Effect of weight-bearing on the alignment after open wedge high tibial osteotomy

Jae Ang Sim · Ji Hoon Kwak · Sang Hoon Yang · Eun Seok Choi · Beom Koo Lee

Abstract This study examined the changes in knee alignment after an open wedge high tibial osteotomy before and after weight-bearing. From 2004 to 2006, 36 high tibial osteotomies were performed to treat unicompartamental arthritis with a varus deformity. Thirteen patients without instability and with an accurate radiographic evaluation were included. The changes in the deviation of the mechanical axis and femorotibial angle were evaluated retrospectively using whole extremity radiographs immediately after surgery (supine position) and 4 months after surgery (weight-bearing position). In the nonweight-bearing radiograph obtained immediately after surgery, the mean deviation of the mechanical axis was 22% laterally and the mean femorotibial angle was valgus 8.9°. The weight-bearing radiograph at 4 months after surgery showed that the former shifted laterally 34% and the latter shifted valgus 10.6°. The changes in the mechanical axis and femorotibial angle were significant ($P < 0.001$). During open wedge high tibial osteotomy, the surgeon should consider the increase in deviation of the mechanical axis and femorotibial angle after weight-bearing.

Keywords High tibial osteotomy · Mechanical axis · Femorotibial angle

Introduction

A varus knee is a major cause of osteoarthritis. High tibial osteotomy (HTO) enables a redistribution of weight loading and a correction of the varus alignment through the lateral translation of the mechanical axis. HTO is a useful treatment for the relief of pain and improvement of function. Generally, the corrective femorotibial angle is aimed at valgus $10^\circ$–$15^\circ$ [5, 14, 16]. Undercorrection can cause recurrence of the varus deformity and an overcorrection can cause cosmetic problems.

The alignment after HTO is affected not only by the bony correction but also by soft tissues around the knee. The patient’s position can also affect the knee alignment [7, 18–22]. Surgeons perform HTO in the supine position but the patients are in the weight-bearing status. It was hypothesized that the patient’s position can affect significantly the alignment of the knee and mechanical axis, and the femorotibial angle in a HTO patient can increase after weight-bearing. This study examined the changes in knee alignment in patients with HTO before and after weight-bearing using the whole extremity radiographs.

Materials and methods

From 2004 to 2006, 36 HTOs were performed on patients with unicompartamental arthritis with a varus deformity. The whole extremity radiographs, including the femoral head, knee and ankle joint, were obtained immediately postoperatively (supine position) and 4 months after surgery (weight-bearing position). Patients with a ligament injury or an inaccurate radiographic evaluation were excluded. Thirteen cases of whole extremity radiograph without rotation were evaluated. None of the patients had a
history of inflammatory or infective arthritis, and had primary osteoarthritis on the medial compartment with a varus deformity. The mean age was 48 years and there were 9 males and 4 females. A medial open wedge osteotomy was performed on all patients. The amount of the corrective angle was determined using the weight-bearing whole extremity radiographs obtained preoperatively.

Subperiosteal dissection was performed to release distal superficial medial collateral ligament (MCL) for effective decompression. After the osteotomy, the osteotomy site was opened gradually using a laminar spreader, while the mechanical axis was evaluated using an image intensifier and electrocautery cable connecting the center of the femoral head to the center of the ankle. The aim was to make the mechanical axis be within 10–20% lateral to the center of the knee joint. The natural posterior slope of the tibia was preserved by placing the distracting laminar spreader only at the posterior cortex. Detached distal superficial MCL was repaired meticulously after the osteotomy. The range of motion and full weight-bearing were allowed immediately after surgery and 8 weeks later, respectively. All radiographic measurements were performed on the PACS (Picture Archiving Communication System, Infiniti Co, Seoul, Korea) monitor, which could automatically measure a length to 2 decimal points. We used the degree that was rounded off the numbers to 2 decimal places. The radiologic evaluation was based on the supine-positioned whole extremity radiograph, and the weight-bearing whole extremity radiograph was taken immediately and 4 months after surgery, respectively. The femorotibial angle was measured using Bauer’s method [3]. The center of the knee and the lateral margin of the tibial plateau were determined to be 0 and 100, respectively. The intersection of the mechanical axis, the deviation of the mechanical axis, was expressed as a percentage. In all cases, one observer measured the percentages in order to negate the interobserver variation.

Statistical analysis

All statistical analyses were performed using the Statistical Package for Social Sciences (version 8.20, SPSS, Chicago, USA). A Wilcoxon signed rank sum test was used to determine the changes in the femorotibial angle and the deviation of the mechanical axis in the supine-positioned whole extremity radiograph immediately after surgery as well as in the weight-bearing whole extremity radiograph taken 4 months after surgery. A \( P \) value \(<0.05\) was considered statistically significant.

Results

The mean femorotibial angle and deviation of the mechanical axis on the supine-positioned radiograph taken immediately after surgery were valgus \(8.9 \pm 1.4^\circ\) (range, valgus \(6.2^\circ–10.8^\circ\)) and \(22\%\) (range, \(8–43\%\)) laterally, respectively (Table 1). On the weight-bearing radiograph taken 4 months after surgery, the mean femorotibial angle and deviation of the mechanical axis were valgus \(10.6 \pm 1.5^\circ\) (\(8.2^\circ–12.9^\circ\)) and \(34\%\) (\(10–52\%\)) laterally, respectively (Table 1). The increase in the mean valgus femorotibial angle was \(1.7^\circ\). The lateral shift of the mechanical axis was \(12\%\) after weight-bearing (Figs. 1, 2; \( P < 0.001\)). No cases of delayed union, nonunion, infection, tissue necrosis, peroneal nerve injury and vascular

<table>
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<tr>
<th>Case</th>
<th>Sex/age</th>
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<tr>
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<td>Mechanical axis (%)</td>
<td>Femorotibial angle (valgus(^{\circ}))</td>
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<td>1</td>
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Table 1 Assessment of the femorotibial angle and deviation of the mechanical axis
injury were encountered. There was no recurrence of the varus deformity.

**Discussion**

The most important finding of the present study was that the corrected femorotibial angle in HTO might increase after weight-bearing that would result in overcorrection. HTO is a widely used treatment for patients less than 60 years of age with symptomatic medial compartmental knee arthrosis associated with varus osseous deformities. HTO corrects the limb malalignment in order to stop or slow the progress of articular cartilage changes secondary to abnormal stresses from malalignment. In addition, it alleviates symptoms by unloading the compartment by decreasing the forces on the subchondral bone, decreasing intraosseous venous hypertension and decreasing the level of stress on the microfractures of the subchondral bone [2, 4, 10, 17]. The optimal corrective angles are controversial. Many authors recommended that the corrective angles be valgus 10°–15° in osteoarthritis with a varus deformity [5, 14, 16]. Fujisawa et al. [8] recommended that the deviation of the mechanical axis be 30–40% laterally. Dugdale et al. [7] recommended that the deviation of the mechanical axis be positioned 24–32% laterally. The aim of this series was to obtain a deviation of the mechanical axis from the center to the lateral 10–20% of the knee joint. In this study, the femorotibial angle was valgus 11°, which consisted of an overcorrection angle of 5°. Precise preoperative planning and surgery should be performed to obtain a good result after HTO. Undercorrection of the deformity during surgery would cause the recurrence of varus. This can lead to the progression of joint arthritis and the subsequent failure of HTO, which may result in the need for secondary procedures, such as total knee arthroplasty. Overcorrection can lead to the subluxation of the patella or patellar baja, and cause medial joint opening and the rapid development of lateral arthritis [6, 7, 11]. In addition, overcorrection can cause cosmetic problems resulting in patient dissatisfaction [6]. In some of our cases, deviation of the mechanical axis >lateral 40% after weight-bearing can cause overloading of the lateral compartment as well as cosmetic problems. The reported complications of open wedge HTO are a loss of correction, delayed union or nonunion, infection, loss of knee motion, deep vein thrombosis, nerve or arterial injury, fracture, change in the tibial slope and complications related to bone grafting etc. No such complications were encountered in the present cases.

The alignment after HTO is affected by the angle of the osteotomy, soft tissues around the knee, weight-bearing status etc. [7, 18–21]. Specogna et al. [22] evaluated hip-to-ankle radiographs of arthritis patients with a varus deformity. The mean mechanical axis measured on a single-limb standing radiograph was greater than that on a double-limb standing radiograph, which was larger than that on the supine radiographs. Although it is unclear if single-limb standing or double-limb standing represents an accurate mechanical loading of the gait, it is obvious that after HTO, the weight-bearing status will increase the deviation of the mechanical axis more than the supine position [7, 19, 20, 22]. However, an intraoperative evaluation of the mechanical axis is generally performed in the supine position. An immediate postoperative evaluation is also performed in the supine position. Therefore, when determining the corrective angle, an axial compression force should be applied to the heel to reproduce the weight-bearing status. Through the axial compression intraoperatively, the operator can easily predict the change in mechanical axis and femorotibial angle after weight-bearing. The present results indicated a 1.7° increase in the mean valgus femorotibial angle and a 12% lateral shift of the mechanical axis after weight-bearing.

Despite shifting laterally, the loading maintains high medial compartment pressure in an open wedge high tibial osteotomy [1]. For effective decompression of the medial
compartment, complete release of the distal fibers of the MCL is necessary [1]. The medial ligament complex of the knee includes superficial MCL, deep MCL and posterior oblique ligament. And the superficial MCL has two separate tibial attachment [15]. The proximal attachment is primarily to soft tissues rather than directly to bone such as the anterior arm of the semimembranosus tendon and the distal tibial attachment is broadly located just anterior to the posteromedial crest of the tibia. The meniscotibial ligament portion of the deep MCL attach just distal to the edge of the articular cartilage of the medial tibial plateau [15]. The POL is a reinforcement of the posteromedial capsule, which courses off the distal aspect of the semimembranosus tendon [12, 13, 15]. Griffith et al. [9] reported load responses of the posterior oblique and superficial MCL to applied loads. The proximal and distal division of superficial MCL provided significant resistance to valgus forces. The response to valgus load was significantly higher in the distal superficial MCL division when compared with the proximal superficial MCL division. Although the valgus load responses for the posterior oblique ligament were significantly lower than were the load responses from both the proximal and distal superficial MCL division, the posterior oblique ligament provided significant resistance to valgus forces near knee extension. In this study, we performed distal superficial MCL release while preserving deep MCL, proximal superficial MCL and posterior oblique ligament in all cases so that adequate stability could be maintained. However, mild valgus instability remained and it may cause increased femorotibial angle and lateral shift of mechanical axis in association with valgus alignment. The effect of applied axial load during surgery may not be same as that of weight-bearing status; however, we observed the lateral shift of mechanical axis under fluoroscopy after applying the axial load manually during surgery. We did not check the difference of mechanical axis and femorotibial angle in supine position with and without axial compression because the applied axial load will be different among the cases, and we thought that the surgeon can get information about the influence of axial load into the mechanical axis and femorotibial angle and intraoperative fluoroscopy, which might help to predict the changes of axis after weight-bearing.

The limitation of present study was as follows. We recognize that the 4 months of follow-up period was not a sufficient time, however, that period can give useful information about the effect of weight-bearing. Also the small sample size will be another weak point of this study. A long-term follow-up and a larger patient group will be needed to confirm these results.

In open wedge HTO for unicompartmental osteoarthritis with a varus deformity, there was an increase in the corrective angle and lateral shift of the mechanical axis associated with weight-bearing. This increase should be considered when performing open wedge HTO. Clinically, axial compression similar to the weight-bearing status might be helpful during the correction of the femorotibial angle in open wedge HTO to prevent unexpected over-correction after weight-bearing.

Conclusion

When performing the open wedge high tibial osteotomy, the surgeon should consider the increase in deviation of the mechanical axis and femorotibial angle after weight-bearing. And intra-operative axial compression during HTO will be helpful to determine the final correction angle.

References