Factors Influencing Fracture Pattern of Proximal Femoral Fractures: A Retrospective Study Investigating Bone Mineral Density and Bone Turnover Markers

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INTRODUCTION: Proximal femoral fractures resulting from osteoporosis can be classified into two categories: intra-capsular (neck) fractures and extra-capsular (trochanteric and subtrochanteric) fractures. However, the relationship between bone mineral density (BMD), bone turnover markers (BTMs), and hip fractures remains unclear. The aim of this retrospective study is to investigate the factors influencing the fracture pattern of proximal femoral fractures.

METHODS: We included 198 cases of femoral neck (FN) fractures and 177 cases of trochanteric/subtrochanteric (T/S) fractures that underwent surgery at our hospital between January 2017 and December 2022. Preoperatively, blood samples were collected to measure BTMs, with procollagen type 1 N-terminal propeptide (P1NP) serving as the bone formation marker and Tartrate-resistant acid phosphatase type 5b (TRACP-5b) as the bone resorption marker. Postoperatively, BMD was measured within one month using dual-energy X-ray absorptiometry in the unaffected proximal femur (including the femoral neck, greater trochanter, and intertrochanteric region). Additionally, based on the Garden and AO/OTA classifications, the FN and T/S fracture groups were further categorized into less severe (Garden I-II/31A1) and more severe (Garden III-IV/31A2-A3) fractures. We evaluated the relationship between fracture types and BTMs or BMD and also investigated the relationship between fracture severity and BTMs or BMD within the FN and T/S fracture groups. Patient demographics (age, sex, body mass index [BMI], estimated glomerular filtration rate [eGFR], and preoperative systemic assessment according to the American Society of Anesthesiologists [ASA] physical status) were adjusted using propensity score matching prior to the analyses. Differences between groups were analyzed using ANOVA or Fisher's exact test, with p-values <0.05 indicating statistical significance.

RESULTS:

Table 1 presents the patients' data for the FN and T/S fracture groups before and after propensity score matching. Before matching, the T/S fracture group was significantly older compared to the FN fracture group (Table1, Age at surgery: $p < 0.001$). No significant differences were observed in BTMs between the two groups, while significant decreases were observed in all regions of BMD in the T/S fracture group compared to the FN fracture group (Table1, Neck: $p = 0.002$, Greater trochanter: $p < 0.001$, Intertrochanter: $p < 0.001$.) After matching, each fracture group included 137 patients. There were no significant differences in BTMs between the FN and T/S fracture groups. However, a significant decrease in BMD was observed in the greater trochanter and intertrochanteric regions (excluding the neck region) in the T/S fracture group compared to the FN fracture group (Table 1, Greater trochanter: $p = 0.008$, Intertrochanter: $p = 0.004$). Table 2 presents data on patients with FN fractures categorized based on fracture severity according to the Garden classification, before and after adjustment using propensity score matching. In the FN fracture group, 62 patients were included in each group categorized as less severe or more severe fracture displacement after matching. A significant elevation of BTMs was observed in the less severe group compared to the more severe group (Table 2, P1NP: $p < 0.001$, TRACP-5b: $p = 0.038$). However, no significant differences were found in the relationship between fracture severity and BMD. Table 3 shows the data on patients with T/S fractures categorized based on fracture severity according to the AO/OTA classification, before and after adjustment using propensity score matching. Similarly, in the T/S fracture group, 69 patients were included in each group categorized as less severe or more severe fracture displacement after matching. A significant elevation of BTMs was observed in the less severe group compared to the more severe group (Table 3, P1NP: $p = 0.001$, TRACP-5b: $p = 0.011$), but no significant differences were found in the relationship between fracture severity and BMD.

DISCUSSION AND CONCLUSION:

T/S fractures are commonly associated with an older age group and higher complication rates compared to FN fractures. Previous studies have indicated a greater decline in BMD around the proximal femur in T/S fractures. Our findings support this observation, demonstrating a significant association between T/S fractures and decreased BMD in the greater trochanter and intertrochanteric region, even after adjusting for patient demographics. This suggests that the fracture crossed through more fragile areas.

Additionally, our study found that BTMs were potentially associated with fracture severity in both FN fractures and T/S fractures. This indicates that BTMs may be useful in predicting fracture severity.

In conclusion, our study provides further evidence of the relationship between BMD, BTMs, and proximal femoral fractures. Our findings suggest that decreased BMD in the greater trochanter and intertrochanteric region may be associated with T/S fractures, while BTMs may be associated with fracture severity.

Table 1. Patients' Data Categorized Based on Fracture Type before and after Extraction by Propensity Score Matching

Before propensity score matching				
Fracture type		FN fracture: N=198	T/S fracture: N=178	*P* value
Gender (female: male)		144:54	136:42	0.48
Age at surgery (years) *		79.7±9.2	84.6±8.3	<0.001
BMI (kg/m²) *		21.2±3.6	21.1±4.2	0.64
eGFR*		63.9±22.8	61.1±26.3	0.28
ASA	1	9	1	0.057
	2	121	106	
	3	67	69	
	4	1	2	
BTMs	P1NP (ng/ml) *	72.4±62.9	76.6±69.6	0.55
	TRACP-5b*	434±213	460±231	0.54
	Neck*	0.58±0.13	0.54±0.13	0.002
BMD (g/cm²)	Greater trochanter*	0.53±0.14	0.47±0.13	<0.001
	Intertrochanter*	0.67±0.15	0.60±0.13	<0.001
After propensity score matching				
Fracture type		FN fracture: N=137	T/S fracture: N=137	*P* value
Gender (female: male)		98:39	101:36	0.79
Age at surgery (years) *		83.4±7.5	83.3±7.4	0.90
BMI (kg/m²) *		20.9±3.3	21.3±4.5	0.40
eGFR*		61.2±23.4	62.9±26.3	0.57
ASA	1	3	1	0.34
	2	81	90	
	3	53	45	
	4	0	1	
BTMs	P1NP (ng/ml) *	71.5±58.0	75.5±71.1	0.61
	TRACP-5b*	485±216	452±247	0.24
	Neck*	0.57±0.12	0.55±0.13	0.13
BMD (g/cm²)	Greater trochanter*	0.52±0.14	0.48±0.13	0.008
	Intertrochanter*	0.65±0.15	0.60±0.13	0.004

*The values are given as the mean, with the standard deviation. Abbreviations: BMI=body mass index; eGFR=estimated glomerular filtration rate; ASA=American Society of Anesthesiologists-physical status; BTMs=bone turnover markers; P1NP= procollagen type I N-terminal propeptide; TRACP-5b=Tartrate-resistant acid phosphatase type 5b; BMD=bone mineral density. Differences between the groups were determined by ANOVA or Fisher's exact test, and Statistical differences were considered significant for *p*-values <0.05.

Table 2. In Femoral neck Fracture Group, Patients' Data Categorized Based on Fracture Severity before and after Adjusting by Propensity Score Matching

Before propensity score matching				
Fracture Severity		Less severe: N=65	More severe: N=133	*P* value
Gender (female: male)		49:16	95:38	0.41
Age at surgery (years) *		78.4±9.7	80.4±8.9	0.16
BMI (kg/m²) *		20.8±2.9	21.5±3.8	0.20
eGFR*		63.3±19.7	64.2±24.2	0.81
ASA	1	6	3	0.13
	2	39	82	
	3	20	47	
	4	0	1	
BTMs	P1NP (ng/ml) *	77.7±61.7	69.8±63.5	0.41
	TRACP-5b*	462±201	488±218	0.58
	Neck*	0.58±0.12	0.58±0.13	0.95
BMD (g/cm²)	Greater trochanter*	0.52±0.12	0.54±0.13	0.20
	Intertrochanter*	0.65±0.12	0.67±0.16	0.25
After propensity score matching				
Fracture Severity		Less severe: N=62	More severe: N=62	*P* value
Gender (female: male)		46:16	46:16	1.00
Age at surgery (years) *		79.3±8.7	79.0±9.9	0.86
BMI (kg/m²) *		20.8±2.9	21.2±3.7	0.53
eGFR*		63.1±20.1	65.3±21.7	0.55
ASA	1	3	2	0.25
	2	39	47	
	3	20	13	
	4	0	0	
BTMs	P1NP (ng/ml) *	78.9±63.0	41.4±16.1	<0.001
	TRACP-5b*	467±205	394±183	0.018
	Neck*	0.58±0.12	0.60±0.11	0.36
BMD (g/cm²)	Greater trochanter*	0.52±0.12	0.55±0.14	0.18
	Intertrochanter*	0.65±0.13	0.68±0.15	0.11

*The values are given as the mean, with the standard deviation. Abbreviations: BMI=body mass index; eGFR=estimated glomerular filtration rate; ASA=American Society of Anesthesiologists-physical status; BTMs=bone turnover markers; P1NP= procollagen type I N-terminal propeptide; TRACP-5b=Tartrate-resistant acid phosphatase type 5b; BMD=bone mineral density. Differences between the groups were determined by ANOVA or Fisher's exact test, and Statistical differences were considered significant for *p*-values <0.05.

Table 3. In Trochanteric/Subtrochanteric Fracture Group, Patients' Data Categorized Based on Fracture Severity before and after Adjusting by Propensity Score Matching

Before propensity score matching				
Fracture Severity		Less severe: N=83	More severe: N=97	*P* value
Gender (female: male)		62:19	74:23	1.00
Age at surgery (years) *		85.5±6.8	83.8±9.3	0.17
BMI (kg/m²) *		20.8±4.5	21.3±3.9	0.41
eGFR*		58.4±29.1	63.4±23.6	0.21
ASA	1	0	1	0.80
	2	50	56	
	3	30	39	
	4	1	1	
BTMs	P1NP (ng/ml) *	92.6±78.2	64.2±60.2	0.007
	TRACP-5b*	501±247	428±212	0.031
	Neck*	0.52±0.11	0.58±0.14	0.074
BMD (g/cm²)	Greater trochanter*	0.46±0.12	0.48±0.13	0.36
	Intertrochanter*	0.58±0.11	0.61±0.14	0.11
After propensity score matching				
Fracture Severity		Less severe: N=68	More severe: N=69	*P* value
Gender (female: male)		51:18	45:15	0.89
Age at surgery (years) *		85.1±6.8	85.6±7.6	0.70
BMI (kg/m²) *		21.5±3.6	21.0±4.1	0.46
eGFR*		60.3±29.9	62.7±25.0	0.60
ASA	1	0	1	1.00
	2	43	37	
	3	25	31	
	4	1	0	
BTMs	P1NP (ng/ml) *	95.2±81.9	57.8±49.3	0.001
	TRACP-5b*	505±251	405±200	0.011
	Neck*	0.53±0.11	0.54±0.13	0.83
BMD (g/cm²)	Greater trochanter*	0.47±0.12	0.47±0.14	0.83
	Intertrochanter*	0.59±0.11	0.59±0.14	0.90

*The values are given as the mean, with the standard deviation. Abbreviations: BMI=body mass index; eGFR=estimated glomerular filtration rate; ASA=American Society of Anesthesiologists-physical status; BTMs=bone turnover markers; P1NP= procollagen type I N-terminal propeptide; TRACP-5b=Tartrate-resistant acid phosphatase type 5b; BMD=bone mineral density. Differences between the groups were determined by ANOVA or Fisher's exact test, and Statistical differences were considered significant for *p*-values <0.05.