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Original article

Factors related to stress fracture after unicompartmental knee arthroplasty

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A B S T R A C T

Background/objective: Unicompartmental knee arthroplasty (UKA) is a low-invasive knee surgery that enables early recovery. Stress fracture of the medial tibial plateau (MTP) is a complication of UKA that prolongs treatment once it has occurred. We investigated factors affecting its occurrence.

Methods: The study subjects were 167 patients who underwent fixed-bearing UKA between 2009 and 2016 (45 men and 122 women of mean age 77 years, including 134 with osteoarthritis of the knee and 33 with spontaneous osteonecrosis). We measured bone mineral density, installation angle of the tibial component, and leg alignment in those patients who developed stress fracture within 3 months after UKA.

Results: Stress fracture did not occur in 155 patients (N group, 45 men and 110 women) and did occur in 12 (SF group, 12 women). The bone mineral density (BMD) of the proximal femur was significantly lower in the SF group, indicating that bone fragility may have contributed to stress fractures at this site. There was no significant difference in the preoperative tibio-femoral angle (TFA), however, postoperative TFA was larger and the magnitude of the change in the valgus direction (ΔTFA) was smaller in the SF group.

Discussion: In usual UKA for medial compartment, the leg is more extroverted postoperatively than preoperatively, and leaving the knee in the genu varus position, which places a greater load on the tibial component, may raise the risk of stress fracture. Although there was no difference between the two groups in the varus angle of the tibial component, in a scatter plot of postoperative TFA and the installation angle of the tibial component members of the SF group were concentrated in the region of high TFA and low varus angle. Varus of the leg and a low varus angle of the tibial component may thus be factors in the occurrence of stress fracture.

Conclusion: Our results suggested that low BMD in the affected femur, large postoperative TFA, and a combination of large postoperative TFA and small varus angle of the tibial component may contribute to stress fracture of the MTP following UKA.

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Introduction

Increased need for knee arthroplasties is reported in the recent aging society. Unicompartmental knee arthroplasty (UKA) is superior strategy for its low invasiveness, good postoperative range of motion (ROM), and early recovery. However, it has been reported that UKA has a lower survival rate and more complications postoperatively than total knee arthroplasty (TKA).[1] Stress fracture on the medial tibial plateau (MTP), where a tibial component is fixed, is known as implant failure after UKA. Berger and others reported that fractures around the tibial component occur in 0.2–5% cases in the early postoperative stage.[2] It is important to prevent this kind of fracture to achieve better results after UKA.

The purpose of this study was to identify the factors related to stress fractures of the MTP after UKA. Our hypothesis was that tibial component positioning, leg alignment, and bone mineral density (BMD) would affect the development of stress fractures. This made us focus on, bone mineral densities (BMDs) of the lumbar vertebrae and proximal femur, and implant installation angle and leg alignment in the coronal plane.

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Materials and methods

Fixed-bearing medial UKA was performed in 167 patients for 134 cases of osteoarthritis (OA) and 33 cases of spontaneous osteonecrosis of the knee (SONK) between 2009 and 2016. The patients included 45 men and 122 women with a mean age of 77 (range, 61–88) years. Patients who developed stress fracture within three months after UKA were classified as group SF. Various factors of group SF were compared with those of remaining 155 patients (Group N). (Table 1).

This study was conducted in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) and was a retrospective review of the medical records, so it did not require a review by the Local Research Ethics Committee.

Surgical procedure

Arthroscopy was carried out just before UKA to confirm that there was no damage to the lateral compartment and anterior cruciate ligament (ACL). Spacer block technique was used with a chisel arranged to have a right-angled edge (Fig. 1). Preventing what we call an extended vertical cut during tibial bone resection,[3] sometimes a cause of fractures of the MTP, the tibia was cut with a bone saw on the front side and cut with the chisel on the back side. Implants were fixed with bone cement, and the surface was chosen based on whether it could keep a space of at least 2 mm for a tension gauge in both extension and flexion.

Rehabilitation

The drainage tube was removed on the day after UKA. Each patient started ROM training on that day. Weight-bearing was then added depending on the degree of each patient's pain from the second day after surgery.

Radiographic assessment of postoperative stress fracture

X-ray fluoroscopy was performed right after the surgery: AP-view images were taken from the direction vertical to the upper and medial edge of the tibial component, ML-view images were from the direction vertical to the upper edge of the component (Fig. 2-a). Fluoroscopic examination was carried out repeatedly in the same way every week up to approximately the 6th week after the surgery. Stress fracture of MTP is observed as a clear zone showing a narrow space in the medial edge of the tibial component (Fig. 2-b). This tiny clear zone, however, cannot be revealed by general imaging without using fluoroscopy (Fig. 2-c).

Factors investigated

BMI and BMD were measured just before a surgery. Dual-energy X-ray absorptiometry (DEXA) was performed to examine BMD at two distinct sites: lumbar vertebrae L1 to L4 in the AP view and the proximal femur on the affected side. The AP view radiograph of the knee joint was used to assess tibial component positioning in the coronal plane. The angle was zero degrees at the vertical line crossing the tibial axis to the tibial installation angle as the tibial component alignment angle (TCAA) (Fig. 3). The tibio-femoral angle (TFA) was evaluated before and after surgery, as well as its degree of change (ΔTFA).

X-ray fluoroscopy images were taken in the tangential direction toward the medial and lower edges of the tibial component at the time of UKA, one week after the surgery, and every weeks post-operatively up to the 6th week. Fluoroscopic imaging helps detect a slight sinking of the implant by showing clear zones between the tibial component and the patient's bone, or the component and cement. Patients' characteristics were investigated and compared between patients who developed stress fracture of the MTP (Group SF) and those who had no fractures (Group N) (Student's T-test). Each of these factors was also included as an explanatory variable in our multivariate analysis. The response variable was whether stress fracture occurred or not.

Results

Stress fractures occurred in 12 of 167 (7.2%) cases after UKA, of which one case required revision surgery (TKA). The remaining 11 cases had remission with conservative treatment, such as weight-bearing reduction according to the degree of pain. Comparing preoperative patients' characteristics between Group N and Group SF, Group N had 123 cases of OA, and 32 cases of SONK, with 45 men and 110 women. Patients in Group SF were all women, with 11 cases of OA and 1 case of SONK. As to other comparisons (mean ± SD), age was 77.2 ± 4.5 years in Group N and 79.4 ± 5.1 years in Group SF. There was no significant difference in BMD of the lumbar vertebrae in the AP view between the two groups: 0.96 ± 0.15 g/m^2 in Group N and 0.89 ± 0.13 g/m^2 in Group SF. For BMD of the affected-side proximal femur, Group SF showed a significantly lower value (0.65 ± 0.16 g/m^2) than Group N (0.73 ± 0.10 g/m^2; Student's *t*-test, $p = 0.03$). Preoperative TFA did not differ significantly (180.1 ± 4.1° in Group N and 180.0 ± 4.8° in Group SF). Postoperative TFA in Group SF, however, was significantly higher (179.3 ± 3.3° versus

Table 1
Data of examined patients.

Group		SF group	N group	P-value[b]
No. of cases		12	155	
Gender		12 females	110 females	
		0 males	45 males	
Primary disease		11 OA	123 OA	
		1 SONK	32 SONK	
Age range (years)		64–91	73–88	0.11
		79.4 ± 5.1[a]	77.2 ± 4.5[a]	
BMD	proximal femur	0.65 ± 0.16[a]	0.73 ± 0.10[a]	0.03
	lumbar vertebra	0.89 ± 0.13[a]	0.96 ± 0.15[a]	0.13
TFA (°)	before surg.	180.1 ± 4.8[a]	180.1 ± 4.1[a]	0.99
	after surg.	179.3 ± 3.3[a]	176.5 ± 3.6[a]	0.012
ΔTFA		0.83 ± 3.30[a]	3.63 ± 3.45[a]	0.007
TCAA		2.83 ± 2.69[a]	4.19 ± 2.94[a]	0.13

BMI: body mass index, TFA: tibio-femoral angle, OA: osteoarthritis, SONK: spontaneous osteonecrosis of the knee. TCAA: Tibial component alignment angle.
[a] Values expressed as mean ± SD.
[b] Student's T-test.

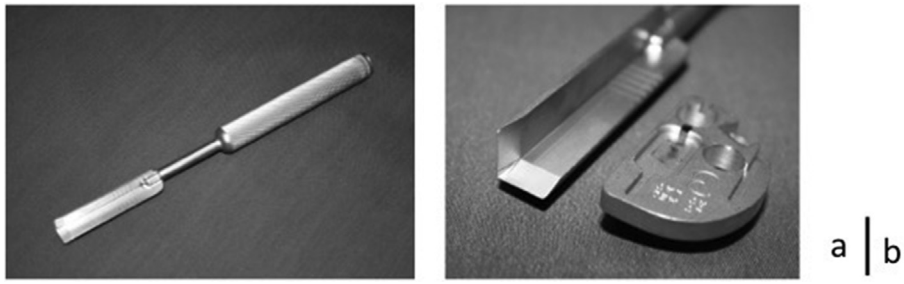

Fig. 1. A: A chisel is arranged for tibial osteotomy, B: The back edge of the tibia is cut with the right-angled chisel, preventing an extended vertical cut.

Fig. 2. AP-view images were taken from the direction vertical to the upper and medial edge of the tibial component, ML-view images were from the direction vertical to the upper edge of the component (Fig. 2-a). Stress fracture of MTP is observed as a clear zone showing a narrow space in the medial edge of the tibial component (Fig. 2-b). This tiny clear zone, however, cannot be revealed by general imaging without using fluoroscopy (Fig. 2-c).

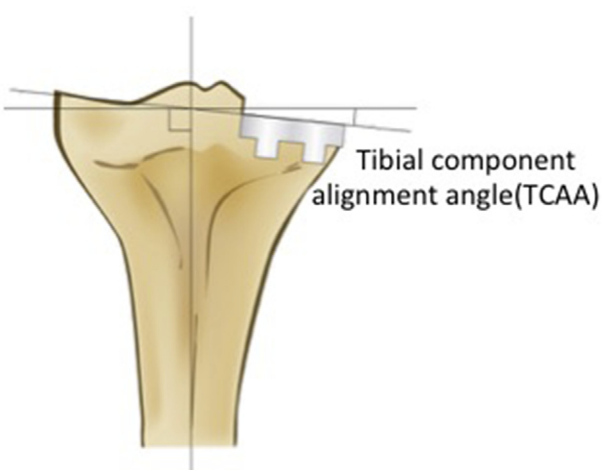

Fig. 3. Tibial component alignment angle (TCAA) was measured in the AP radiographic of the knee. TCAA was defined as the angle between the tangential line of the tibial component and the line vertical to the tibial shaft axis.

176.5 ± 3.6° in Group N; Student's *t*-test, $p = 0.012$). For ΔTFA, the degree of varus deformity was 0.83 ± 3.30° in Group SF, significantly lower than in Group N (3.63 ± 3.45°; Student's *t*-test, $p = 0.007$). Tibial varus alignment was comparable in the two groups, with a Tibial component alignment angle of 2.83 ± 2.69° in Group SF and 4.19 ± 2.94° in Group N (Table 1).

In the multivariate analysis, explanatory variables were refined by stepwise. It was detected that BMD of the proximal femur (Odds ratio 0.388, P value = 0.028) and postoperative TFA (Odds ratio 2.470, P value = 0.001) (Table 2) were independent variables.

Discussion

Stress fracture of the MTP is one of the serious complications after UKA because it requires revision surgery, such as TKA or osteosynthesis, in some cases. In the present study, conservative treatment, except for one conversion to TKA, was performed for stress fractures. However, the treatment period was prolonged by a restriction of weight-bearing according to the degree of pain or some other procedures. These cases were examined to determine whether BMD, tibial component positioning, and leg alignment might be related to stress fractures. They were diagnosed when a slight sinking of the tibial component was seen on postoperative radiographs.

Table 2
Results of multivariate logistic regression analysis.

		Odds ratio	P-value
TFA	after surg.	2.470	0.001
BMD	proximal femur	0.388	0.028

Akagi and others reported that the stress concentration on the tibia becomes high at the proximal end of the medial diaphyseal cortex and the anterior and posterior cortices of the corner on the osteotomy surface after UKA.[4] Then, in the report of Iesaka and others,[5] the most concentrated stress was found to be on the proximal end of the medial diaphyseal cortex under the tibial component. As seen in the Fig. 2, stress fracture was identified as a small amount of sinking from the corner of the osteotomy surface toward the proximal end of the medial diaphyseal cortex. Such sinking is too small to be demonstrated by general imaging of the knee joint. This kind of fracture can be seen when a clear zone occurs in the medial edge of the tibial component with its varus deformity. The present study found a higher incidence (7.2%) than previous studies for insufficiency fractures after UKA.[1] The diagnosis was made by X-ray fluoroscopy both during and after surgery, which showed the slight sinking that might otherwise have been missed in the usual examinations.

The surface area of the tibial component fixation in UKA is smaller than that in TKA, and it is supposed to apply greater stress on the MTP per unit area in UKA. Bone fragility can be factors causing stress fractures of the MTP. The postoperative relationship between BMD and the results of UKA has not been evaluated in many studies. In the present study, BMD of the affected-side proximal femur was low in Group SF, while that of the lumbar vertebrae in the AP view showed no difference between the groups. Bone fragility in the affected leg is thus implicated in stress fractures around the tibial component.

It is still controversial whether leg alignment should be corrected in UKA. It becomes valgus in many cases due to the detachment of medial soft issue or thickness of the implant. Postoperative TFA decreased significantly in the present study as well. In general, leg alignment is corrected within a small range in UKA; therefore, medial OA with varus leg alignment usually remains varus after surgery. It can be easily surmised that the medial tibial component has much more load in a varus knee joint. Furthermore, there is a report supporting it.[6]

Many implant failures of the tibial component have been reported in varus knee joints after UKA.[7–9] The significance of this was confirmed in the present study, since patients in Group IF with varus knee joints showed large TFA and low ΔTFA postoperatively. The results of the present study suggest that varus knee joints may have insufficiency fractures after UKA when leg alignment does not change to valgus but stays in varus. This means that a varus leg deformity should be corrected as much as possible to prevent insufficiency fractures.

The stress on the MTP is related to the tibial implant installation angle in the coronal plane. This was also reported by Akagi and others[4]; the stress on the proximal end of the medial cortex of the tibia decreased 9% when the tibial component was 3° varus and decreased 17% with the component at 6° varus. On the other hand, there was a 10% increase with the tibial component at 3° valgus, and a 16% increase at 6° valgus. For this reason, the tibial component is better fixed in the varus position to reduce stress toward its lower part.

The present study showed that TCAA in Group IF was apt to be small, but there was no significant difference. The relationship between stress fractures and varus or valgus angles of the tibial implant could not be identified. However, patients in Group IF were in the area on the scatter diagram for having large postoperative TFA and TCAA in slight varus (Fig. 4). This means that they were distributed where the load on the tibial component was thought to be large. This indicates that we have to fix the tibial component in varus to some extent for high varus knee joints with large TFA to prevent stress fractures.

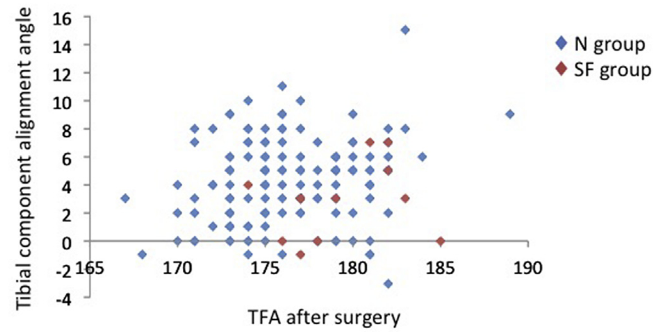

Fig. 4. The scattered black diamonds show varus angles of the tibial components and postoperative TFA s in Group IF. Most of them are distributed in the lower-right area. This suggests that patients may develop stress fractures when they have a larger TFA postoperatively with a TCAA.

In this study, stress fracture of the MTP was possibly induced by low BMD in the affected leg and a varus knee joint after UKA. It can be predicted that fracture is likely to be associated with the increase of the load on the tibial component having a small varus angle.

In many cases, UKA is performed for elderly and female patients, who usually have low BMD. It is difficult to increase BMD in a very short period. We should correct a varus knee joint as best as possible and decrease the load on the tibial component by setting it varus to prevent stress fractures. Then, for cases having large postoperative TFA with the tibial component in slight varus, careful attention to stress fractures is needed during follow-up.

The limitation of this study is that a fracture without sinking was likely to develop during the surgery, and it could not be ruled out.

Conclusion

In most cases, stress fractures of the MTP after UKA had low BMD at the proximal femur in the affected leg and large postoperative TFA. They also tended to have a small varus angle of the tibial component, suggesting that the fractures occur under the stress of the load there.

This leads us to the conclusion that leg alignment should be corrected toward more valgus than that in the preoperative position to prevent stress fractures around the tibial component after UKA.

Conflict of Interest

The authors have no conflicts of interest relevant to this article.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.asmart.2018.10.001.

References

1. Pabinger C, Berghold A, Boehler N, Labek G. Revision rates after knee replacement. Cumulative results from worldwide clinical studies versus joint registers. *Osteoarthritis Cartilage*. 2013;21:263–268.
2. Berger RA, Meneghini RM, Jacobs JJ, et al. Results of unicompartmental knee arthroplasty at a minimum of ten years of follow-up. *J Bone Joint Surg Am.*

2005;87:999–1006.
3. Clarius M, Haas D, Aldinger PR, et al. Periprosthetic tibial fractures in unicompartmental knee arthroplasty as a function of extended sagittal saw cuts: an experimental study. *Knee*. 2010;17:57–60.
4. Akagi M, Asada S, Mori S, et al. Stress analysis of the medial tibial condyle in unicompartmental knee arthroplasty: effects of tibial implant alignment. *J Biomech*. 2012;33:287–292.
5. Iesaka K, Tsumura H, Sonoda H, et al. The effects of tibial component inclination on bone stress after unicompartmental knee arthroplasty. *J Biomech*. 2002;35:969–974.
6. Innocenti B, Pianigiani S, Ramundo G, et al. Biomechanical effects of different varus and valgus alignments in medial unicompartmental knee arthroplasty. *J Arthroplasty*. 2016;31:2685–2691.
7. Chatellard R, Sauleau V, Colmar M, et al. Société d'Orthopédie et de Traumatologie de l'Ouest (SOO). Medial unicompartmental knee arthroplasty: does tibial component position influence clinical outcomes and arthroplasty survival? *Orthop Traumatol Surg Res*. 2013;99(4 Suppl):S219–S225.
8. Kim KT, Lee S, Kim TW, et al. The influence of postoperative tibiofemoral alignment on the clinical results of unicompartmental knee arthroplasty. *Knee Surg Relat Res*. 2012;24:85–90.
9. Kennedy WR, White RP. Unicompartmental arthroplasty of the knee. Postoperative alignment and its influence on overall results. *Clin Orthop Relat Res*. 1987;221:278–285.