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Original Article

Stress fractures of the lateral tibial plateau after open wedge high tibial osteotomy could be delayed type III lateral hinge fractures

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ABSTRACT

Purpose: To examine the condition and triggers of stress fractures of the lateral tibial plateau (LTP) similar to type III lateral hinge fractures (LHFs) after open wedge high tibial osteotomy (OWHTO).
Methods: OWHTO was performed in 118 knees. They were examined for LHFs by computed tomography (CT). Patients were divided into the stress fracture group (Group SF) if they showed fracture lines on CT performed after starting weight-bearing walking and the normal group (Group N) for others.
Results: The mean age was significantly older in Group SF ($P = 0.022$). Preoperatively, Group SF showed a significantly higher tibio-femoral angle (TFA, $P = 0.014$). No significant differences were observed in TFA and weight-bearing line ratio after surgery. Correction angle was significantly higher in the SF group. And all of the SF were more than 13 degrees. There was no significant difference in LHF incidence between groups, whereas stress fracture incidence differed significantly for each type of LHF (chi-squared test, $P = 0.0001$): 14.6% of type I cases, 100% of type II cases, 0% of type III cases, and 6.1% of those without LHF.
Discussion: The load on the LTP is assumed to act as a shearing force in type II fractures, which may contribute greatly to stress fractures. In type III, stress fractures may not occur because of the load dispersed at the fracture part. The stress fracture site is similar to type III LHF, and this kind of fracture is thought to be a delayed type III because it occurs after patients start weight-bearing walking. Moreover, they are observed in type I cases with a stable hinge and in 6% of cases without LHF. This study showed that high varus knees corrected with a large correction angle may develop stress fractures. OWHTO requires attention to stress fractures of the LTP, which can be regarded as delayed type III, in those developing LHFs postoperatively or having a high varus knee preoperatively.
Conclusion: These results indicated the possibility of stress fracture in LTP during weight-bearing exercise after OWHTO, which was regarded as a delayed type III fracture. The results showed that Correction angle was more than 13 degrees, and lateral hinge fracture type II of the Takeuchi classification was an inducement of this stress fracture.
Level of evidence: Level IV.

Introduction

High tibial osteotomy (HTO) is one of the treatment procedures for medial type knee osteoarthritis (KOA). In particular, open wedge HTO (OWHTO) is a relatively easy surgical procedure that is characterized by early load walking after surgery.[1] A lateral hinge fracture (LHF) is a common complication of OWHTO. Takeuchi and others reported the clinical importance of LHFs, classifying them into three types, of which type II and type III may cause correction loss and nonunion.[2] The classification was examined by Nakamura and others, and they reported that LHFs cause delayed union in type II and overcorrection or correction loss in type III. Therefore, a type II or type III LHF is a complication that should be avoided after OWHTO.

Some of our patients reported transient pain in the lateral knee joint during postoperative rehabilitation. On detailed CT, it was found that the pain was caused by a fracture of the lateral tibial

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plateau (LTP), similar to a type III LHF.

This study examined the conditions and triggers of such fractures under our hypothesis that it is a stress fracture of the LTP and a delayed type III LHF.

Materials and methods

Of the 164 knees that underwent OWHTO by one surgeon between 2012 and 2015, 118 cases were included in this study, excluding cases of simultaneous surgery for bilateral knees and of postoperative infection. There were 44 men and 74 women, with a mean age of 64 years (range, 40–72 years). The specific focus was on 110 cases of medial type KOA and 8 cases of spontaneous osteonecrosis of the knee (SONK) (Table 1). The correction angle was determined under the preoperative plan with the weight-bearing line ratio (WBL-R) set at 63%. In OWHTO, pes anserinus was resected, and then biplane osteotomy was performed from the upper edge of pes anserinus toward the proximal tibiofibular joint surface. While correcting the tibia, the superficial layer of the medial collateral ligament (sMCL) was separated, resected, or extended with the pie crust method until flexion contracture disappeared due to the tense sMCL. An original aluminum spacer was prepared with the angle determined as the opening angle in the preoperative planning for each patient.[3] Then, artificial bone (OSFerion 60®) was also formed in the same angle as the spacer. The tibia was cut and opened with two spacers, which were replaced with the formed OSFerion60® one by one. Then, the osteotomy site was fixed by a locking plate (Tomofix®) (Fig. 1).

CT was performed two days after surgery to classify cases by the appearance of LHFs and, if any, by the type according to the Takeuchi classification.[2] Then, on the same day, patients started range of motion (ROM) training after drain tube removal. Weight-bearing walking was added depending on the degree of the pain on the third postoperative day. CT was performed every week up to three weeks after surgery.

Some patients developed pain at the outside of the knee joint in the follow-up training, and CT showed a small fracture of the LTP not observed on the day after surgery. These cases were diagnosed as stress fractures of the LTP (Fig. 2). We defined Delayed Type III fractures as follows. The fracture cannot be confirmed on CT scan right after OWHTO and during the non-weight bearing walking, but a fracture resembling Takeuchi's Type II lateral hinge fracture after the start of weight bearing walking has been confirmed in LTP. And they constituted the stress fracture group (Group SF), while the others were considered the normal group (Group N). For every case, the body mass index (BMI) and the pre- and postoperative tibio-femoral angles (TFA)s and WBL-Rs were measured. These characteristics were compared between the two groups, and their relationships with LHFs and the LTP were examined.

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.

Results

There were 12 cases in Group SF, with 11 cases of KOA and 1 case of SONK, and there were 106 cases in Group N, with 99 cases of KOA and 7 cases of SONK ($P = 0.1191$, Chi-squared for independence test). Group SF consisted of 2 men and 10 women, and Group N consisted of 42 men and 64 women ($P = 0.8213$, Chi-squared for independence test). Comparing the characteristics (mean ± SD) of the two groups, the mean age was 65.8 ± 5.8 years in Group SF and 60.8 ± 7.2 years in Group N; the mean age was significantly older in Group SF ($P = 0.0228$), while no difference in BMI was observed between the groups ($P = 0.3465$). Preoperatively, the TFA in Group SF was 182.9 ± 3.5°, significantly higher than in Group N (180.5 ± 3.2°; $P = 0.0146$). The WBL-R was 3.4% ± 14.7% in Group SF and 16.6% ± 13.9% in Group N; it was significantly lower in Group SF ($P = 0.0025$). Postoperative results indicated that the opening angle was 13.7 ± 2.3° in Group SF and 11.1 ± 2.1° in Group N; Group SF required a significantly larger opening angle ($P = 0.0002$). There were no significant differences in the TFA and WBL-R between the two groups after surgery (Table 1). LHFs were detected in 52 cases (44% of the total), and they were classified into 3 types according to the Takeuchi classification: 41 cases of Type I; 2 cases of Type II; and 9 cases of Type III. LHFs occurred in 41% of Group N cases (44 cases) and 67% of Group SF cases (8 cases), with no significant difference between the groups (Fisher's exact test, $P = 0.087$) (Table 2). In contrast, the incidence of stress fractures in each type differed significantly (Chi-squared test, $P = 0.0001$) (Table 3): 6 (14.6%) cases of Type I; 2 (100%) cases of Type II; and none (0%) of Type III. There were 66 cases that did not develop LHFs, and they included 4 cases (6.1%) with stress fractures.

Discussion

HTO is a good surgical treatment to keep the patient's own knee

Table 1
Patient demographics.

		Group N	Group SF	P-value[a]
Cases		106	12	
Sex	Female	64	10	0.1191[a]
	Male	42	2	
Disease	OA	99	11	0.8213[a]
	SONK	7	1	
Age, y		60.8 ± 7.2	65.8 ± 5.8	0.0228**
BMI, kg/m^2		25.9 ± 3.5	26.9 ± 3.4	0.3465**
TFA	Before surgery	180.5 ± 3.2	182.9 ± 3.5	0.0146**
	After surgery	169.7 ± 2.5	171.0 ± 3.2	0.1117**
WBL-R	Before surgery	16.6 ± 13.9	3.4 ± 14.7	0.0025**
	After surgery	63.1 ± 12.4	57.8 ± 13.4	0.1810**
Correction angle		11.1 ± 2.1	13.7 ± 2.3	0.00002**

BMI = body mass index; OA = osteoarthritis; SONK = spontaneous osteonecrosis of the knee; TFA = tibio-femoral angle; WBL-R = weight-bearing line ratio.
[a] Chi-squared for independence test, **Student's *t*-test.

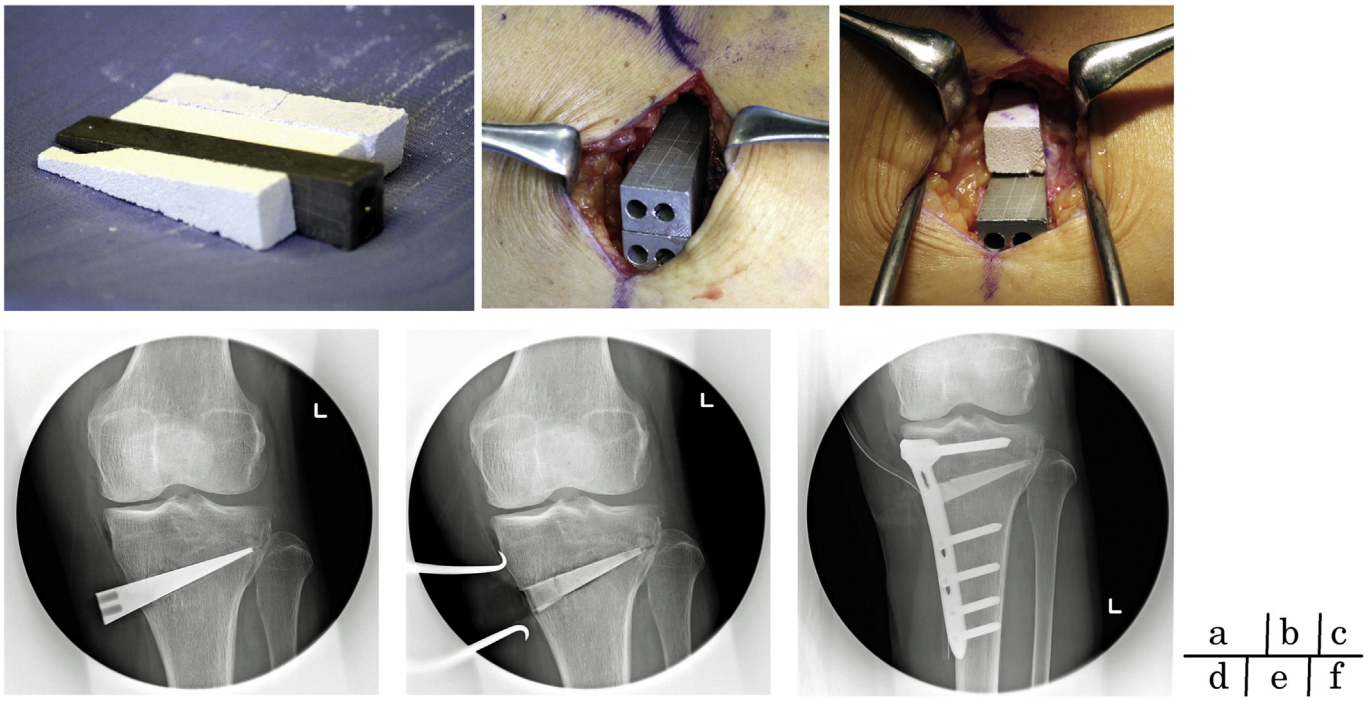

Fig. 1. An original aluminum spacer is prepared with the same angle as the opening angle, and an artificial bone (OSFerion 60®) is also formed with the same angle (a). The tibia is opened with two spacers at the osteotomy site (b, d). One of the spacers is replaced with the formed artificial bone (OSFerion 60®) (c, e). A locking plate is used to fix the site.

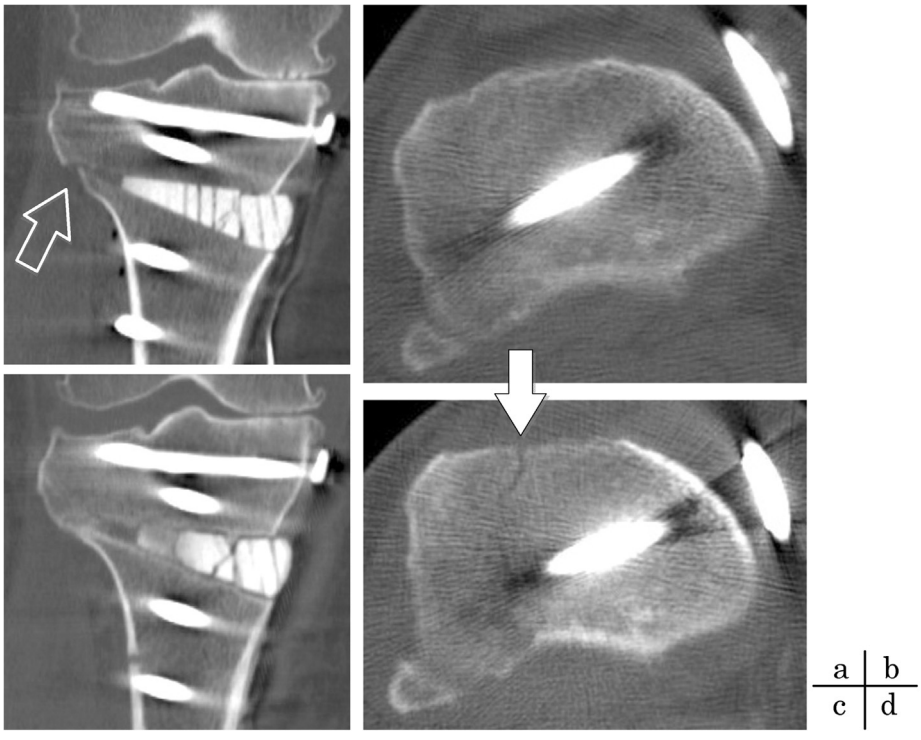

Fig. 2. OWHTO with an opening angle at 16° for medial type knee osteoarthritis. Type I LHF is shown on the CT on the second day after surgery (a, clear arrow), but no fracture of the LTP is observed (b). Two weeks after surgery, a fracture of the LTP is not diagnosed on the coronal view CT (c), but it is detected on the axial view CT (d, white arrow).

that is affected by KOA or SONK. However, the number of HTO cases decreased due to its prolonged treatment after surgery, and artificial joint replacement has taken its place. In recent years, OWHTO has spread with a relatively easy technique and an improved implant that can provide early weight-bearing walking.[1] An LHF is a complication that occurs with high frequency after OWHTO.[4] Once a patient develops an LHF, advantages of OWHTO, such as early weight-bearing walking and early social rehabilitation, are not achievable. Therefore, surgeons have to take measures to avoid LHFs.

Table 2
Number of LHFs between groups.

	LHF(−)	LHF(+)	P-value[a]
Group N	62	44	0.0878
Group SF	4	8	

LHF = lateral hinge fracture; N group = normal group; SF group = stress fracture group.
[a] Fisher's exact test.

Table 3
Number of stress fractures according to type of LHF.

	N group	SF group	P-value[a]
No LHF	62	4	0.0001
Type I	35	6	
Type II	0	2	
Type III	9	0	

LHF = lateral hinge fracture; N group = normal group; SF group = stress fracture group.
[a] Chi-squared for independence test.

There were 52 LHF cases (44% of the total) in the present study. This was clearly a higher rate than in other reports. During surgery, when we find strong resistance against opening of the tibial osteotomy site, we perform a complete cut until reaching the proximal tibiofibular joint to intentionally cause a type I fracture based on the suggestion of Kessler and others.[5] That is a procedure to avoid an LHF of Takeuchi classification type II or type III. Then, CT performed on the day after surgery led to a diagnosis of LHF without sinking, and it was not detected on the radiograph taken during or after surgery was finished. For these reasons, it is assumed that the incidence of LHF in this study was high.

There was a significant difference not in the incidence of LHF between Group N and Group SF, but in that of stress fractures between each type of LHF (Chi-squared test, P = 0.0001). It is suggested that stress fractures and LHFs have some relationships. Takeuchi and others[2] reported that type II and type III fractures in their classification of LHF cause instability at the hinge point, and in particular, type II may cause nonunion because there is no support from the fibula toward the hinge site. The present study included two cases of type II, all of which developed stress fractures. It is supposed that the load on the LTP acted as a shearing force in type II fractures with an unstable hinge (Fig. 3a), which resulted in stress fractures. Thus, patients with type II fractures should have delayed weight-bearing walking and be carefully observed for stress fractures of the LTP, which could occur after surgery.

Stress fractures do not occur in patients with type III fractures. It can be assumed that the load caused by the lateral femoral condyle (LFC) would disperse at the fracture part in type III cases (Fig. 3b). Then, a similar condition is observed between the fracture part of the stress fracture and that of the type III LHF. Stress fractures in Group SF were not demonstrated on CT on the second day after surgery, while they were diagnosed on CT performed after patients started weight-bearing walking. Nakamura and others[6] reported on type III cases of a total of 15 LHF cases that were detected 1 month after surgery. That is, a delayed onset type III fracture can be found in some cases, suggesting that the stress fractures of the LTP in this study are delayed type III.

Then, the problem is that stress fractures also occurred in the following cases: 14% of type I cases with a stable hinge, and 6% of cases with no LHF. Takeuchi and others[3] reported that, in type I, the load is able to exert stress on both the proximal tibiofibular joint and the hinge to keep them stable. Therefore, the load caused by the LFC is predicted to become a bending stress on the LTP (Fig. 3c). Stress fractures in cases without LHFs may occur in the same way.

OWHTO is generally performed aiming to correct the FTA to 170° and the WBL-R to 62.5%. A higher varus knee naturally requires a larger degree of correction. In this study, the correction angle was significantly larger (P = 0.0002) in Group SF as well, preoperatively having a significantly large FTA (P = 0.014) with a high varus knee. This means that stress fractures are likely to occur in higher varus knees corrected with a larger opening angle. Madsen and others[7] reported that bone mineral density (BMD) of the LTP is lower than that of the medial tibial plateau (MTP) in high varus knees. It is possible that the LTP is fragile in high varus knees, allowing stress fractures to occur after OWHTO. Correction angle and BMI scatter plots show that the Correction angle is at least 13 degrees of correction in all SF groups (red diamonds). No specific trends were found in BMI (Fig.4). In other words, if the correction angle is more than 13 degrees, attention may be paid to the Stress Fractures of the Lateral Tibial Plateau.

This study has a limitation that bone mineral density and other bone indices were not evaluated.

Collectively, patients who underwent OWHTO should be carefully examined for postoperative stress fractures of the LTP, which can be described as delayed type III fractures, in cases developing LHFs or undergoing surgery for high varus knees.

Conclusions

Our experience with cases of stress fractures of the LTP that occurred after OWHTO was reported. Our results indicated the

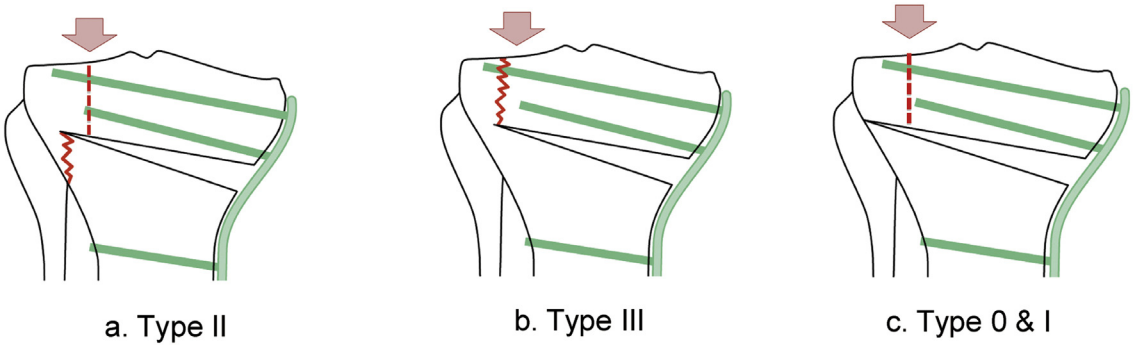

Fig. 3. In type II, the load on the lateral compartment becomes a shearing force because the hinge site is unstable (a). In type III, the load on the lateral compartment is dispersed at the site of the type III fracture (b). In no LHF cases and type I, with the hinge site stable, the load on the lateral compartment provides bending stress on the LTP (c).

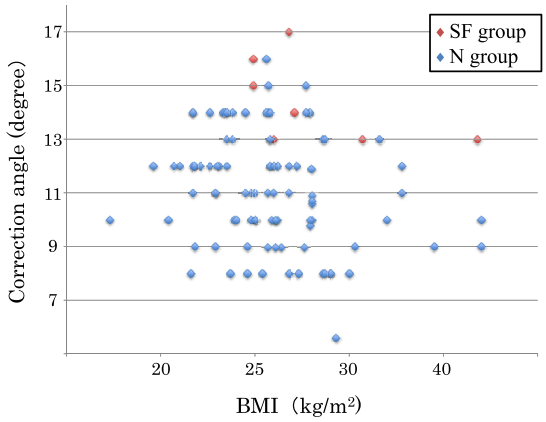

Fig. 4. Scatter plots of Correction angle and BMI. The red diamond represents SF, and the blue diamond represents N. The SF group has a Correction angle of at least 13 degrees.

possibility of stress fracture in LTP during weight-bearing exercise after OWHTO, which was regarded as a delayed type III fracture. The results showed that Correction angle was more than 13 degrees, and lateral hinge fracture type II of the Takeuchi classification was an inducement of this stress fracture.

Conflicts of interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.asmart.2019.10.001.

References

1. Takeuchi R, Ishikawa H, Aratake M, et al. Medial opening wedge high tibial osteotomy with early full weight bearing. *Arthroscopy*. 2009;25:46–53.
2. Takeuchi R, Ishikawa H, Kumagai K, et al. Fractures around the lateral cortical hinge after a medial opening-wedge high tibial osteotomy: a new classification of lateral hinge fracture. *Arthroscopy*. 2012;28:85–94.
3. Yokoyama M, Nakamura Y, Doi M. Development of a spacer for easy to do, exactly the medial opening high tibial osteotomy. *Joskas*. 2013;38:600–604.
4. Schröter S, Freude T, Kopp MM, et al. Smoking and unstable hinge fractures cause delayed gap filling irrespective of early weight bearing after open wedge osteotomy. *Arthroscopy*. 2015;31:254–265.
5. Kessler OC, Jacob HA, Romero J. Avoidance of medial cortical fracture in high tibial osteotomy: improved technique. *Clin Orthop Relat Res*. 2003;395:180–185.
6. Nakamura R, Komatsu N, Murao T, et al. The validity of the classification for lateral hinge fractures in open wedge high tibial osteotomy. *Bone Joint Lett J*. 2015;97-B:1226–1231.
7. Madsen OR, Schaadt O, Bliddal H, Egsmose C, Sylvest J. Bone mineral distribution of the proximal tibia in gonarthrosis assessed in vivo by photon absorption. *Osteoarthr Cartil*. 1994;2:141–147.