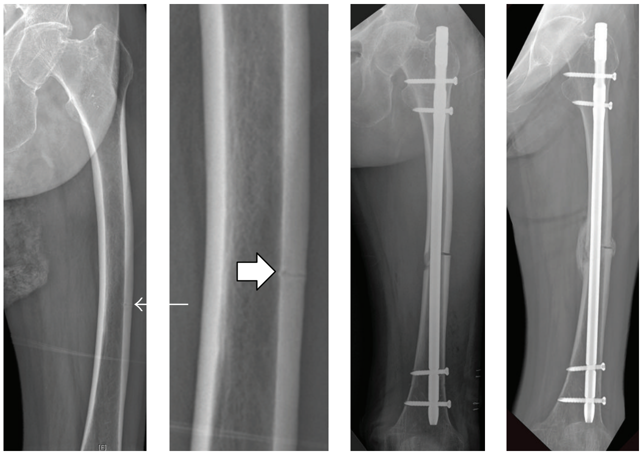
Nineteen of the 20 cases healed with the dissolution of the incomplete fracture of the lateral aspect. A complete fracture developed at the time of nailing in one patient, but it healed with callus bridging by 18 weeks after surgery. This complication was attributed to a mismatch of curvature between the femoral bow and IM nail (Figure 2).

With the exception of 3 patients with a complete atypical femoral fracture on the contralateral side, which were operated simultaneously, the average hospital stay was 5.8 days.

No patients had hardware removed for symptomatic reasons after the completion of fracture healing. No infections were documented in any of the study patients.

4. Discussion

Over the past few years, a number of case series have suggested an association between low-energy atypical fractures of the femur and BP use for osteoporosis management, even though some of non-BP users also developed similar lesions [12]. The definition, incidence, and characteristics of atypical femoral fractures are unclear, because of multiple associated risk factors [13]. But, a recent nation-wide study showed a high prevalence of current bisphosphonate use among patients with atypical fractures and its relative risk about 47 in the cohort analysis [14]. Therefore, for patients receiving BP therapy and who reported the symptoms of pain originating from the femur, an appropriate radiographic examination of both femurs is recommended to find any suspicious lesions, including the prefracture radiographic findings. Several studies [9, 10] reported that the spontaneous healing



(a) (b) (c) (d)

Figure 2: (a) A 74-year-old woman suffered thigh pain and her AP radiograph showed exaggerated femoral bowing with a transverse radiolucent line (arrow) in the lateral cortex of the distal 1/3 of the left femur. (b) A magnified view (box arrow) of the lesion revealed an incomplete, prefracture lesion of an atypical femoral fracture. (c) After preventive IM nailing, a complete fracture occurred. (d) The union was achieved with callus bridging at 18 weeks postoperatively.

of atypical femur fractures was not expected. Most non-displaced fractures progressed to fractures with secondary displacement, and complete fractures inevitably developed even with a low-energy injury. Although established atypical femoral fractures require surgical treatment, there are few reports of surgical treatment to prevent incomplete lesions from progressing to complete fractures. In this study, 20 cases of incomplete or non-displaced lesions were found. The aim of this study was to determine the efficacy and results of preventive IM nailing in patients with incomplete lesions of atypical femoral fractures.

The union rate varies after the surgical treatment of complete atypical femoral fractures. Although Capeci and Tejwani [6] reported that all 7 fractures achieved union after reamed IM nailing, they included four cases of non-displaced lesions. On the other hand, in a recent study excluding the prefracture lesions [15], the healing of atypical femoral fractures after IM nailing was unsatisfactory with a low union rate (54%), and many patients required additional procedures. The result of 100% union means that prophylactic IM nailing is a meaningful method. This is in contrast to the long duration of healing and the late return to normal daily activities after non-surgical treatment, which is successful only in a small proportion of cases.

Traditionally, IM nailing of femoral shaft fractures was reported to be a very successful surgical procedure, with a 98% to 99% healing rate and a very low complication rate [16]. On the other hand, Weil et al. [15] reported a higher failure rate of IM nailing in atypical femoral fractures. They insisted that these fractures might reflect an impaired bone healing process rather than the differences in surgical technique. In this series, there was only one minor complication of further fracture during nail insertion, which healed without secondary procedures. This is comparable to the report of a high complication rate in a series of complete fractures [17]. IM nailing is easier before than after fracture completion, and the healing time is much less. In addition, there is a shorter postoperative hospital stay. Therefore, the significance of preventive nailing is noteworthy.

The most frequent complication of IM nailing of atypical femoral fractures was intraoperative femoral shaft comminution during nail insertion up to 29.4% [17]. This complication was also experienced in non-displaced femoral shaft fractures in the present study, which appears to be an iatrogenic fracture during nail placement. Lim et al. [18] reported that femoral bowing deformities are a high-risk factor of femoral insufficiency fractures. The mismatch of curvature between the implant and femur is believed to be the reason for this intraoperative complication due to the observation of exaggerated femoral bowing in the present case.

This study had several limitations. This study was a retrospective case series, and the sample size of this study was relatively small. Because of the different locations of pathologic lesions, the nails used were not the same. In addition, plate fixation was not included as a preventive operation, even though IM nails can be impractical in certain situations. In a recent report [15], the results of plate fixation were unsatisfactory in atypical femoral fractures and they were excluded from the study design. Therefore, a prospective randomized trial with a larger cohort will be needed to compare IM nailing with plate fixation.

5. Conclusion

Prophylactic fixation of atypical femoral fractures is recommended. Despite the small number of patients who underwent prophylactic fixation, this procedure appears to achieve a more efficient postoperative course.

Conflict of Interests

All authors have certified that they have no commercial associations (e.g., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interests in connection with this paper.

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Clinical Study

The Bristol Hip View: Its Role in the Diagnosis and Surgical Planning and Occult Fracture Diagnosis for Proximal Femoral Fractures

J. Harding,[1] T. J. S. Chesser,[2,3] and M. Bradley[1]

[1] *Departments of Radiology, Frenchay Hospital North Bristol NHS Trust, Bristol BS16 1LE, UK*
[2] *Departments of Trauma and Orthopaedic Surgery, Frenchay Hospital North Bristol NHS Trust, Bristol BS16 1LE, UK*
[3] *Departments of Orthopaedics, Frenchay Hospital North Bristol NHS Trust, Bristol BS16 1LE, UK*

Correspondence should be addressed to T. J. S. Chesser; timandsallychesser@hotmail.com

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Aim. To evaluate whether a modified radiographic view of the femoral neck improves the diagnosis of occult proximal femoral. *Materials and Methods*. Prospective study of patients presenting with clinically suspected proximal femoral fractures or who underwent traditional plain radiographic views and the Bristol hip view (a 30-degree angled projection). Six blinded independent observers assessed the images for presence of a fracture, anatomical level, and displacement. *Results*. 166 consecutive patients presenting with the clinical diagnosis of a proximal femoral fracture, of which 61 sustained a fracture. Six of these were deemed occult due to negative plain and had proven fractures on subsequent cross-sectional imaging. The Bristol hip view demonstrated five of these six fractures. It performed better than the traditional lateral hip view to identify the injury. The Bristol hip view predicted correctly the fracture type and displacement in all cases and missed only one of the occult fractures. *Conclusion*. The Bristol hip view is more sensitive and clearer than a lateral projection for patients. It adds useful diagnostic information and performs better than the traditional views in occult fractures. Its use may prevent the need for further cross sectional imaging and subsequent surgical delay.

1. Introduction

There is a recent impetus in the early diagnosis and treatment of hip fractures [1]. The incidence of occult femoral neck fractures on plain radiographs is reported between 1% and 4% but this figure is higher in selected study groups [2–5]. Little has been published regarding optimising plain radiography to increase sensitivity and decrease the incidence of occult femoral neck fractures. Such an approach would help obviate the need for expensive additional imaging investigations. The standard radiographic views for the patient with a suspected femoral neck fracture have traditionally been an anteroposterior (AP) pelvis with lateral hip view.

Previously, we have suggested a new radiographic projection (Figure 1) for femoral neck fractures in an experimental study (the Bristol hip view) [6]. The Bristol hip view is obtained with 30° tube angulation, the angle of incidence to the femoral neck being nearer to 90°, and has been shown to demonstrate femoral neck fractures with greater clarity in both the subcapital and mid-cervical regions than on a standard AP view [6].

In this study, the aim was to assess the relative sensitivity and specificity of all the three of these radiographic views and in particular assess whether the Bristol hip view added information leading to the diagnosis of otherwise occult fractures of the neck of femur.

Data was collected surrounding the clinical impact of the Bristol hip view, to establish whether the view allows better anatomical description of any fracture, its displacement, and whether it assists in surgical treatment planning.

2. Materials and Methods

The study was granted approval by the local research ethics committee. The Bristol hip view (Figure 2) was added to the standard views for suspected fractured neck of femur in patients presenting to the emergency department (ED). Patients are imaged on the ED trolley in the same position as the AP view. A standard 30 × 24 cm cassette (landscape) was used, with the beam angled 30° from vertical towards the midline on the symptomatic side, centred on the hip joint, with the beam coned to the size of the cassette and the cassette displaced appropriately by the radiographer in the cassette tray. Exposures are manual and equivalent to the standard AP view (30–40 mAs, 75 kV). Patients are not imaged on the X-ray tables due to their fixed grid running perpendicular to the cassette. This technique does not require movement or rotation of the patient, thus avoiding pain.

Prospectively a series of consecutive patients with clinically suspected fracture of the neck of femur presenting to the ED over a nine-month period were included. Patients were followed up for three months from presentation to allow for any further development of relevant symptoms and ensure accuracy of occult fracture diagnosis.

Patient outcomes were classified as either "fracture" or "no fracture." The fracture group was determined on the basis of:

(a) unequivocal plain film evidence at the presenting episode,

(b) additional imaging (plain radiography, CT, MRI, and isotope bone scan) had been performed and reported as positive for fracture, or

(c) the patient had definitive surgery for fractured neck of femur during the clinical episode.

Those included under (b) were designated as "occult fractures" for the purposes of the study. The "no fracture" group had no evidence of fracture on initial plain radiography or on any subsequent imaging and were discharged from hospital without surgery (whether from the ED or elsewhere).

166 patients met the inclusion criteria in the study period. Of these, 61 were in the fracture group of which 6 (9.8%) were "occult." For blind assessment of the films, the 61 patients were balanced for image viewing with 39 randomly selected patients from the "no fracture" group. Accordingly, 300 images were coded with a number and letter (A, B, C-AP, Bristol hip view, and lateral, resp.) and saved from the trust PACS system as standard digital image files using a web PACS application.

Images were labelled with a single experimental code identifier but all other identifying information was removed from images; side markers were permitted but any information added to the original images by radiographers was removed. These images were made available to observers and viewed on standard PC monitors in the normal viewing conditions for clinicians in the ED.

Images were supplied to six assessors, three radiologists with musculoskeletal imaging interest and three experienced Consultant orthopaedic surgeons actively participating in the trauma team. All observers viewed images independently in a randomised order and completed the same response form: each image was viewed in isolation and judged as "fracture" or "no fracture." When judged a fracture, the observers also

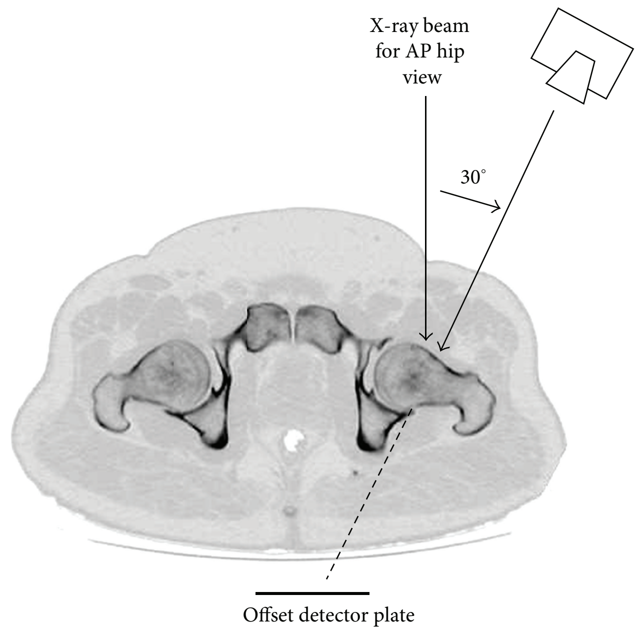

Figure 1: X-ray tube is angled 30° from the vertical, centered on the femoral head with the detector plate offset so that the whole femoral neck and acetabulum are included in the field.

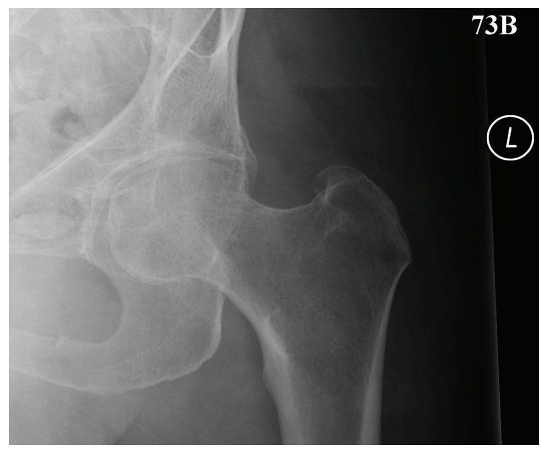

Figure 2: Example of the Bristol hip view—no fracture.

recorded the anatomical level (subcapital, basicervical, or pertrochanteric) and whether the fracture was displaced or not. These are all key features for orthopaedic surgeons in deciding their approach to any surgical management.

3. Results

166 consecutive patients demonstrated 61 proximal femoral fractures with 105 not sustaining a fracture; the latter were discharged and did not represent in the 3 month follow up period. There were 21 pertrochanteric fractures and 40 neck of femur fractures (Table 1).

For the six fractures designated "occult," the standard AP and lateral views were either negative for fracture or suspicious and they all underwent collaborative imaging (3 MRIs, 2 CTs, and 1 isotope bone scan). All the observers confirmed fractures on the Bristol hip view in four of the six occult fractures, four of the six observers in one case, and two of the six in one case.

The lateral view is traditionally the most technically challenging view to obtain and this was highlighted in this study; incomplete fracture data was obtained in 20 of the 40 fracture neck of femur patients; this was due to radiographic positioning in frail/sick patients, exposure, and limitation of utility of the digital radiography system. Thus from the lateral view, only 21/40 showed the fracture and 12/40 confirmed the displacement. The Bristol hip view demonstrated the fractures in all cases. It was felt that this view accurately predicted displacement in comparison to the AP view and performed better than the lateral, mainly due to the failure rate of the lateral view. Only in one patient was it felt the AP showed the displacement more accurately.

Treatment involved either fixation with cannulated screws or sliding hip screws. Displaced intracapsular fractures were treated with replacement arthroplasty. One patient died before surgery could be undertaken.

4. Discussion

The Bristol Hip view is modified from the angled view already performed routinely for surgical planning in the assessment of acetabular fractures (the Judet obturator oblique view). The concept is that this angled view should reflect a truer and more reproducible right angle of X-ray beam incidence to the femoral neck and thus demonstrate the anatomy and fractures more clearly (Figure 3). This study highlights how the lateral may often fail to be optimal and thus often non-contributory to the diagnosis and planning. It was shown that half of the laterals in the fracture neck of femur group gave incomplete information. This was due partly to the exposure factors which are dictated by the digital radiography system but also radiographic positioning difficulties in this elderly sick population who are immobile with a leg deformity and often obese. There has been an article suggesting the lateral view is of little use in this population with its only use in detecting displacement of a subcapital fracture which appears displaced on the AP view [7]. It is now accepted that if the fracture is displaced on either view then replacement arthroplasty is recommended rather than internal fixation, so this displacement is important to diagnose as it dictates alternative treatment [1].

The Bristol hip view also needs care to reproduce accurately the correct positioning; but overall it appears more reproducible than the lateral. Too much angulation may lead to the neck not appearing sufficiently elongated and thus the posterior rim of the acetabulum may mask the fracture (Figure 4). The Bristol hip view was originally described by Bradley et al. using an average femoral neck anteversion angle derived from a combination of CT and historical data, so errors in angulation may also occur due to differences in the anteversion angle as well as the positioning of the leg due to the fracture. In the authors' opinion the success of the Bristol hip view lies with the way it elongates the anatomy of the femoral neck, similarly achieved when investigating the scaphoid fracture with the utilisation of the elongated view along the long axis of the bone.

Regarding the "occult" fractures, the lateral view did not identify any of fractures, whereas the AP was suspicious in

Table 1: shows the distribution of femoral neck fractures with their displacement.

	Neck of femur fracture	
	Subcapital	Basicervical
Total	16	24
Displaced	13	19
Nondisplaced	3*	5^

*3 occult fractures in this group.
^3 occult fractures in this group.

Figure 3: Example of a femoral neck fracture shown on the Bristol hip view.

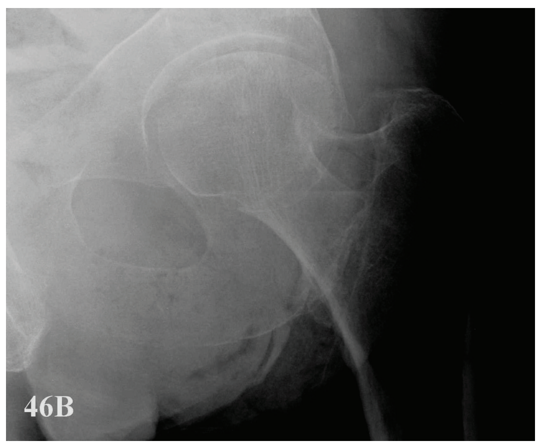

Figure 4: Bristol hip view demonstrating the importance of correct tube angulation. Over angulation of the beam means the fracture could be confused with the posterior border of the acetabulum.

two of the six cases. The Bristol hip view however confidently diagnosed four, reported by all the six observers. One fracture was reported by four observers and one by only two. This was due to overangulation of the X-ray tube rendering the posterior wall of the acetabulum over the fracture. They were all correctly reported on subsequent imaging but the Bristol hip view appears to have good potential for occult fracture diagnosis and may therefore obviate the need for further expensive imaging and avoid delays in surgical management whilst waiting for these investigations. Current recommendations are for patients to undergo magnetic resonance scanning for the diagnosis of occult hip fractures; however this is not routinely accessible out of hours, carries additional cost, and can be difficult in those with cognitive impairment [1].

Limitations of the study include the low numbers of occult fractures which precludes calculation of statistical significance. To achieve significance a sample size of over 3000 patients would be required. For displacement, although the study did not have a gold standard against which the criterion was measured, the AP and Bristol Hip view were both comparable, with the lateral view preforming poorly. This is increasingly important due to a change of surgical practice, where displaced fractures are now undergo replacement arthroplasty rather that fixation.

5. Conclusion

In the acute setting, for relatively little additional financial cost, time, and radiographic resource, the Bristol hip view adds useful diagnostic information with significantly greater clarity than the traditional lateral view. The Bristol hip view may be of added clinical utility as an additional film, particularly when the optimal lateral view is not obtainable.

The Bristol hip view may perform better than the traditional two views in the setting of occult fractures; however, any statistical significance of this effect in this study is hampered by low numbers.

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