Case Report

Anterior Opening Wedge Osteotomy of the Proximal Tibia for Genu Recurvatum Caused by Partial Proximal Tibial Epiphyseal Arrest

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Abstract For genu recurvatum deformity after tibial fracture, precise correction osteotomy is necessary to acquire a good clinical outcome. No report on genu recurvatum has evaluated precise preoperative planning with image-processing software for three-dimensional (3D) design and modeling. We herein report a case of osseous genu recurvatum treated by anterior opening wedge osteotomy according to precise preoperative 3D simulation. This is a useful tool for precise correction of osseous deformity.

Keywords genu recurvatum; proximal tibial epiphyseal arrest; osteotomy

1. Introduction

Genu recurvatum has various causes, including osseous, soft tissue, and combined deformities [6]. Post-traumatic bony deformity is the most frequent type of deformity in genu recurvatum [2]. Because precise correction of osseous deformities is quite difficult, preoperative planning is very important to treat genu recurvatum and obtain an outcome identical to that of the contralateral knee [8]. We herein present a case in which genu recurvatum following conservative therapy for proximal tibial epiphyseal injury was treated by anterior opening wedge osteotomy according to preoperative three-dimensional (3D) planning results using the mirror image of the contralateral normal knee obtained from a computed tomography (CT) scan with 3D reconstruction software.

2. Case presentation

A 25-year-old man presented for evaluation of increasing pain and genu recurvatum in his left knee. He had injured his left knee while landing during gymnastics at 14 years of age. Radiographs at that time demonstrated an undisplaced proximal tibial epiphyseal injury. He was treated with a cast for 2 months followed by progressive weight-bearing and range-of-motion exercises. He gradually became aware of the genu recurvatum in his left knee, and progressive pain in this knee was noted about 2 years before referral to our department.

The patient’s left knee appeared to have genu recurvatum, and knee flexion was limited to 135° with the inability to assume a kneeling position. The patient felt instability during walking. The preoperative Lysholm score was 55. There was no length discrepancy of the lower limbs and general joint laxity. A lateral radiograph showed that the angle between the lines of the anatomical axis of the distal part of the femoral shaft and that of the tibial shaft was 24° in the left leg, while it was 11° during extension at the contralateral normal knee. The angle between the lines of the anatomical axis of the distal part of the femoral shaft and the plane of the tibial plateau was identical to that of the intact side, and the posterior tilt angle of the tibial plateau was −6°, which was 13° less than that of the intact side. The femorotibial angle (FTA) was 177° and 178° in the injured and intact knee, respectively. Therefore, the patient was diagnosed with purely osseous genu recurvatum (Figure 1).

A preoperative CT scan of both lower extremities was performed to simulate operative planning using image-processing software (Mimics; Materialise, Leuven, Belgium) for 3D design and modeling. An injured-side image was manually created from CT data overlaid on the mirror image of the contralateral normal knee obtained from a computed tomography (CT) scan with 3D reconstruction software.

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**Figure 1:** Preoperative lateral X-ray. Genu recurvatum deformity is evaluated as the angle between the lines of the anatomical axis of the distal part of the femoral shaft and that of the tibial shaft (x). (a) Normal side shows an 11° extension. (b) Injured side shows a 24° genu recurvatum deformity. The angle between the lines of the anatomical axis of the distal part of the femoral shaft and the plane of the tibial plateau (y) is identical to that of the normal side, and the posterior tilt angle of tibial plateau (90° minus z) is −6°, which is 13° smaller than that of the normal side.

Therefore, anterior opening wedge osteotomy 2 cm distal to the tibial plateau and plate (TomoFix, Synthes, Solothurn, Switzerland) fixation were performed. Bone resection was impossible because of hardness of the posterior cortex; only anterior opening elevated with an 18-mm length was possible. The gap at the osteotomy site was filled with hydroxyapatite block (NEOBONE; Toshiba Ceramics Co., Ltd., Tokyo, Japan). Correction of genu recurvatum from 24° to 6° (5° overcorrection of the contralateral knee) was obtained during the surgery. The posterior tilt angle of the tibial plateau increased to 12° (Figure 3(a)).

The patient wore a knee brace for 1 week postoperatively. Continuous passive motion was begun 1 week postoperatively. Partial and full-weight bearing were permitted 4 and 8 weeks postoperatively, respectively. Running was started at 4 months. The posterior tilt angle of the tibial plateau decreased gradually and stopped at 8° 1 year after surgery (Figures 3(b) and 3(c)). This angle was 1° larger than that of the contralateral knee. At 2 years after surgery, removal of the plate was performed, and at the 3-year follow-up, the patient could run without pain and obtained full range of motion. The Lysholm score at the final follow-up improved to 93. A 3D model image 2 years after surgery was 4 mm longer than the mirror image of the contralateral normal side (Figure 4), but alignment was almost identical to normal side.

**3. Discussion**

This is the first report of evaluation of genu recurvatum involving an osseous deformity using precise preoperative...
disease, and minor knee trauma [2,5,6,7,8]. Involving the proximal tibial epiphysis, Osgood-Schlatter disease is a problem caused by stress on the tibial tubercle from casting or bracing, operative procedures to the tibia, prolonged immobilization, excessive pressure on the patellar tendon, and combined. The causes of acquired genu recurvatum include trauma (especially an epiphyseal fracture of the proximal tibia), skeletal traction via the proximal tibia, prolonged immobilization, excessive pressure on the tibial tubercle from casting or bracing, operative procedures involving the proximal tibial epiphysis, Osgood-Schlatter disease, and minor knee trauma [2,5,6,7,8].

During evaluation of patients with acquired genu recurvatum, it is necessary to determine whether the deformity is osseous, soft tissue, or combined [6]. The posterior tilt angle of the tibial plateau and the angle between the lines of the anatomical axis of the distal part of the femoral shaft and the plane of the tibial plateau on lateral X-ray are important for diagnosis of genu recurvatum. The posterior tilt angle of the tibial plateau in soft tissue genu recurvatum is normal, but the angle between the femoral shaft and tibial plateau is irregular. On the other hand, in osseous genu recurvatum, the posterior tilt angle is irregular, but the angle between the femoral shaft and tibial plateau is normal. Some articles reported anterior opening wedge high tibial osteotomy (HTO) for treatment of genu recurvatum caused by partial proximal tibial epiphyseal arrest. However, these cases were only evaluated by X-ray photography [2,5,8].

Lateral X-ray is insufficient for preoperative planning to acquire precise bony correction. In this case, correction osteotomy was performed according to the preoperative precise 3D simulation by Mimics. The computer-assisted template can indicate the optimum pattern and plane of corrective osteotomy by calculating the axis and amount of 3D deformity [9]. Under the simulation, osseous deformity was mainly caused by anterior tibial shortening from partial proximal epiphyseal arrest, and a correction center located on the epiphysis and an anterior opening correction of 13° was necessary. We chose to perform an opening osteotomy with internal fixation according to the preoperative planning.

For surgical treatment of genu recurvatum due to osseous deformity, osteotomy options include dome osteotomy, opening wedge osteotomy, and closed wedge osteotomy with internal, external, or cast fixation [1,2,3,7]. Closed or dome osteotomy has the advantage of a wide contact area but has risks of neurovascular injury and leg shortening. Opening wedge osteotomy has the disadvantage of bone defect but has the advantage of ease of treatment.

In terms of the fixation method, external fixation can adjust the alignment at the osteotomy site even after the surgery. However, it is bulky and has risks of pin site infection, joint contracture, nerve palsy, and prolonged treatment [2,3]. On the other hand, plate fixation can implant materials in the body, avoids postoperative immobilization, and allows the patient to begin early range of motion exercise of the knee; however, it has a risk of skin irritation and does not allow for adjustment of the alignment at the osteotomy site after the surgery. The precise 3D simulation can redeem this disadvantage of plate fixation. A bone graft from the iliac crest is the most common donor site but is associated with local complications such as wound pain, hypersensitivity, and buttock anesthesia [4]. To avoid donor site morbidity associated with harvesting the iliac crest, the use of hydroxyapatite is reasonable. The use of 3D simulation software can simulate precise operative planning and is a powerful tool to compensate for technical shortcomings of plate fixation.

4. Conclusion
Preoperative simulation with image-processing software for three-dimensional design and modeling is a useful tool for precise correction of osseous deformity.

References

**Figure 4:** Postoperative evaluation of 3D model imaging 2 years after surgery. (a) This showed almost the same image overlaid on the mirror image of the contralateral normal side. (b) The operated side (green lines) was 4 mm longer than the mirror image of the contralateral normal side (yellow lines) (white arrowheads).
