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Femoral neck shortening after internal fixation

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Objective: The aim of this study was to assess the factors affecting femoral neck shortening after internal fixation of femoral neck fractures.

Methods: Eighty-six patients with femoral neck fractures were treated using three parallel cannulated screws between May 2004 and January 2011. The shortening of the femoral neck in the horizontal (X), vertical (Y), and along the resultant along the (Z) vector (X→, Y→, Z→) was measured on anteroposterior radiographs corrected by screw diameter and analyzed using TraumaCad software. Age, gender, Garden classification, Garden's alignment index, Pauwels angle, Singh index, body mass index and weight-bearing time were also analyzed.

Results: Follow-up duration was 8 to 36 months. Significant femoral neck shortening of the abductor lever arm (greater than 5 mm) was present in 33 of 86 (38.4%) patients. Average Harris score (HSS) was 90.05±7.04 (range: 71 to 100). The 5 predictors for shortening greater than 5 mm in the multivariate logistic regression model were age, Singh index, Pauwels classification, Garden's alignment index and body mass index.

Conclusion: Femoral neck shortening associated with three parallel cannulated screws for fixation of femoral neck fractures is a common phenomenon. Femoral neck shortening after internal fixation is affected by multiple cofactors.

Key words: Femoral neck fractures; fixation; functional outcome after fixation; multiple factor regression analysis; shortening.

Femoral neck fractures are difficult injuries with challenging problems for orthopedic surgeons and severe health care burdens on society.[1] Operative treatment of hip fractures is standard.[2] Various treatment options exist for the operative fixation of the femoral neck.[3] Although numerous reports and textbooks recommend parallel multiple screws as the preferred surgical technique,[4] evidence remains inconclusive. As previously published, the senior authors have emphasized the complications of nonunion and femoral head avascular necrosis.

Zlowodzki et al. have shown that femoral neck shortening (FNS) after femoral neck fracture fixation with multiple cancellous screws is common and has a significant negative impact on physical functioning which has prompted more investigation into this phenomenon, its incidence rate and possible solutions.[5,6] Boraiah et al. fixed femoral neck fractures using non-sliding con-

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structs, resulting in a high union rate with very minimal shortening of the femoral neck.[7,8]

Multiple recent studies have investigated the impact of shortening after internal fixation of femoral neck fractures using parallel multiple screws on functional outcomes. However, few studies have attempted to determine the risk factors for the shortening using multiple factor regression analysis. Our study hypotheses were two-fold: (1) femoral neck shortening after hip fracture fixation is common and can affect patients' physical function and (2) multiple cofactors contribute to the shortening.

The aim of this study was to qualitatively assess the incidence of FNS in patients treated with multiple cannulated screws for displaced and undisplaced femoral neck fractures, investigate its influence on functional outcome and evaluate which factors are associated with FNS and poor functional outcomes using multiple factors regression analysis.

Patients and methods

Databases of the Gongli Hospital in Shanghai Pudong New Area were used for retrospective analysis between May 2004 and January 2011.

Patients who underwent cannulated screw fixation for femoral neck fractures using closed reduction with evidence of fracture healing within a minimum of 6 months of radiographic follow-up and 1 year of clinical follow-up (range: 1 to 7 years) were eligible for the study. Fractures that resulted in nonunion after treatment, patients with bilateral hip fractures and patients without complete sets of preoperative, postoperative, and follow-up radiographs, as well as pathologic fractures were excluded. Eighty-six patients meeting the inclusion criteria were located within the hospital records between 2004 and 2011. Minimum follow-up was 12 months (average: 32.1 months; range: 12 to 42 months). No patients were lost to follow-up. Prior approval was obtained from the Ethics Committee of our hospital.

Radiographs between 2009 and 2011 were retrieved from the PACS system (Centricity; Jinshida, China) and printed films from 2006 to 2009 were digitized into the system. TraumaCad v.2.0 (Voyant Health Ltd., Tel Aviv, Israel) software was used for radiographic analysis. All images were calibrated using the known screw diameter (6.5 mm). The neck shaft angle (NSA) was measured using the technique described by Paley[9] with the same software and a specialized software tool. Femoral neck shortening was measured using the method described by Zlowodzki et al.;[5,6] injured and uninjured sides were matched, the resultant distances between the operated (shortened) and the uninjured edge of the femoral heads were measured, yielding the horizontal shortening or abductor lever arm shortening (X) and the corresponding femur shortening in the vertical plane (Y). The resultant femoral neck shortening vector at the angle of the femoral neck (Z) was calculated using the ı as the corresponding angle to the NSA as follows; $Z = Y \sin(\theta) + X \cos(\theta)$.[10]

Follow-up was conducted at the postoperative 2nd and 6th weeks and the 3rd, 6th, 12th and 24th months. Plain radiographs were obtained at each follow-up visit. In each model, the dependent variable was the shortening distance and we recorded the Harris scores.[11] Independent variables analyzed by multiple factor regression analysis were age, gender, Garden's alignment index, Garden classification,[12] Pauwels angle,[13] Singh index,[14] body mass index (BMI)[15] and weight-bearing time.

Data were entered using an Excel spreadsheet (Microsoft Corp., Redmond, WA, USA), rechecked for missing and potentially illogical data by an independent reviewer and subsequently copied into SPSS software v.13.0 (SPSS Inc., Chicago, IL, USA).

Studies have reported significantly lower SF-36 scores in patients with shortening of the abductor moment arm by at least 5 mm. Therefore, patients were divided into two groups; those shortened by at least 5 mm and greater than 5 mm. Harris scores (≥85 as good, <85 as no good) were collected and compared. If there was a statistical difference in Harris scores by at least 5 mm grouping, we ran the cofactor analysis; if not, we sub-grouped the patients by 10 mm shortening.

Univariate analysis was used to determine risk factors for the shortening and the logistic regression analysis for multiple factors analysis to determine real risk factors and establish the multiple factor regression equation.

Results

Significant FNS of the abductor lever arm (greater than 5 mm) occurred in 33 of 86 (38.4%) patients and severe shortening (greater than 10 mm loss of abductor lever arm) in 21 (24.4%) patients (Table 1). Femur shortening (Y vector) (greater than 5 mm) occurred in 34.9% of

Table 1. Results of measuring the shortening.

	X (abductor lever arm) shortening	Y (femur vertical length) shortening	Z shortening (resultant vector of X, Y and NSA)
≤5 mm	53	56	56
5.1-10.0 mm	12	17	15
10.1-20.0 mm	16	11	12
>20.0 mm	5	2	3

NSA: neck shaft angle

patients and severe femur shortening (greater than 10 mm) in 15.1%. Overall (resultant Z vector) femoral shortening (greater than 5 mm) occurred in 34.9% of patients and severe overall shortening (greater than 10 mm) occurred in 17.4%.

Average Harris score (HSS) was 90.05±7.04 (range: 71 to 100) for the 8 to 36 month follow-ups. There was a significantly negative correlation between HSS and Z shortening greater than 5 mm (χ^2=25.476, p=0.000< 0.05). Similar results occurred for shortening greater than 10mm (χ^2=20.525, p=0.000<0.05), and 20 mm (χ^2=14.326, p=0.000<0.05). Shortening greater than 5 mm was used as the cut-off for the cofactor analysis. Table 2 shows factors used as the eight variables in the cofactor analysis.

Univariate analysis was performed to evaluate the association between cofactor characteristics and shortening in the modeling group. Table 3 shows the differences among each factor to shortening greater than 5 mm using the chi-square test. Characteristics including age, Singh index, Pauwels classification, Garden's alignment index and BMI were used as cofactors in the univariate analysis.

To avoid omitting significant indicators, factors with a significance of p<0.05 in the univariate analysis were included in the multivariate model. Therefore, 5 predictors were involved into the multivariate logistic regression model; age, Singh index, Pauwels classification, Garden's alignment index and BMI. These factors were significantly associated with femoral neck shortening greater than 5 mm (Table 4). The final logistic regression model for predicting femoral neck shortening was as follows: Logit (P) = 11.465 + 1.624 X2 + 1.699 X3 + 1.989 X4 + 2.042 X6 + 1.482 X7

Table 2. Variables used in the cofactor analysis and their characteristics.

Variable	Characteristics		Code	n (%)
X1	Gender	Male	0	35 (40.7)
		Female	1	51 (59.3)
X2	Age	≤55 yrs	0	58 (67.4)
		>55 yrs	1	28 (32.6)
X3	Singh index	4-6	0	30 (34.9)
		1-3	1	56 (64.1)
X4	Pauwels classification	Type 1, 2	0	52 (67.4)
		Type 3	1	34 (32.6)
X5	Garden's classification	Non-displaced	0	44 (51.2)
		Displaced	1	42 (48.8)
X6	Garden alignment index (AP)	Good	0	56 (65.1)
		No good	1	30 (34.9)
X7	BMI	≤24	0	47 (54.7)
		>24	1	39 (45.3)
X8	Weight-bearing time	≤3 months	0	27 (31.4)
		>3 months	1	59 (68.6)

BMI: body mass index

Table 3. Results of the univariate analysis.

Variable	Characteristics	Total number (n)	Shortening distance ≤5 mm (n)	Shortening distance >5 mm (n)	χ^2	p value
X1	Gender					
	Male	35	21	14	0.4	NA
	Female	51	34	17		
X2	Age					
	≤55 yrs	58	44	14	10.859	0.002
	>55 yrs	28	11	17		
X3	Singh index					
	4-6	44	23	10	12.837	0.000
	1-3	42	32	21		
X4	Pauwels classification					
	Type 1, 2	52	40	12	9.597	0.002
	Type 3	34	15	19		
X5	Garden classification					
	Non-displaced	44	29	15	0.149	NA
	Displaced	42	26	16		
X6	Garden's alignment index (AP/lateral)					
	Good	56	45	11	18.738	0.000
	No good	30	10	20		
X7	BMI					
	≤24	47	38	9	12.837	0.001
	>24	39	17	22		
X8	Weight-bearing time					
	≤3 months	27	18	9	0.126	NA
	>3 months	59	37	22		

BMI: body mass index, NA: not available

Table 4. Variables in the multivariate equation.

Variable	Characteristics	B	S.E.	Wald	P	OR	95% CI for OR	
							Lower	Upper
X2	Age	1.624	0.690	5.540	0.019	5.075	1.312	19.625
X3	Singh index	1.699	0.717	5.608	0.018	5.467	1.340	22.305
X4	Pauwels classification	1.989	0.721	7.601	0.006	7.307	1.777	30.044
X6	Garden's index	2.042	0.686	8.855	0.003	7.704	2.008	29.561
X7	BMI	1.482	0.697	4.519	0.034	4.403	1.123	17.267
	Constant	11.465						

BMI: Body mass index, CI: confidence interval, OR: odds ratio

Discussion

Cannulated threaded screws are the internal fixation device of choice in the treatment of femoral neck fractures.[5-8] The design of these threaded screws allows for intraoperative compression to aid in reduction and primary bone healing and postoperative settling. Despite ensuring direct bony contact between the proximal and distal fragments, it ultimately produces the unintended and undesired consequence of femoral neck shortening. In a recent questionnaire of 203 surgeons, the majority (83%, range: 78 to 88%; 95% CI) believed shortening of the femoral neck is a common occurrence seen after parallel screw fixation of femoral neck fractures. However, surgeons' opinions were divergent on the degree of shortening that led to clinically important limitations in function and disagreed on the negative impact caused by the shortening of the femoral neck on patients' quality of life. A recent multicenter study including patients with severe shortening of the femoral neck reported significantly lower SF-36 questionnaire physical functioning scores in mild (<5 mm) vs. severe shortening (>10 mm) and that in a regression analysis shorting was the only significant variable predictive of a low SF-36 physical functioning score.[5]

Various methods have been used in assessing the shortening in femoral neck fractures. Zlowodzki[5,6] and Boraiah[7,8] reported some useful methods for the measurement of shortening while Weil[10] measured shortening using data on films by a PACS system analyzed with CAD software in order to reduce bias efficiently. In the current study, use of digital films and CAD software may be an ideal way to measure the shortening of femoral neck fractures due to the ability of CAD software to magnify the image, save the pictures and adjust differences between different films.

Boraiah et al.[7] studied the relationship between sex, age, construct type, Garden classification and Pauwels angle with shortening. However, no significant difference was found in these variables groups due to the small sample size and number of cofactors. In order to overcome these limitations, we used multiple regression analysis with multiple cofactors in order to determine the risk factors of shortening. Logistic regression analysis was used as shortening could be divided into mild and severe groups. It can not only find the most significant factor group, dislodge the confounding factors in the multiple model but also give the odds ratio (amounting to the relative risk) of multiple cofactors. In our regression model, age, Singh index, Pauwels classification, BMI, and Garden's alignment index had the highest odds ratio (7.704, lower: 2.008 – upper: 29.561; 95% CI).

The Garden's alignment index is the most widely used index to evaluate reduction quality and is considered a highly sensitive cofactor for bone healing and femoral head survival.[16] According to the principle of geometry, in incomplete reduction, the line of femoral neck would be a folding line with short ending points of the former line. In the current study, 20 of the 30 cases with no satisfied reduction were shorter than 11 of the 56 cases with good reduction.

Pauwels classification was originally identified as factor for the stability of femoral neck fractures.[13] According to recent literature, this factor does not appear to be more significant than the Garden classification[17,18] for the prediction of union and femoral head necrosis. However, Pauwels Type 3 fractures had a higher movement tendency relative to the Pauwels Type 1 and 2. In light of our findings, Pauwels Type 3 fractures were prone to coxa vara, so that the femur vertical shortening length (Y value) increased, to the extent that Z shortening (resultant vector of X, Y and NSA) also increased.

The Singh index is a radiographic evaluation method for osteoporosis based on the radiological appearance of the trabecular bone structure in the proximal femur.[14] Many authors have stated that there was a correlation between Singh index and dual-energy X-ray absorptiometry. In our results, it is believed that the Singh index was an ignored cofactor due to loosing bone density and compression of fracture segments.

Age is an indispensable factor in research because of wide differences in nutrition level, activity, bony healing ability, blood supply, and bone density. Low BMI is a well-documented risk factor for future fracture.[15] A recent meta-analysis study reported that low BMI confers a risk of substantial importance for all fractures that is largely independent of age and sex, but dependent on bone mineral density. It appeared that low BMI was a risk factor for fracture but not for shortening as shortening requires compression of the segment by weight.

One limitation of our study was its retrospective nature and the small number of patients available for clinical follow-up. Results were obtained from a single, fellowship-trained trauma surgeon in one trauma center. Further larger multiple center studies are needed. However, we showed the risk factors for FNS after multiple cannulated screw fixation.

In conclusion, femoral neck fractures remain an unsolvable problem for orthopedic surgeons. Femoral neck shortening occurs due to multiple factors. Fixation using multiple cannulated screws may not be the optimal technique and development of other instruments for this fracture is possible.

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Conflicts of Interest: No conflicts declared.

References

1. Berkes MB, Little MT, Lazaro LE, Cymerman RM, Helfet DL, Lorich DG. Catastrophic failure after open reduction internal fixation of femoral neck fractures with a novel locking plate implant. J Orthop Trauma 2012;26:e170-6.
2. Bhandari M, Devereaux PJ, Swiontkowski MF, Tornetta P 3rd, Obremskey W, Koval KJ, et al. Internal fixation compared with arthroplasty for displaced fractures of the femoral neck. A meta-analysis. J Bone Joint Surg Am 2003;85-A:1673-81.
3. Crossman PT, Khan RJ, MacDowell A, Gardner AC, Reddy NS, Keene GS. A survey of the treatment of displaced intracapsular femoral neck fractures in the UK. Injury 2002;33:383-6.
4. Parker MJ. Parallel Garden screws for intracapsular femoral fractures. Injury 1994;25:383-5.
5. Zlowodzki M, Brink O, Switzer J, Wingerter S, Woodall J Jr, Petrisor BA, et al. The effect of shortening and varus collapse of the femoral neck on function after fixation of intracapsular fracture of the hip: a multi-centre cohort study. J Bone Joint Surg Br 2008;90:1487-94.
6. Zlowodzki M, Ayieni O, Petrisor BA, Bhandari M. Femoral neck shortening after fracture fixation with multiple cancellous screws: incidence and effect on function. J Trauma 2008; 64:163-9.
7. Boraiah S, Paul O, Gardner MJ, Parker RJ, Barker JU, Helfet D, et al. [Retracted Article] Outcomes of length-stable fixation of femoral neck fractures. Arch Orthop Trauma Surg 2010;130:1523-31.
8. Boraiah S, Paul O, Hammoud S, Gardner MJ, Helfet DL, Lorich DG. Predictable healing of femoral neck fractures treated with intraoperative compression and length-stable implants. J Trauma 2010;69:142-7.
9. Paley D, Herzenberg JE. Principles of deformity correction. Berlin: Springer; 2002.
10. Weil YA, Khoury A, Zuaiter I, Safran O, Liebergall M, Mosheiff R. Femoral neck shortening and varus collapse after navigated fixation of intracapsular femoral neck fractures. J Orthop Trauma 2012;26:19-23.
11. Nilsdotter A, Bremander A. Measures of hip function and symptoms: Harris Hip Score (HHS), Hip Disability and Osteoarthritis Outcome Score (HOOS), Oxford Hip Score (OHS), Lequesne Index of Severity for Osteoarthritis of the Hip (LISOH), and American Academy of Orthopedic Surgeons (AAOS) Hip and Knee Questionnaire. Arthritis Care Res 2011;63 Suppl 11:S200-7.
12. Van Embden D, Rhemrev SJ, Genelin F, Meylaerts SA, Roukema GR. The reliability of a simplified Garden classification for intracapsular hip fractures. Orthop Traumatol Surg Res 2012;98:405-8.
13. Parker MJ. Results of internal fixation of Pauwels type-3 vertical femoral neck fractures. J Bone Joint Surg Am 2009;91: 490-1.
14. Bes C, Güven M, Akman B, Atay EF, Ceviz E, Soy M. Can bone quality be predicted accurately by Singh index in patients with rheumatoid arthritis? Clin Rheumatol 2012;31: 85-9.
15. De Laet C, Kanis JA, Odén A, Johanson H, Johnell O, Delmas P, et al. Body mass index as a predictor of fracture risk: a meta-analysis. Osteoporos Int 2005;16:1330-8.
16. Lindequist S, Törnkvist H. Quality of reduction and cortical screw support in femoral neck fractures. An analysis of 72 fractures with a new computerized measuring method. J Orthop Trauma 1995;9:215-21.
17. Gaspar D, Crnkovic T, Durovic D, Podsednik D, Slisuric F. AO group, AO subgroup, Garden and Pauwels classification systems of femoral neck fractures: are they reliable and reproducible? Med Glas (Zenica) 2012;9:243-7.
18. Caviglia HA, Osorio PQ, Comando D. Classification and diagnosis of intracapsular fractures of the proximal femur. Clin Orthop Relat Res 2002;(399):17-27.