



ORIGINAL ARTICLE

# Does fully-threaded Headless Compression Screw provide a length-stable fixation in undisplaced femoral neck fractures?



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## KEYWORDS

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Thread

**Summary Objective:** Femoral neck shortening is a common complication after surgical treatment for intracapsular femoral neck fractures. This study investigated whether fully-threaded Headless Compression Screw (FTHCS) can be a more length-stable implant than partially-threaded cannulated screw (PTCS) in reducing femoral neck shortening.

**Methods:** A total of 50 patients with undisplaced femoral neck fractures (17 treated by internal fixation with three FTHCS, and 33 treated by three PTCS) from 2011 to 2014 were enrolled in this study. The radiography of the hips and medical records were reviewed for proximal femur geometry and complications.

**Results:** Significant shortening of the femoral neck length until union were noted in both group (FTHCS group:  $-2.5$  mm,  $p = 0.045$ ; PTCS group:  $-2.4$  mm,  $p = 0.011$ ). There was no significant difference in the length of femoral neck shortening between groups ( $p = 0.855$ ). Age was the only significant risk factor for  $>5$  mm of femoral neck shortening ( $p = 0.041$ ). The femoral neck-shaft angle tended to reduce and become more varus in both groups (FTHCS:  $-2.7^\circ$ ,  $SD = 4.5$ ,  $p = 0.028$ ; PTCS:  $-5.0^\circ$ ,  $SD = 8.3$ ,  $p = 0.002$ ), but the differences between groups were nonsignificant ( $p = 0.577$ ). The complication rates were similar between FTHCS and PTCS (17.6% and 21.2%,  $p > 0.999$ ).

**Conclusion:** The FTHCSs may be a substitute for PTCSs, but it cannot prevent femoral neck shortening and varus collapse after fracture fixation. Future studies should focus on how to preserve femoral neck length and hip function after femoral neck fractures.

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## 1. Introduction

Internal fixation with either cannulated screws or a sliding hip screw is the most widely accepted treatment for undisplaced intracapsular femoral neck fractures.<sup>1–3</sup> However, uncontrolled collapse and subsequent shortening of the femoral neck have been reported in 31%–66% of cases.<sup>4,5</sup> These conditions lead to impairment in hip abduction, gait function, and quality of life.<sup>5–8</sup> Non-sliding, length-stable implants have been advocated to avoid femoral neck shortening. One recent study suggested that adding a fully-threaded screw to the conventional partially threaded lag screws could provide a length-stable fixation and result in minimal shortening of the femoral neck.<sup>9</sup> A biomechanical study also showed a three-screw configuration with fully-threaded screws could improve fixation strength and load-to-failure than partially-threaded screws.<sup>10</sup> However, clinical results regarding the use of fully-threaded Headless Compression Screws were inconclusive.<sup>11,12</sup> This study aimed to investigate whether fully-threaded Headless Compression Screw (FTHCS) is a more length-stable implant than partially-threaded cannulated screw (PTCS) in preventing femoral neck shortening in undisplaced femoral neck fractures.

## 2. Materials and methods

### 2.1. Patients

We retrospectively reviewed the medical records and radiology findings of patients who received internal fixations for acute femoral neck fractures between August 2011 and February 2014, in a tertiary referral center. We enrolled patients that received fixation with either three FTHCS (Acutrak 6/7, Acumed, Hillsboro, Oregon, USA) or three PTCS (7.3-mm cannulated screws, DePuy Synthes, Warsaw, Indiana, USA). These patients had been advised to refrain from weight-bearing for at least 8 weeks after surgery, followed by progressive weight-bearing as tolerable, except for patients presented with delayed union or progressive loss of fixation. Eligible patients ranged in age from 20 years to 99 years, and had an undisplaced fracture (Garden type I or II). Two independent orthopedic surgeons reviewed the fracture classifications and performed radiographic measurements. We excluded patients with less than one year of follow-up, multiple fractures, pathologic fractures, fixation with mixed types of screws, and having previous proximal femur fractures (Fig. S1). Demographic data including age, gender, bone mineral density (BMD, T-score), body mass index (BMI), and operation time were obtained from medical records. The Research Ethics Committee of the National Taiwan University Hospital approved this study (201409025RINA).

### 2.2. Radiologic measurements

We evaluated each patient's antero-posterior (AP) plain radiographs of the hip using AGFA-Orthopedic-Tools Version 2.10 (Agfa HealthCare N.V. Septestraat 27, B-2640 Mortsel, Belgium) by two independent authors. Radiographs taken within 2 days of the operation were compared to those taken at >1 year of follow-up. Patients who received any revision surgery that altered the hip geometry were excluded from the radiographic measurements (1 in FTHCS group, 4 in PTCS group).

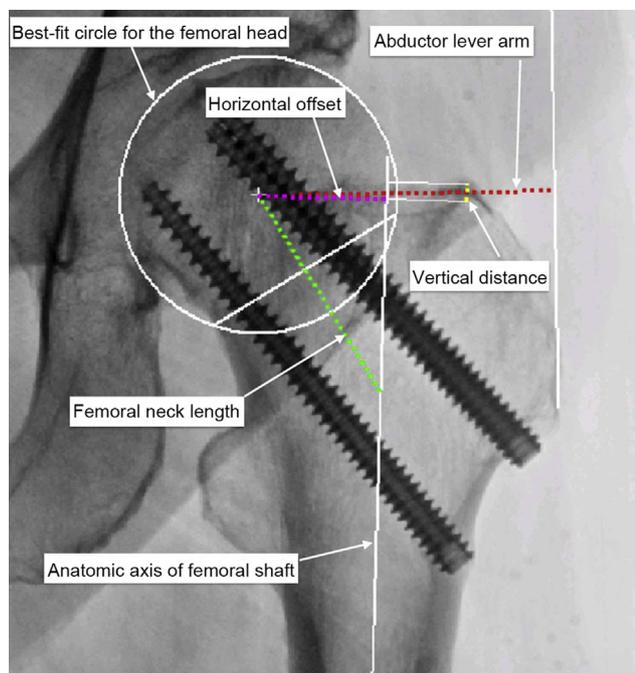
The actual diameter of a given screw was used to correct the magnification error in consecutive examinations. A standardized measurement protocol was established, and every observer involved in this study adhered to the protocol (Fig. 1). First, a best-fit circle was drawn around the border of the femoral head. The center of the circle was defined as the femoral head center. The circle intersected the femoral neck at two points, and a line was drawn connecting them. Perpendicular to this line, another line was drawn that passed through the femoral head center. This line was defined as the femoral neck axis in this study. The femoral shaft axis was defined with the 4-point method provided in the software.

The following parameters were measured:

- Femoral neck length: measured from the femoral head center along the femoral neck axis until touching the femoral shaft axis.
- Vertical distance between the femoral head center and the greater trochanter:<sup>13,14</sup> two lines were drawn perpendicular to the femoral shaft axis; one passed through the tip of greater trochanter, and the other touched the head center. The distance between the two lines was measured to obtain the vertical distance; this value was positive when the head center was superior to the greater trochanter tip.
- Horizontal offset of the femoral head:<sup>15</sup> the shortest distance from the femoral head center to the femoral shaft axis.
- Hip abductor lever arm:<sup>16</sup> an imaginary abductor vector was drawn from the anterior superior iliac spine (ASIS) to the lateral border of proximal femur. The shortest distance from the femoral head center to the abductor vector was defined as the abductor lever arm.
- Femoral neck-shaft angle: angle formed by the femoral shaft axis and the femoral neck axis.

### 2.3. Complications

Complications including nonunion (loss of fixation or persistent fracture line that failed to show progressive healing within 9 months), osteonecrosis (new cystic and sclerotic lesion or collapse/loss of the spherical shape of



**Fig. 1** First, a best-fit circle was drawn around the border of the femoral head, and it bisected the femoral neck. The center of the circle was defined as the head center. A line connecting the bisecting points was drawn, and another line perpendicular to this line, which passed through the head center, was defined as the femoral neck axis. The anatomic femoral shaft axis was defined with the 4-point method provided in the software. *Femoral neck length* (green line): from the head center to the intersection of the femoral neck axis and the femoral shaft axis. *Horizontal offset* (purple line): distance from the head center to the femoral shaft axis. *Vertical offset* (yellow line): vertical distance between the greater trochanter tip and the head center. *Abductor lever arm* (red line): the distance from the head center to the abductor vector.

the femoral head, or periprosthetic fracture (fractures occurred through the screw entry point) after the index surgery were recorded according to the medical records and radiography.

## 2.4. Statistical analysis

Statistical analyses were performed with SPSS 22 (SPSS Inc, Chicago, IL, USA). The power analysis determined that a sample of 28 patients (14 patients in each group) was needed to obtain differences of 5 mm on the change of femoral neck length with a statistical power of 80% and a significance level of 5%. The intraclass correlation coefficient (ICC) was used to determine the intra-rater and inter-rater reliabilities for the measurements. Groups were compared with the Wilcoxon signed rank test for two related samples (i.e., changes within individuals from treatment to union in femoral neck length, offset, abductor lever arm, and neck-shaft angle). The Mann–Whitney U test was used to compare two independent groups. Fisher’s exact test was used to analyze dichotomous variables and complication rates. Statistic significance was set as a p-value <0.05. Logistic regression model was used to analyze the relationship between >5 mm of femoral neck shortening and the type of intervention, the first postoperative femoral neck-shaft angle, and the demographic data (age, gender, BMD, and BMI).

## 3. Results

Fifty patients (17 in FTHCS group, 33 in PTCS group) fulfilled our selection criteria and were included in this study (Table 1). There were no significant differences between groups in age ( $p = 0.705$ ), gender ( $p = 0.292$ ), BMI ( $p = 0.975$ ), BMD ( $p = 0.814$ ), Pauwels classification ( $p = 0.424$ ), side of the body ( $p < 0.999$ ), mean follow-up time ( $p = 0.378$ ), and operation time ( $p = 0.943$ ).

**Table 1** Demographic data for patients with undisplaced femoral neck fractures.

	FTHCS	PTCS	p-value
N	17	33	
Gender			0.292 <sup>f</sup>
Male	2	9	
Female	15	24	
Age, years (range, SD)	71.0 (38–95, 16.1)	72.1 (37–89, 16.0)	0.705 <sup>m</sup>
BMI, kg/m <sup>2</sup> (range, SD)	20.9 (13.1–27.3, 4.0)	21.3 (12.7–27.8, 3.7)	0.975 <sup>m</sup>
Pauwels classification			0.424 <sup>f</sup>
I	4	12	
II	12	17	
III	1	4	
Side			>0.999 <sup>f</sup>
Right	6	13	
Left	11	20	
BMD, g/cm <sup>2</sup> (range, SD)	−2.61 (−4.40~−1.57, 0.76)	−2.44 (−4.20~0.70, 0.87)	0.814 <sup>m</sup>
Mean follow-up time, months (range, SD)	26.5 (13.7–38.4, 8.7)	23.8 (12.6–40.3, 8.0)	0.378 <sup>m</sup>
Operation time, min (range, SD)	57.2 (39–72, 8.4)	57.6 (42–71, 7.2)	0.943 <sup>m</sup>

Values are the numbers of patients, unless otherwise indicated.

<sup>m</sup>Mann-Whitney U test, <sup>f</sup>Fishers Exact test, BMI: body mass index, BMD: bone mineral density, SD: standard deviation.

The overall complication rate in FTHCS group was 17.6%, including 1 case of nonunion and 2 cases of osteonecrosis. The overall complication rate in PTCS group was 21.2%, including 3 cases of nonunions and 4 cases of osteonecrosis. No periprosthetic fracture was observed in this study. There was no significant difference between groups in the rates of overall complications ( $p > 0.999$ ).

The results of the radiographic measurements are shown in Table 2. Both groups showed significant shortening of the femoral neck length at final follow-up (FTHCS group:  $-2.5$  mm, SD = 4.6,  $p = 0.045$ ; PTCS group:  $-2.4$  mm, SD = 4.3,  $p = 0.011$ ), and there was no significant difference in the length of shortening between groups ( $p = 0.855$ ). Five of 16 patients (31.3%) in FTHCS group, and 8 of 29 patients (27.6%) in PTCS group experienced  $>5$  mm of femoral neck shortening before fracture union. Logistic regression analysis showed that age was the only significant risk factor for  $>5$  mm of femoral neck shortening ( $p = 0.041$ ). The mean age was 78.9 years in patients with shortening  $>5$  mm, compared to 69.2 years in patients with shortening  $<5$  mm. No associations were found for gender ( $p = 0.958$ ), the first postoperative femoral neck-shaft angle ( $p = 0.302$ ), BMD ( $p = 0.640$ ), BMI ( $p = 0.673$ ), or the screw type ( $p = 0.282$ ). The vertical distance between femoral head center and greater trochanter reduced in both groups (FTHCS:  $-2.4$  mm, SD = 3.8,  $p = 0.015$ ; PTCS:  $-5.5$  mm, SD = 6.0,  $p < 0.001$ ). The femoral neck-shaft angle tended to reduce and become more varus (FTHCS:  $-2.7^\circ$ , SD = 4.5,  $p = 0.028$ ; PTCS:  $-5.0^\circ$ , SD = 8.3,  $p = 0.002$ ), but the differences between groups were nonsignificant ( $p = 0.577$ ). We found no significant changes in the horizontal offset of the femoral head and the abductor lever arm in both groups.

#### 4. Discussion

Despite the hypothesis that fully-threaded screws may create a nonsliding length-stable construct, using three FTHCS did not prevent femoral neck shortening in this study. The shortening was more obvious in the vertical axis in both groups, leading to a reduce neck-shaft angle. These findings were consistent with previous report that shortening and varus collapse of the neck are common after fixation of intracapsular fracture of the hip.<sup>6</sup> Shortened neck are related to leg length discrepancy, hip impingement, decreased abductor length, and impaired hip function with a gradient effect.<sup>5-7,15</sup> Regression analyses in this study showed that age was related to more femoral neck shortening. Our results should raise the awareness of the elevated risk of functional impairment in the elderly.

Some concerns had been raised that screw threads crossing the fracture site may impede fracture consolidation and increase the risk of fracture non-union. In a study comparing 16-mm with 32-mm threaded screws, no difference was found in fracture healing complications.<sup>17</sup> Zhang et al showed that adding two FTHCSs to one PTCS improved the outcome of vertical femoral neck fractures.<sup>12</sup> However, we observed no significant differences in nonunion rates and overall complication rates between

**Table 2** Summary of radiographic measurements for patients with undisplaced femoral neck fractures.

	FTHCS			PTCS			FTHCS vs. PTCS		Inter-rater reliability	
	pre-OP Mean (SD)	post-OP Mean (SD)	Difference Mean (SD)	pre-OP Mean (SD)	post-OP Mean (SD)	Difference Mean (SD)	p-value <sup>w</sup>	p-value <sup>m</sup>	Intra-rater reliability Correlation coefficient	Inter-rater reliability Correlation coefficient
Femoral neck length (mm)	46.0 (9.04)	43.5 (11.0)	-2.5 (4.6)	41.1 (7.4)	38.7 (8.1)	-2.4 (4.3)	0.011*	0.855	0.942	0.938
Horizontal offset (mm)	27.8 (6.8)	27.6 (7.7)	-0.2 (3.8)	27.4 (6.3)	28.0 (6.1)	0.6 (3.2)	0.446	0.648	0.916	0.903
Abductor lever arm (mm)	53.5 (5.5)	53.4 (6.2)	-0.1 (3.9)	55.0 (5.6)	53.8 (8.4)	-1.2 (6.1)	0.463	0.675	0.917	0.946
Vertical distance between femoral head center and greater trochanter (mm)	-2.9 (4.1)	-5.3 (4.5)	-2.4 (3.8)	-4.1 (5.5)	-9.8 (5.4)	-5.5 (6.0)	<0.001*	0.036*	0.962	0.953
Femoral neck-shaft angle (degrees)	142.8 (4.5)	140.1 (5.3)	-2.7 (4.5)	137.9 (7.0)	132.9 (8.4)	-5.0 (8.3)	0.002*	0.577	0.922	0.914

<sup>w</sup> Wilcoxon-Signed Rank test. <sup>m</sup> Mann-Whitney U test. \* $p < 0.05$ .

the fully-threaded and the partially-threaded groups. Other factors, including the patient's characteristics, fracture patterns, and the quality of fracture reduction and fixation may be more important than the thread length alone. Okcu et al reported that PTCS provided a shorter union time and lower complication rates than FTHC in a younger patient group with both displaced and undisplaced fractures.<sup>11</sup> Femoral neck fractures in young patients are usually caused by high-energy trauma, which are related to higher rates of fracture displacement, osteonecrosis, nonunion, and poor outcomes after fracture fixation.<sup>18,19</sup> The differences in patient selection may have impact on the conclusion among studies. Fracture healing after multiple screw fixation may be more predictable in patients with undisplaced fractures (Garden type I/II), as in our study subjects.

Despite the outcomes were similar between patients treated by FTHCS and PTCS, headless screws may be more favorable for its less risk of local discomfort caused by prominent screw heads. Titanium fixation devices (FTHCSs in this study) are also recommended as a substitute for stainless steel (PTCS in this study) in patients who may need future magnetic resonance imaging of the hip for early detection of osteonecrosis.<sup>20</sup> However, it may be more difficult to be remove embedded headless screws in a secondary surgery. Besides, the average price of one FTHCS is about 800USD in our hospital, almost 8 times more expensive than a conventional stainless steel PTCS. The costs can be an economic burden to patients when multiple screws are needed. These factors should be considered when choosing different types of implants.

This study had several limitations. First, this was a retrospective study. The criteria of implant selection were not clearly defined among surgeons. Second, the patient number were relatively small in both group. Third, the differences in the methods of screw fixation may affect stabilities and failure rates,<sup>21–23</sup> but we did not analyze these factors. In our institute, most surgeons prefer to place three parallel screws in an inverted triangular configuration (one inferior screw and two superior screws). Finally, we didn't have a functional score in the medical records to correlate with our radiographic findings.

## 5. Conclusion

The FTHCSs may be a substitute for PTCSs, but they could not provide a length-stable fixation in undisplaced intracapsular femoral neck fractures. These implants did not reduce femoral neck shortening and varus collapse before fracture union, and advanced age was a significant risk factor of more shortening. Cost-effectiveness should be considered before choosing different implants. Future studies should focus on how to preserve femoral neck length and hip function after femoral neck fractures.

## Ethics review committee statement

Each author certifies that his institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent was obtained.

## Conflicts of interest and source of funding

The authors declare no funding, financial support, or potential source of a conflict of interest related to this work.

## Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.asjsur.2018.05.009>.

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