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Original article

High tibial osteotomy using two threaded pins and figure-of-eight wiring fixation for medial knee osteoarthritis: 14 to 24 years follow-up results

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Abstract

Background. High tibial osteotomy (HTO) is an established surgical treatment for medial knee osteoarthritis (OA). Several studies have reported the deterioration of clinical results with time, especially after more than 10 years. The purpose of this study was to evaluate the long-term results after HTO using our originally developed fixation method and to clarify the factors affecting the long-term clinical outcome.

Methods. Sixty-eight HTO treatments in 55 patients were evaluated. Eighteen patients were unable to be analyzed, thus reducing the study to 48 knees in 37 patients. The follow-up rate of the knee joint was 70.6% and the mean follow-up period was 17.1 years. The first evaluation was performed at a mean of 6.5 years postoperatively, and the most recent evaluation was done at more than 10 years postoperative follow-up. A closing-wedge osteotomy was performed, and the osteotomy site was fixed with two threaded pins and a figure-of-eight wiring technique. The Japanese Orthopaedic Association knee rating score (JOA score) was used for the clinical assessment. The change of the femorotibial angle (FTA) and progression of knee OA were radiographically analyzed. The whole knees were subsequently divided into two groups, satisfactory group and unsatisfactory group, according to the JOA score at the most recent follow-up.

Results. The mean JOA score was 59.1 before HTO and 83.1 at the most recent evaluation. In comparing the satisfactory and unsatisfactory groups, the JOA score before HTO was the same, but the JOA score of the unsatisfactory group was significantly lower at the first evaluation. The FTA in the unsatisfactory group was the same as in the satisfactory group preoperatively, but it was significantly larger after HTO. The radiographic OA was significantly progressed at the most recent evaluation, but no difference was observed in the distribution of the preoperative OA grade between the two groups.

Conclusions. HTO with two threaded pins and figure-of-eight wiring fixation showed an acceptable clinical outcome, but careful attention was needed for correction loss in early postoperative periods. In addition, the proper correction angle is necessary in order to achieve satisfactory long-term results.

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Introduction

Osteoarthritis (OA) is the most common form of degeneration of the joints. The knee joint is the key structure in the lower extremity and has much influence on the activity of daily life (ADL) and the quality of life (QOL) in elderly persons. These include standing, walking, running, jumping, stair climbing, deep knee bending such as squatting or Japanese-style sitting, and other lower extremity tasks. Approximately 10% to 15% of people aged 60 years and older have symptomatic knee OA.[1] Therefore, knee OA is a major source of chronic disability and is becoming a serious public health problem.

High tibial osteotomy (HTO) is one of the successful surgical treatments for medial compartment knee OA. HTO was first described by Jackson and Waugh,[2] and it is now widely accepted as an attractive procedure with good pain relief and preservation of knee function. Previous studies of early to midterm results of HTO have shown excellent outcomes in more than 80% of cases.[3–5] However, several studies with long-term follow-up reported that the results of HTO deteriorated with time, especially after more than 10 years. Several factors have been identified as affecting the results of HTO, but they remain controversial. These include sex, age at surgery, body weight, preoperative severity of knee OA, method of osteotomy and fixation, correction angle, amount of preoperative adduction moment, and postoperative period.[6–14]

Among these factors, the type of fixation following osteotomy remains important, and, in the past, the following methods have been reported: bone staples, blade plate with screws, one third tubular plate with a cortical screw (tension bend principle), L-buttress plate, and external fixator.[3,15–20] We developed a fixation method using two threaded pins and figure-of-eight wire and used this method for our consecutive HTO cases.

The purpose of this retrospective study was to assess the long-term results after HTO using our fixation method and to clarify the factors affecting the long-term clinical outcome.

Subjects and methods

Our indications for HTO were basically as follows: (1) degenerative change was mainly located in medial compartment (medial knee osteoarthritis), (2) normal or mild degeneration in lateral and patello-femoral compartment, (3) patient was younger than 70 years old and had relatively high activity in ADL, and (4) good range of motion and no remarkable knee joint instability. Between 1980 and 1990, HTO was performed in 68 consecutive knees in 55 cases by our senior surgeon (Y. K.). Seven patients died, 6 patients were unable to be evaluated due to the presence of other severe medical illnesses, and 2 patients were lost to follow-up. Three knees in 3 patients were converted to total knee arthroplasty (TKA) at 10 years, 12 years, and 15 years after HTO, respectively. Therefore, the remaining 48 knees in 37 cases were available for the present study, and the follow-up rate of the knee joint was 70.6%. There were 43 knees in 33 women and 5 knees in 4 men. The mean age at HTO was 59 years with a range from 40 to 69 years. The mean follow-up period was 17.1 years, but individual follow-up ranged from 14 to 24 years. The preoperative diagnosis was medial compartment knee OA in all the cases, and the preoperative Kellgren-Lawrence classification[21] showed grade II in 8 knees, grade III in 35 knees, and grade IV in 5 knees. All of the patients were evaluated initially in 1993, with a mean follow-up of 6.5 years, and evaluated at more than 10 years follow-up postoperatively. All of the patients were fully informed about the procedures and gave their informed consent.

Operative procedures and postoperative regimen

In all knees, the closing-wedge interlocking osteotomy through a lateral approach was performed according to the technique described by Ogata.[22] The correction angle was preoperatively determined to allow the mechanical axis, which is the line connecting the center of the femoral head and the ankle joint, to pass through the midpoint of the lateral compartment. The preoperative planning was performed using non-weight-bearing supine radiograph of the whole lower extremity according to Ogata et al.[23] Ogata mentioned that the relative angle of the articular surface (condylar-plateau angle) in the weight-bearing knee changed after osteotomy, and this might give unpredictable results postoperatively. He also found that the condylar-plateau angle in the postoperative standing radiograph was very similar to that seen in the non-weight-bearing supine condition, and recommended that a non-weight-bearing supine radiograph was better for preoperative planning. The femorotibial angle (FTA) that met this condition was around 165° to 168° in the majority of cases. The fibula was resected at the mid portion of the shaft. The osteotomy site was fixed with two threaded pins and a figure-of-eight wiring technique. First, two threaded pins, 2.4 or 3.0 mm in diameter, were inserted from distal and lateral of the osteotomy site to the medial corner of the proximal tibia passing through the medial half of the osteotomy line. Next, figure-of-eight wiring, 0.8 to 1.0 mm in diameter, was placed between the distal end of the pins and lateral wall of the proximal tibia. After the osteotomy site was fixed, leg alignment was checked by X-ray and cancellous bone fragments harvested from the resected bone wedge were grafted to the osteotomy site (Fig. 1). Postoperatively, the knee joint was immobilized with a cast for 6 weeks. Range-of-motion exercise was started after the cast was removed. Partial weight bearing was started 4 weeks after HTO and full weight bearing was allowed at 8 to 10 weeks postoperatively.

Clinical evaluation

All of the patients were directly interviewed and examined. The clinical result was evaluated using the Japanese Orthopedic Association knee rating score (JOA score).[24] The JOA score consisted of four categories and 100 points as full marks: pain and walking (30 points), pain and ascending or descending stairs (25 points), range of motion (35 points), and joint effusion (10 points). In this study, the preoperative JOA score was compared with the JOA score at the first evaluation in 1993 and at the most recent follow-up. Subsequently, the results of the JOA score were classified as excellent if the most recent score was 91 to 100, good if 81 to 90, fair if 71 to 80, and poor if the most recent score was less than 70 points. Furthermore, all knee joints were divided into two subgroups according to the result of the most recent follow-up. The patients who were classified as excellent and good were referred to as the satisfactory group, and the patients who were classified as fair and poor were referred to as the unsatisfactory

Fig. 1. Radiography of the knee joint before and after high tibial osteotomy (HTO) with two threaded pins and figure-of-eight wiring fixation technique. **a** Before HTO, **b** after HTO, **c** first evaluation, **d** most recent evaluation

group. Thirty-seven knees in 22 patients (1 male, 21 female) were included in the satisfactory group, with an average age at surgery of 57.9 ± 5.0 years and average follow-up period of 14.0 ± 2.9 years. On the other hand, 11 knees in 10 patients (3 male, 7 female) were included in the unsatisfactory group, with an average age at surgery of 60.1 ± 8.7 years and average follow-up period of 14.3 ± 3.1 years. No statistical difference was observed in the demographic data between the two groups.

Radiographic evaluation

The change of FTA and the grades of knee OA according to the Kellgren-Lawrence classification were analyzed with a standing whole-leg X-ray taken before surgery, at 1 to 3 weeks after HTO, and at each follow-up point.

Statistical analysis

The obtained data were expressed as the mean values ± standard deviation (SD). The relationships of analyzed parameters were determined using the paired *t*-test and the Wilcoxon signed rank test. In all analyses, a *P* value of less than 0.05 was considered to be significant.

Results

Clinical results

The mean JOA score of all patients improved significantly from 59.1 ± 7.6 before HTO to 86.3 ± 6.5 at the first evaluation (Table 1). At the most recent follow-up, the JOA score had slightly declined to 83.1 ± 9.3 but this change was not significant. In each category of JOA scores in all patients, the pain and walking score improved from 14.5 ± 5.2 before HTO to 26.6 ± 5.6 at the most recent evaluation, the pain and stairs score from 12.7 ± 6.6 to 20.2 ± 4.9, the score for range of motion from 25.6 ± 4.8 to 27.8 ± 4.6, and the score for joint effusion from 6.3 ± 5.7 to 8.5 ± 4.3. The mean range of motion was 9.3° ± 8.0° fixed flexion to 133.0° ± 18.1° of flexion before HTO, and 2.6° ± 4.3° to 132.5° ± 16.2° of flexion at the most recent evaluation. In comparing the satisfactory group and the unsatisfactory group, the mean JOA score was similar before HTO, but at the first and the most recent evaluation, the JOA score of the unsatisfactory group was significantly lower than that of the satisfactory group. Furthermore, in the unsatisfactory group, the JOA score had significantly declined from first evaluation to the most recent follow-up (Table 1). In the current study, there were two postoperative complications. One patient had peroneal nerve palsy and spontaneously recovered in 3 months after surgery. Another patient had delayed union and autologous iliac bone graft was performed. Final bone union was obtained at 7 months after HTO. These complications did not affect the clinical results.

Radiographic results

The mean FTA of all patients was corrected from 185.4° ± 4.4° before HTO to 168.2° ± 2.9° postoperatively, and this alignment was maintained at the most recent evaluation. In the satisfactory group, the change of FTA was almost same as the results of all patients. In contrast, the FTA of the unsatisfactory group changed from 185.3° ± 2.1° preoperatively to 170.2° ± 2.3° after HTO, and gradually increased at first evaluation and increased even more at the most recent follow-up. The FTA of the unsatisfactory group was the same as the satisfactory group preoperatively, but was significantly larger at each time of postoperative evaluation (Table 2). Seven of the unsatisfactory group (63.6%) had an FTA larger than 168° (170°: 3 cases, 172°: 3 cases, 173°: 1 case). The radiographic OA of all patients before HTO were classified as follows: 8 knees as Grade II, 35 knees as Grade III, and 5 knees as Grade IV. At the most recent evaluation, the distributions were 1 knee as Grade II, 18 knees as Grade III, and 29 knees as Grade IV. The number of Grade IV OA at the latest evaluation was significantly greater than that of before HTO (Table 3). In comparing the satisfactory group and the unsatisfactory group, no statistical difference was observed in the distribution of preoperative radiographic OA grade (Table 4). At the latest evaluation, the distributions of OA in the satisfactory group were 1 knee in Grade II, 18 knees in Grade III, and 18 knees in Grade IV. On the other hand, in unsatisfactory group, all knees were classified as Grade IV OA.

Table 1. Japanese Orthopaedic Association (JOA) score before high tibial osteotomy (HTO), at the first evaluation, and at the latest evaluation

		JOA score		
Classification	Number of knees	Before HTO	First evaluation[a]	Latest evaluation[b]
All Patients	48	59.1 ± 7.6	86.3 ± 6.5	83.1 ± 9.3
			**	
Satisfactory group	37	59.1 ± 9.1	90.0 ± 5.4	87.3 ± 4.3
			**	* **
Unsatisfactory group	11	59.1 ± 5.8	82.2 ± 7.2	69.1 ± 5.8
			**	*

Data given as mean ± standard deviation
* $P < 0.05$; ** $P < 0.01$
[a] Mean follow-up 6.5 years
[b] Mean follow-up 17.1 years

Table 2. Femorotibial angle (FTA) before HTO, at the first evaluation, and at the latest evaluation

Classification	Number of knees	FTA (degrees)			
		Before HTO	After HTO	First evaluation[a]	Latest evaluation[b]
All Patients	48	185.4 ± 4.4	168.2 ± 2.9	169.1 ± 4.5	169.8 ± 5.2
Satisfactory group	37	185.5 ± 4.8	167.6 ± 2.8 *	168.0 ± 4.1 *	168.4 ± 4.4 **
Unsatisfactory group	11	185.3 ± 2.1	170.2 ± 2.3 *	172.7 ± 3.8 *	174.4 ± 5.2 **

Data given as mean ± standard deviation
* $P < 0.05$; ** $P < 0.01$
[a] Mean follow-up 6.5 years
[b] Mean follow-up 17.1 years

Table 3. Distribution of the radiographic osteoarthritis (OA) grade before HTO and at the latest evaluation

Classification	Number	OA grade[a]		
		Grade II	Grade III	Grade IV
Before HTO	48	8	35	5
Latest evaluation[b]	48	1	18	29**

** $P < 0.01$
[a] Radiographic OA grade according to the Kellgren-Lawrence classification
[b] Mean follow-up 17.1 years

Table 4. Distribution of the preoperative radiographic OA grade between the satisfactory group and the unsatisfactory group

Classification	Number	OA grade[a]		
		Grade II	Grade III	Grade IV
All Patients	48	8	35	5
Satisfactory group	37	8	26	3
Unsatisfactory group	11	0	9	2

[a] Radiographic OA grade according to the Kellgren-Lawrence classification

Discussion

The first purpose of this study was to evaluate our fixation methods. We used two threaded pins and figure-of-eight wire, and the basic concept of this procedure was similar to a tension band or modified tension band fixation as previously described.[17,18] Generally speaking, rigid fixation and early rehabilitation is important for good clinical outcome after HTO,[15,25] and there have been several studies concerning the primary stability of the implants for HTO.[26–28] Flamme et al.[27] tested the initial stability of the following devices: one third tubular plate with a cortical screw, blade plate with screws (Giebel's plate), bone staples, and external fixator. In their study, the highest stability was achieved by the bone staple and external fixator, while Giebel's plate and one third tubular plate were less stable. Recently, we biomechanically evaluated the initial stability of our fixation method and compared it with the bone staple, Giebel's plate, and L-buttress plate. The results of this study indicated that our method showed similar stability to Giebel's plate and the bone staple against compression and bending stress except rotational force.[29] In the present study, we additionally used cast immobilization after HTO in consideration of initial stability of our fixation method, and we clinically experienced 11 of 48 unsatisfactory cases. Furthermore, 7 of the unsatisfactory cases showed correction loss in early postoperative periods. The main reason for this early correction loss is thought to be combination of the lack of initial stability especially against rotational stress and the bone quality of the osteotomy site. Thus, we think the two threaded pins and figure-of-eight wiring fixation is an acceptable fixation procedure for HTO; however, careful attention should be paid to correction loss in the early postoperative periods.

The second purpose of the present study was to evaluate the long-term clinical results after HTO and to determine the factors related to the outcome. There are many studies about the clinical results after HTO. The

majority of authors have reported satisfactory results in the short to midterm, but these results gradually deteriorated over time, especially at more than 10 years after surgery. The reported probability of a good or excellent result after HTO was 75% to 96% after 6 years, 45% to 94% after 10 years, and 46% to 90% after more than 15 years.[3–14] In the current study, the percentage of satisfactory results (excellent or good) after HTO was 93.7% after 6 years and 77.1% after 17 years. Our results had the same tendency of deterioration over a long period as the other studies, but still maintained a favorable result up to 17 years after HTO. We think the main reason for the good clinical outcome in spite of the progression of radiographic OA is that good alignment was maintained in the majority of cases during the follow-up period and the ADL of the patients slowly deteriorated with time. Recently, Koshino et al.[14] evaluated 75 knees with a mean follow-up of 19 years and reported good or excellent results in 90% of their series. Good alignment was described as the most important factor for good long-term clinical results.[14]

There is still considerable discussion about which factors affect the long-term outcome of HTO, and the present study focused on the correction angle at the surgery and the preoperative severity of knee OA. As for the correction angle, previous studies have reported that the optimum clinical outcomes were associated with a correction of 6° to 16° valgus, and an undercorrection less than 5° was strongly related to a high failure rate.[5,8–14] In this study, the mean FTA after HTO was 167.6° in the satisfactory group and 170.2° in the unsatisfactory group. In addition, in the unsatisfactory group, progressive varus recurrence was found at the follow-up. We believe that the most important concept for HTO is to shift the loading axis from the medial compartment to the lateral compartment, and this will lead good long-term clinical outcomes in HTO. In order to achieve this safely, we recommend that we should target a valgus correction of at least 10° for medial compartment knee OA.

In western countries, the patients with advanced knee OA were primarily indicated for total knee arthroplasty. Therefore, there have been few studies that evaluate the relationship between the preoperative severity of the knee OA and the clinical result of HTO. Holden et al.[30] followed 51 knees for 10 years and found no correlation between the clinical results and the radiographic severity of the knee OA preoperatively. Rinonapoli et al.[10] evaluated 60 knees with an average follow-up of 15 years and their multivariate analysis indicated that the length of follow-up and the amount of preoperative osteoarthritis affected the clinical results. On the other hand, there have been many studies about this issue in Japan, because the preservation of range of motion is important for ADL in Japanese people. Yasuda et al.[8] found no statistical difference between the preoperative OA stage and the clinical results, but also described that no stage IV patients obtained good results. Sasazaki et al.[31] compared HTO in mild to moderate OA with advanced OA, and found no clinical difference between the two groups. They also indicated that overcorrection was effective for HTO in advanced OA cases.[31] In this study, the radiographic OA grade of the knee joint was significantly deteriorated at the mean follow-up of 17 years, but no statistical difference was observed regarding the preoperative severity of the radiographic knee OA between the satisfactory and the unsatisfactory group. Furthermore, three of five patients with preoperative Grade IV OA were included in the satisfactory group at the recent follow-up. Therefore, we agree that the mild to moderate stage is expected to have better results after HTO, but we could also expect good clinical outcomes for the advanced stage if the cartilaginous condition of the lateral compartment is acceptably preserved and the proper postoperative alignment is achieved.

We believe that there are two limitations in this study. The first limitation is that this is a retrospective study and the 70.6% follow-up rate is perhaps low even for the long-term periods of more than 10 years. The second limitation is that we used the JOA score for clinical evaluation. The JOA score is a good scoring system and is popular in Japan. In addition, several recent studies about HTO using this scoring system have been published in international journals.[24,32,33] However, even though the JOA score is not a worldwide universal measuring system, we believe that we can compare the result of this study with other clinical reports.

In conclusion, HTO with two threaded pins and figure-of-eight wiring fixation showed an acceptable and good clinical outcome for an average of 17 years of follow-up. The present study also suggests that the proper correction angle is necessary to achieve satisfactory long-term clinical results and HTO is considered to be indicated for the patients with a moderate to advanced stage of medial knee OA.

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References

1. Felson DT, Zhang Y. An update on the epidemiology of knee and hip osteoarthritis with a view to prevention. Arthritis Rheum 1998;41:1343–55.
2. Jackson JP, Waugh W. Tibial osteotomy for osteoarthritis of the knee. J Bone Joint Surg Br 1961;43:746–51.
3. Coventry MB. Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee. A preliminary report. J Bone Joint Surg Am 1965;47:984–90.

4. Coventry MB. Upper tibial osteotomy for gonarthrosis. The evolution of the operation in the last 18 years and long-term results. Orthop Clin North Am 1979;10:191–210.
5. Rudan JF, Simurda MA. High tibial osteotomy. A prospective clinical and roentgenographic review. Clin Orthop 1990;255: 251–6.
6. Insall JN, Joseph DM, Msika C. High tibial osteotomy for varus gonarthrosis. A long-term follow-up study. J Bone Joint Surg Am 1984;66:1040–8.
7. Berman AT, Bosacco SJ, Kirshner S, Avolio A. Factors influencing long-term results in high tibial osteotomy. Clin Orthop 1991;272: 192–8.
8. Yasuda K, Majima T, Tsuchida T, Kaneda K. A ten-to 15-year follow-up observation of high tibial osteotomy in medial compartment osteoarthrosis. Clin Orthop 1992;282:186–95.
9. Coventry MB, Ilstrup DM, Wallrichs SL. Proximal tibial osteotomy. J Bone Joint Surg Am 1993;75:196–201.
10. Rinonapoli E, Mancini GB, Corvaglia A, Musiello S. Tibial osteotomy for varus gonarthrosis. Clin Orthop 1998;353:185–93.
11. Naudie D, Bourne RB, Rorabeck CH, Bourne TJ. Survivorship of the high tibial valgus osteotomy. Clin Orthop 1999;367:18–27.
12. Aglietti P, Buzzi R, Vena LM, Baldini A, Mondaini A. High tibial valgus osteotomy for medial gonarthrosis. J Knee Surg 2003;16: 21–6.
13. Sprenger TR, Doerzbacher JF. Tibial osteotomy for the treatment of varus gonarthrosis. J Bone Joint Surg Am 2003;85:469–74.
14. Koshino T, Yoshida T, Ara Y, Saito I, Saito T. Fifteen to twenty-eight years' follow-up results of high tibial valgus osteotomy for osteoarthritic knee. Knee 2004;11:439–44.
15. Koshino T, Morii T, Wada J, Saito H, Ozawa N, Noyori K. High tibial osteotomy with fixation by a blade plate for medial compartment osteoarthritis of the knee. Orthop Clin North Am 1989; 20:227–43.
16. Hofmann AA, Wyatt RW, Beck SW. High tibial osteotomy. Use of an osteotomy jig, rigid fixation, and early motion versus conventional surgical technique and cast immobilization. Clin Orthop 1991;271:212–7.
17. Weber BG, Wörsdörfer O. Zuggurtungsosteosynthese bei tibiakopfosteotomie. Z Orthop 1980;118:637–43.
18. Flamme CH, Ruhmann O, Schmolke S, Wichmann R. Long-term outcome following high tibial osteotomy with tension bend principle. Arch Orthop Trauma Surg 2003;123:12–6.
19. Koshino T, Tsuchiya K. The effect of high tibial osteotomy on osteoarthritis of the knee. Clinical and histological observations. Int Orthop 1979;3:37–45.
20. Schatzker J, Burgess RC, Glynn MK. The management of nonunions following high tibial osteotomies. Clin Orthop 1985;193: 230–3.
21. Lawrence JS, Bremner JM, Bier F. Osteo-arthrosis. Prevalence in the population and relationship between symptoms and X-ray changes. Ann Rheum Dis 1966;25:1–24.
22. Ogata K. Interlocking wedge osteotomy of the proximal tibia for gonarthrosis. Clin Orthop 1984;186:129–34.
23. Ogata K, Yoshii I, Kawamura H, Miura H, Arizono T, Sugioka Y. Standing radiographs cannot determine the correction in high tibial osteotomy. J Bone Joint Surg Br 1991;73:927–31.
24. Kanamiya T, Naito M, Hara M, Yoshimura I. The influences of biomechanical factors on cartilage regeneration after high tibial osteotomy for knees with medial compartment osteoarthritis: clinical and arthroscopic observations. Arthroscopy 2002;18: 725–9.
25. Billings A, Scott DF, Camargo MP, Hofmann AA. High tibial osteotomy with a calibrated osteotomy guide, rigid internal fixation, and early motion. J Bone Joint Surg Am 2000;82:70–9.
26. Zhang Y, Shall LM, Kiritsis PG, Wolfinbarger L, Fairclots JR. Varus tension testing of fixation devices used in proximal tibial osteotomy. Contemp Orthop 1995;30:471–6.
27. Flamme CH, Kohn D, Kirsch L, Hurschler C. Primary stability of different implants used in conjunction with high tibial osteotomy. Arch Orthop Trauma Surg 1999;119:450–5.
28. Gautier E, Thomann BW, Brantschen R, Jakob RP. Fixation of high tibial osteotomy with AO cannulated knee plate. Acta Orthop Scand 1999;70:397–9.
29. Yasumoto H, Omori G, Tanabe Y, Koga Y. Mechanical stability of different fixation procedures after high tibial osteotomy (in Japanese). J Jpn Soc Clin Biomech 2001;22:319–23.
30. Holden DL, James SL, Larson RL, Slocum DB. Proximal tibial osteotomy in patients who are fifty years old or less. J Bone Joint Surg Am 1988;70:977–82.
31. Sasazaki Y, Fujikawa K, Kobayashi T, Miwa M. Clinical results of the overcorrected high tibial osteotomy for advanced osteoarthritis of the knee (in Japanese). Bessatsu Seikeigeka 2002;42: 153–58.
32. Choi HR, Hasegawa Y, Kondo S, Shimizu T, Ida K, Iwata H. High tibial osteotomy for varus gonarthrosis: a 10- to 24-year follow-up study. J Orthop Sci 2001;6:493–7.
33. Takemae T, Omori G, Nishino K, Terajima K, Koga Y, Endo N. Three-dimensional knee motion before and after high tibial osteotomy for medial knee osteoarthritis. J Orthop Sci 2006;11: 601–6.