

# Changes in Bone Mineral Density of Both Proximal Femurs after Total Knee Arthroplasty

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**Background:** This study investigated the effects of total knee arthroplasty (TKA) on bone mineral density (BMD) of the proximal femur in patients who underwent the procedure.

**Methods:** Forty-eight patients scheduled to undergo unilateral TKA because of primary knee osteoarthritis were included in this study, which was conducted at a medical center between October 2006 and October 2009. In these 48 patients, 96 hips were evaluated. Measurement of BMD was performed preoperatively and one month, three months, six months, and one year after unilateral TKA. Repeated measured analysis of variance and paired *t*-tests for comparison of two repeated samples were used to compare differences between time points (preoperation, one, three, six, and 12 months) and between the operative and nonoperative sides.

**Results:** Preoperatively, BMD of the femoral neck, trochanter, and total hip on the operative side were lower than on the nonoperative side; however, there was no statistical difference. BMD of both femoral neck areas was significantly lower than preoperative BMD at one month and three months after TKA. BMD of both trochanter areas was significantly lower than preoperative BMD at one month and three months after TKA. BMD of both total hips was significantly lower than preoperative BMD at three months after TKA. However, no statistical differences of changes in BMD were observed between the operative and nonoperative sides at each measurement time.

**Conclusions:** According to our results, TKA was found to affect both proximal femurs during the acute period. However, TKA did not affect a change in BMD of the proximal femur during one year postoperative.

**Keywords:** Proximal hip, Bone mineral density, Total knee arthroplasty

Due to a growing aging population and prevalence of osteoarthritis, rates of total knee arthroplasty (TKA) have increased. TKA offers relief from pain, and improvement in knee function and quality of life. However, TKA may result in postoperative complications, such as infection, thromboembolism, and nerve injury.

The authors experienced one patient who com-

plained of groin pain of the ipsilateral side without a history of trauma at three months after TKA, and we found a femoral neck fracture. We searched reports and journals on femoral neck stress fracture following TKA. Some studies have reported ipsilateral femoral neck fracture as a rare complication of TKA. Morbidity associated with hip fractures may include serious complications, such as deep vein thrombosis, postoperative infection, pain, and loss of mobility. Therefore, we thought that femoral neck fracture following TKA was a very serious problem and that is why we embarked on this study.

With increased demand of daily activity, microfractures during surgery due to hammer blows, the design of prosthesis, and decreased bone mineral density (BMD)

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after TKA, a few hypotheses regarding the etiologies of femoral neck stress fractures have been proposed.<sup>1-5)</sup> However, reports regarding changes of BMD in the proximal hip after TKA have been rare.<sup>6,7)</sup> Therefore, we first investigated whether TKA can affect changes in proximal hip BMD. Second, if so, does TKA have different effects on BMD of the operative and nonoperative sides? Some cases have reported the occurrence of femoral neck stress fracture within one year after an operation. Therefore, we studied the change in BMD within one year after TKA.

## METHODS

### Patients

Among patients who underwent TKA because of primary knee osteoarthritis from October 2006 to October 2009, we included only patients who had BMD measured with unilateral TKA at preoperation, and one, three, six, and 12 months after the operation. TKA was performed with patients who had a radiographic Kellgren-Lawrence grade III<sup>8)</sup> or greater and wanted the operation due to severe knee pain. We excluded patients who had undergone a contralateral TKA (seven cases) within one year after TKA or who had any neurological issues (cerebral infarction, 1 case; Parkinson disease, 3 cases; peroneal nerve injury, 1 case) or took medicine (steroid, 32 cases; osteoporosis drug, 41 cases). A total of 48 consecutive patients (11 males and 37 females) were included in this study. The mean age of the patients was 63 years (range, 53 to 76 years). The 40 cases of the nonoperative side were Kellgren-Lawrence grade II or less. Eight cases had Kellgren Lawrence grade III or more, but did not receive TKA. They did not feel the need to undergo surgery of the con-

tralateral knee.

### Measurement of BMD

BMD of both hips was measured at baseline and at one, three, six, and 12 months follow-up. The femoral neck, trochanter, and total area of the hip were measured in the proximal femur. BMD was measured using dual energy X-ray absorptiometry (DEXA; lunar PPX-L, Medison, WI, USA). The *in vivo* coefficients of variation for BMD were 1.4% for the lumbar spine, 2.1% for the femoral neck, 2.1% for ward's triangle, 1.1% for the greater trochanter, and 1.0% for the total proximal femur. We used a leg holding device provided by the manufacturer to gain high-quality anteroposterior scans of the hips. The least significant change (LSC) was calculated for each skeletal variable studied using the formula  $CV\% \times 2 \times 1.41$ , which would represent a significant statistical difference at the 95% confidence level.<sup>9)</sup>

### Statistics

SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. Repeated measured analysis of variance (ANOVA) was performed for testing changes of BMD at each measurement time on the operative side and nonoperative side. A paired *t*-test was performed for testing the difference in changes of BMD between the operative side and nonoperative side at each time point (baseline, one, three, six, and 12 months). Statistical significance was defined as  $p < 0.05$ .

## RESULTS

In this study, the authors classified two categories from

**Table 1.** Preoperative and Postoperative BMDs of Both Sides of the Hip

Measurement time (mo)	Region of interest					
	Femoral neck		Trochanter		Total femur	
	Operative side	Nonoperative side	Operative side	Nonoperative side	Operative side	Nonoperative side
Preoperative	0.699 ± 0.054	0.709 ± 0.035	0.636 ± 0.066	0.647 ± 0.075	0.682 ± 0.046	0.686 ± 0.084
Postoperative						
1	0.672 ± 0.075	0.683 ± 0.058	0.620 ± 0.107	0.633 ± 0.057	0.672 ± 0.086	0.678 ± 0.093
3	0.656 ± 0.106	0.667 ± 0.084	0.624 ± 0.093	0.637 ± 0.089	0.637 ± 0.119	0.654 ± 0.075
6	0.683 ± 0.099	0.697 ± 0.067	0.627 ± 0.127	0.640 ± 0.012	0.669 ± 0.082	0.675 ± 0.063
12	0.684 ± 0.067	0.701 ± 0.096	0.631 ± 0.067	0.645 ± 0.049	0.675 ± 0.093	0.677 ± 0.063

BMD: bone mineral density, TKA: total knee arthroplasty.

**Table 2.** Changes in BMD from the Preoperative Baseline after TKA

Postoperative (mo)	ROI	Operative side		Nonoperative side		<i>p</i> -value
		Mean ± SD	<i>p</i> -value	Mean ± SD	<i>p</i> -value	
1	Femoral neck	0.026 ± 0.049	0.008	0.025 ± 0.037	0.004	0.136
	Trochanter	0.016 ± 0.053	0.009	0.014 ± 0.031	0.005	0.359
	Total femur	0.009 ± 0.062	0.187	0.082 ± 0.049	0.153	0.634
3	Femoral neck	0.042 ± 0.087	0.003	0.042 ± 0.073	0.023	0.196
	Trochanter	0.012 ± 0.099	0.026	0.010 ± 0.014	0.033	0.295
	Total femur	0.037 ± 0.045	0.032	0.035 ± 0.058	0.015	0.614
6	Femoral neck	0.017 ± 0.069	0.232	0.014 ± 0.052	0.291	0.269
	Trochanter	0.009 ± 0.082	0.487	0.007 ± 0.063	0.418	0.158
	Total femur	0.013 ± 0.059	0.314	0.011 ± 0.086	0.334	0.723
12	Femoral neck	0.013 ± 0.093	0.900	0.011 ± 0.073	0.821	0.256
	Trochanter	0.005 ± 0.079	0.859	0.002 ± 0.008	0.881	0.452
	Total femur	0.007 ± 0.058	0.597	0.008 ± 0.096	0.631	0.832

BMD: bone mineral density, TKA: total knee arthroplasty, ROI: region of interest, SD: standard deviation.

each subject, one was bone density of the proximal femur that underwent TKA (ipsilateral side), and the other was bone density of the proximal femur that did not undergo TKA (contralateral side). There were no statistically significant differences in mean baseline BMD of the femur neck, trochanter, or total area between the ipsilateral and the contralateral side. (femur neck,  $p = 0.153$ ; trochanter,  $p = 0.184$ ; total area,  $p = 0.169$ ).

On the ipsilateral side, BMD in the femur neck was measured as  $0.672 \pm 0.075$  g/cm<sup>2</sup> after postoperative one month, and  $0.656 \pm 0.106$  g/cm<sup>2</sup> after postoperative three months, and these values were significantly lower than baseline BMD. BMD in the trochanter was measured as  $0.620 \pm 0.107$  g/cm<sup>2</sup> after postoperative one month and  $0.624 \pm 0.093$  g/cm<sup>2</sup> after postoperative three months, and these values were significantly lower than baseline BMD. BMD in the total area was measured as  $0.637 \pm 0.119$  g/cm<sup>2</sup> after postoperative three months, and these values were significantly lower than baseline BMD.

On the contralateral side, BMD in the femur neck was measured as  $0.683 \pm 0.058$  g/cm<sup>2</sup> after postoperative one month, and  $0.667 \pm 0.084$  g/cm<sup>2</sup> after postoperative three months, and these values were significantly lower than baseline BMD. BMD in the trochanter was measured as  $0.633 \pm 0.057$  g/cm<sup>2</sup> after postoperative one month, and  $0.637 \pm 0.089$  g/cm<sup>2</sup> after postoperative three months, and these values were significantly lower than baseline BMD.

**Table 3.** Changes (%) in BMD at Postoperative One Year

Variable	Operative side (%)	Nonoperative side (%)
Femur neck	2.14	1.12
Trochanter	0.78	0.03
Total femur	1.01	1.31

BMD: bone mineral density.

BMD in the total area was measured as  $0.654 \pm 0.075$  g/cm<sup>2</sup>, and these values were significantly lower than baseline BMD (Table 1). However, when the LSC was not included in the calculation, only BMDs in the femoral neck and total area after postoperative three months were significantly lower than baseline BMD.

No statistical differences in changes of BMD were observed between the two groups at each measurement time (Table 2). The changes (%) of BMD after postoperative one year are shown in Table 3.

## DISCUSSION

Severe complications in elderly patients with a hip fracture included pneumonia, thromboembolism, and death. Known risk factors for hip fracture include falls, proximal femoral geometry, vitamin D level, muscle strength, and

BMD.<sup>10,11)</sup> Among these, decrease in BMD is an important factor. Melton et al.<sup>12)</sup> reported that the more BMD decreased, the greater the risk of femur neck fracture as the square of BMD change, and greater the risk of trochanteric fracture as the cube of BMD change.

If a certain area of an object under loading shows a change in material property or mechanical property or microstructure, the transmission of stress is changed. Changes of the knee, such as osteoarthritis or TKA would have an effect on the mechanical properties of surrounding regions.<sup>13,14)</sup> Many studies have reported that knee osteoarthritis influences bone strength of the proximal femur and patients with osteoarthritis usually have increased BMD in the femur neck.<sup>15-18)</sup> In our study, preoperatively, BMD of the hip on the operative side was lower than on the nonoperative side in accordance with the study reported by Ishii et al.<sup>7)</sup> However, no statistical differences were observed. Soininvaara et al.<sup>6)</sup> reported that preoperative BMD of the proximal femur on the operative side was significantly lower than that of the contralateral side in all region of interests. Considering the results, degree of exercise restriction due to pain and limited range of motion of the joint, degree of osteoarthritis, pain scale before operation, dominant-leg, individual demands in daily life, and discordance between BMD of the left- and right-hip were considered compositively.<sup>19-22)</sup> Also, according to the results of our analysis, the fact that 83% of the nonoperative side showed Kellgren-Lawrence stage II or less (83%) should be considered, and there was a limit to the application of the result to severe osteoarthritis of both knees.

Regarding discordance between BMD of the left- and right-hip, many studies have reported that the difference was not statistically significant, and BMD measurements of both hips were meaningless.<sup>22)</sup> However, some studies have reported that measurement of BMD of both hips has an effect on diagnosis according to WHO osteoporosis diagnostic criteria, asserting the need for measurement of BMD in both hips.<sup>22)</sup> However, in our study, we analyzed changes of BMD on each side and differences of the change in BMD between the operative side and nonoperative side. Therefore, discordance between BMD of the left- and right-hip was not our concern.

BMD in the femoral neck and total area showed a significant decrease after postoperative three months on both the nonoperative side and the operative side. However, BMD at twelve months after operation showed similar values compared to preoperative levels, but lower than baseline, and followed predicted rates of age related loss.<sup>17,21,23,24)</sup> We believe that an early decrease of BMD occurred with decreased activity and weight load due to

postoperative pain, and less recovery of general condition and nutritional state before postoperative three months and recovery to baseline BMD after six months were due to their restoration.

Our results followed predicted rates of age related loss at postoperative one year. Age-related loss of BMD after postoperative one year differs according to ethnic group. Hannan et al.<sup>21)</sup> reported BMD losses of 0.04%–2.85% per year. Dennison et al.<sup>23)</sup> reported that women aged 60–75 years showed a BMD loss of 1.43% naturally. Young et al.<sup>24)</sup> reported that changes of BMD in white people was 0.35%–0.96% in the femur neck, 0.32%–0.95% in total, and 0.36%–1.14% in the trochanter. In our study, for change in BMD after TKA at postoperative one year, recovery of BMD after the operation at one year was not sufficient to reach a baseline state and followed age related loss. This differed from the report by Ishii et al.,<sup>7)</sup> which indicated that early intervention by TKA might also be protective against later hip fracture.

We checked the difference in BMD of both hips in order to determine whether TKA can affect proximal BMD differently between the operative side and nonoperative side. According to our results, there was no significant difference in change of BMD between the operative side and nonoperative side. Therefore, we suggest that changes in general condition, nutritional state, and degree of weight bearing did not influence BMD of either hip differently. In addition, factors directly and indirectly related to TKA, such as less recovery of range of motion and decrease of periprosthetic BMD, did not influence either hip differently. In considering these results, a decrease in postoperative BMD is not a direct cause of ipsilateral femoral neck stress fracture after TKA.<sup>1-5)</sup> We deem there could be another cause, such as the occurrence of femoral neck microfracture intraoperatively because of hammering or forceful manipulation in osteoporotic patients. A constrained type design would be a cause that would demand increased range of motion and result in increased bending and shearing force on the hip joint.

There were some limitations of our study. First, the number of patients was only 49 of 871 cases who underwent an operation during the research period. Second, our study may include more ambulating patients and patients who showed good results, who visited the hospital regularly and accepted measurements of BMD five times for a set period. Third, we evaluated bone strength with only BMD. We suggest that further study is needed, with inclusion of a larger number of cases, and additional analysis together with bone quality, such as the microstructure.

Although TKA has an effect on BMD in both the

femur neck and trochanter after postoperative one month and three months, it does not affect the ipsilateral side and contralateral side differently. Therefore, we thought that a temporary decrease in BMD after TKA was not the direct cause of ipsilateral femoral stress fracture, but the indirect cause of ipsilateral femur neck stress fractures after TKA. Therefore, there is a need to conduct a variable study on

the causes of ipsilateral femoral neck stress fracture after TKA.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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