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Modified biplanar open-wedge high tibial osteotomy with rigid locking plate to treat varus knee*

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Abstract: Objective: To introduce and characterize the modified biplanar opening high tibial osteotomy with rigid fixation to treat varus knee in young and active patients. Methods: Between June 2001 to July 2008, 18 patients with monocompartmental degeneration of the knee combined with a varus malalignment of the leg had the modified biplanar opening high tibial osteotomy and the osteotomy was fixed with the locking plates (Locking Compression Plate System). The mean varus deformity before operation was 11.5° (5°~19°) and no degenerative changes were found in other departments. Stability of the knee was normal in 15 patients, but ruptures in anterior cruciate ligaments or lateral collateral ligament were presented in the remaining 3 patients. Preoperative symptom was mainly limited in the pain of medial compartment. The preoperative and follow-up data for the range of motion and Lysholm score were determined. Subjective satisfactory examination was also applied to the patients for the operation they selected. Results: All of the patients were followed up with an average of 32.5 months (12~82 months). There was no ununion or delayed union in this group during the follow-up period. No complications like broken plate, nerve injury, or blood vessel injury occurred. The postoperative average corrected degree was 9.5° (5.5°~18°). No degenerations developed in the three departments of the knee. The Lysholm scores before and after surgery were 42.5 and 77.5, respectively (P<0.01). The overall fineness rate was 83.3%. The subjective satisfactory survey demonstrated that about 83.3% patients showed satisfactory on the operation. There was no obvious difference in the range of motion before and after operation, but significant changes were found in the Lysholm score and varus degree from preoperative to follow-up. Conclusion: Proximal opening high tibial osteotomy performed in conjunction with the special rigid locking plate yielded good results for symptomatic genu varum. This new classic technique can be effectively applied to the medial compartment degeneration of the knee in active young patients.

Key words: Osteotomy, Varus, Osteoarthritis, Fixation
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INTRODUCTION

Musculoskeletal disorders, among which knee osteoarthritis is the key issue, are considered the leading reason of disability in the elderly population. It afflicts 1% of men and 0.9% of women by the age of early 50 years, increasing to 2% of men and 6.6% of women by their 70 years (Kim *et al*., 2007). The progression of this disease has been attributed to several factors, one of which is the malalignment of the mechanical axis of the lower extremity. Particularly, the young patients with knee osteoarthritis present a challenging treatment dilemma to the orthopaedic surgeon for selecting the suitable treatments. High tibial osteotomy (HTO) was historically started by Langenbeck (1854) in the 19th century and has been widely accepted since the Coventry (1965) who first performed osteotomy proximal to the tuberosity, with the advantage of faster healing. It has become a well established procedure to treat the varus knee and medial gonarthritis in young patients. It is

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indicated in patients with medial cartilage damage and varus deformity due to osteoarthritis, traumatic cartilage lesions, osteochondrosis dissecans, and condylar osteonecrosis. The principle of correcting malalignment is to transfer load to the relatively normal compartment of the knee to relieve symptoms and suppress the disease progression. The middle-term and short-term results are rather acceptable in aspects of cost-effect ratio. Results of high tibial osteotomy vary considerably in the literature, but the procedure generally provides good relief of pain and restoration of function in approximately 80% to 90% of patients at 5 years old, and 50% to 65% at 10 years old (Muller *et al*., 2000; Aglietti *et al*., 1983; Herningou *et al*., 1987; Insall *et al*., 1984). The good results are directly related to achieving optimal alignment. With total knee arthroplasty, significant concern remains regarding the longevity of these prostheses, particularly in younger and active patients. As one of the substitutes of joint arthroplasty, this technique maintains the advantages of low cost and less invasion, as well as the possibility of transfer to joint arthroplasty (Muller *et al*., 2000). The most popular osteotomy is the closed-wedge technique from Coventry (1965), which removes a bone wedge from the lateral tibia and fixes the osteotomy site with staples or special plate in a tension-band fashion. Some disadvantages that accompany this fashion additional fabular osteotomy and lateral approach include the risk of peroneal nerve injuries, more detachment of extensor muscles, possible compartment syndrome, and the instability of the osteotomy sites (Aglietti *et al*., 1983). Large corrections can cause marked shortening of the extremity and an offset of proximal tibia, which may compromise later placement of a tibial component of total knee arthroplasty. So open-wedge osteotomy from the medial side of the tibia has been developed to avoid the leg shortening and muscle detachment. Furthermore, biplanar open-wedge osteotomy contains the advantages such as being easy to regulate and fast healing. While the technique has been invented for several years, few surgeons used this traditional technique, partially because the harvest of bone autografts can cause morbidity and delay the healing process. Since June 2001, we have treated adult varus knee with modified biplanar open-wedge HTO and fixed the osteotomy with rigid locking plate, and have thus verified this suitable procedure.

MATERIALS AND METHODS

Patients

From June 2001 to July 2008, 18 serial patients (11 males and 7 females, 32~49 years old, mean age of 41 years) with monocompartmental degeneration of knee combined with a varus malalignment of the leg had the modified biplanar high tibial osteotomy in our institution, and were enrolled in this study retrospectively. The patients had no severe overweight, and the range of motion was over 90°. The mean varus deformity before operation was 11.5° (5°~19°) and no degenerative changes were found in other departments. Stability of the knee was normal in 15 patients, but in the other 3 patients ruptures in anterior cruciate ligaments or lateral collateral ligament were presented. The patients with ligament injury had osteotomy after stability reconstruction surgery. Preoperative symptom was mainly in the pain of medial compartment.

Preoperative planning

Before operation, careful clinical examination must be taken to exclude any possible degeneration of the lateral compartment and patellofemoral compartment, and to assess the stability of the knee. Radiographs of the knee should include posteroanterior weight-bearing in flexion and extension, and the whole lower extremity. It is needed to draw out the position that weight-bearing line passed through, and the implants in the knee, including the suture anchor, staple or interference screw on a transparent paper. The osteotomy should exactly avoid every implant (Fig.1). The new weight-bearing line should be located at a point 62% of the total width of the proximal tibia from medial to lateral (Fujisawa *et al*., 1979). Then the paper was cut through the planned osteotomy line, and the distal part of the paper was rotated until the right position while the proximal part of the paper remains fixed on the radiograph. The opening of the medial cortex of the tibia in millimeters should be determined and the relevant magnification factor of the radiograph should be considered. The systemic diseases like coronary artery disease and diabetes should be retrieved preoperatively. The operation of this group was performed under lumbar (16 patients) or general anesthesia (2 patients).

Fig.1 The AP view of the varus knee preoperatively. Reconstruction of the posterior cruciate ligament (PCL), lateral collateral ligament (LCL), and posterolateral complex (PLC) had been preformed before the osteotomy procedure

Surgical techniques

After anesthesia, a tourniquet was placed on the thigh of the patient and drape only left the knee free. A C-arm fluorescent machine was prepared to check the correct visualization of the knee in both planes. A longitudinal incision was made parallel to the pes anserinus, from the medial part of the tibial tuberosity to the joint line. The fascia was incised parallel to the medial border of the patellar tendon and medial collateral ligament. The periosteum was detached limitedly from the proximal tibial cortex. The flexion angle of the knee was adjusted to make the correct fluoroscope to show the exact anteroposterior projection of the tibial plateaus. Then two Kirschner wires were drilled from the medial cortex to lateral cortex obliquely, exactly at the level of the tibiofibular joint. These two wires must be absolutely parallel in the anteroposterior plane. In order to enhance the healing process and avoid the offset, the osteotomy level should be oblique along with the wires with an oscillating saw. Then the second cut was behind the tibial tuberosity, about 120° angulated with the first cut. During this step, a thin and smaller saw blade should be used to avoid the damage of the tuberosity. Then a broad chisel was inserted into the osteotomy site under the Kirschner wires as deep as the saw had produced. Some spacers or chisels were tapped into the transverse and anterior oblique osteotomy sites to open the bone gradually until the correct angle desired. Whenever the correction was achieved, an examination of the alignment of the lower extremity under the fluorescence was taken. Modification of the correction could be regulated by opening or closing the gap gradually. The tibial slope was modified to normal angle to enhance the stability in extension. The appropriate tibial proximal locking plate (Locking Compression Plate System, Trauson, Changzhou, China) was placed at the anteromedial cortex of the tibia. The special design of the holes allows for the insertion of the lock screws or conventional screws into the plate if required. Bone substitute or autograft granules were impacted into the osteotomy gap to enhance the healing process. The proximal self-tapping long bolts were inserted into the special plate-mounted drill sleeves after the lengths were measured. In proximal segment, locking screws were placed into the cancellous bone, while in the distal tibial shaft, bicortical or monocortical fixation was used. The screws were tightened gradually and the osteotomy was carefully monitored to avoid the loss of correction. Bone substitute or autograft granules were used to fill the residual defects further. No drain was used and the subcutaneous layer and skin were closed with interrupted sutures. Elastic compression drape was applied over the entire leg.

Postoperative rehabilitation

The patients were allowed to move the knee in bed 48 h after surgery, and then were allowed to walk without weight-bearing. From the third day, passive knee motion was permitted. The rehabilitation process should consider both function and protection, especially avoiding the flexion with rotation stress and early weight-bearing. No brace is necessary after this procedure. The range of motion must be normal within four weeks and the patient should be pain free. The patients were allowed to partially weight-bear (30% of the body weight) after four weeks. Whenever radiographs of the knee in two planes demonstrate healing of the osteotomy and no lysis zones or instability signs, full weight-bearing without crutches was allowed. The implants can be removed one year after surgery but may also be left in the knee if the patients do not want its removal.

Follow-up

The preoperative and follow-up data for the range of motion and Lysholm score were determined (Lysholm and Gillquist, 1982). Subjective satisfactory examination was also applied to the patients for the operation they selected. Student's paired *t*-tests was used to reveal differences between the data before and after surgery, with alpha level less than 0.05 selected for significance.

RESULTS

All of the patients were followed-up with an average of 32.5 months (12~82 months). There was no ununion or delayed union in this group and all patients were encouraged to start full weight-bearing after six or eight weeks. The lateral cortical bridge of the osteotomy demonstrated partial callus formation in some patients and the osteotomy was still partially open on the medial side (Fig.2). All of the osteotomies were healed in 12 to 16 weeks (Fig.3). No complications like plate broken nerve injury or blood vessel injury occurred. One patient had superficially delayed healing of the incision with liquefaction, but healed after dressings were changed. No tendonitis of the pes anserinus was found and no medial instability was recorded after surgery. The postoperative average corrected degree was 9.5° (5.5°~18°) compared with the varus deformity before surgery. During follow-up, the weight-bearing lines of the lower extremities maintained the level after operation, and no degenerations developed in the three departments of the knee. The overall fineness rate was 83.3% (15/18)

Fig.2 After the osteotomy, symmetric compartment gaps were presented

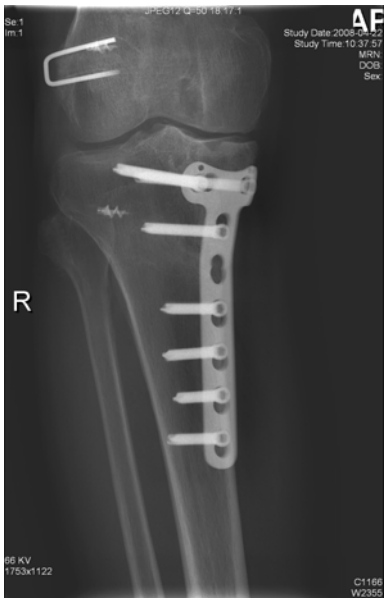

Fig.3 One year after surgery, thick cortical native bone can be found in the osteotomy gap without degenerative development in both compartments

in the end of the follow-up with improved symptoms. The subjective satisfactory survey demonstrated that about 83.3% patients showed satisfactory on the operation, although 16.7% patients still had residual symptoms such as pain and locking. The majority of the patients thought that they would re-select this surgery if possible, based on the therapy process and ultimate results.

There was no obvious difference of the range of motion before and after operation, but significant changes were found in the Lysholm score and varus degree from preoperation to follow-up (Table 1).

Table 1 Comparison of knee function before and after operation

	Range of motion	Lysholm score	Varus degree
Before op.	115±6	42.5±3.5	11.50±6.35
After op.	112±7	77.5±5.5	1.15±2.05
t value	1.87	36.65	15.45
P value	>0.05	<0.01	<0.01

DISCUSSION

Deformity of the knee frequently associated with severe osteoarthritis or sports injury is a problem confronting the patients and surgeons (Niemeyer *et*

al., 2008). The varus knee with unicompartmental osteoarthritis of the medial compartment has an altered limb alignment, and subsequently more load is distributed to the affected compartment. Knee arthroplasty is a good treatment option especially for generalized osteoarthritis, but it has several disadvantages, especially if only unicompartmental osteoarthritis is present or the patient is younger than 50~55 years (Asik *et al*., 2006). The limited lifetime, the higher infection risk, and multiresistance of bacteria have been an increasing problem (Esenkaya and Elmali, 2006).

Osteotomy is the classic surgery in the standard orthopaedic armamentarium to treat early degenerative arthritis and correct varus deformity in younger patients. The first reports on osteotomies can be found in German literature in the 19th century (Langenbeck, 1854). Until 1965, osteotomy was popularized by Coventry (1965), who modified the procedures by executing the osteotomy proximal to the tibial tubercle. The advantages of the modified surgery were that the cancellous bone could heal rapidly, and early weight-bearing on the leg could be ensured by the tensile strength of the quadriceps, which could stabilize the osteotomy (Marti *et al*., 2004). Retrospectively, long-time studies had documented the efficacy of HTO, indication, planning, and techniques, and reported that it could delay the necessity of a knee arthroplasty often by more than 10 years. For active unicompartmental osteoarthritis patients younger than 55 years, an osteotomy is generally a better choice due to a better range of motion and a better proprioception that allows an active life. Conversion of knee arthroplasty is still possible, when the degeneration deteriorates (Koshino *et al*., 2001).

The medial opening wedge osteotomy was presented in the 1970s. Herningou *et al*.(1987) introduced a 10~13-year follow-up of 93 patients treated with the opening technique and concluded that this was a suitable procedure for medial compartment gonarthrosis unless the precise correction of the malalignment. An interesting and important observation is that success depends on the postoperative alignment, as patients with an ankle-knee-hip angle of 183°~186° showed best results and none of the patients had symptoms and progression of the osteoarthritis in either the medial or the lateral tibiofemoral compartment after 10 years. This shows the importance of an accurate correction of the axis, and similar long-term results as in the closed wedge surgery can be expected. This technique avoids several concerns associated with lateral closing wedge and dome osteotomies, which include violation of the tibiofibular joint, possible peroneal nerve injury, patella infera, and bone loss (Fowler *et al*., 2000). Young patients less than 40 years old with moderate degenerative changes in one compartment should be corrected to the neutral position. If the degenerative changes are advanced and/or the patients are older, a slight over correction of 3°~4° into the contralateral compartment should be performed (Koshino *et al*., 2003).

The success of the procedure depends mainly on the biologic healing of the osteotomy planes (Billings *et al*., 2000). Plate fixation and external fixator application have been introduced to opening wedge osteotomy. In general, the opening wedge osteotomy has similar survival rates compared with closing wedge techniques. The approximate survivorship at 5 years is 80%~90% and falls to 70%~80% at 10 years (Insall *et al*., 1984). Koshino *et al*.(2003) used an opening wedge osteotomy together with hydroxyapatite inserts and plate internal fixation. The results showed an improvement in all 12 patients with an average follow-up of 6 years. The opening HTO was not a general application although this technique developed earlier, because the autograft needs to fill in the gaps, and an earlier fixation is uncertain. Minimal injury and earlier weight-bearing can be maintained due to the development of stronger fixation and advanced bone substitutes.

In a comparison of 27 patients treated with opening wedge external fixation versus 26 patients treated with lateral closing wedge HTO and internal fixation, the results demonstrated a benefit of external fixation in improved maintenance of correction and avoidance of patella infera (Madan *et al*., 2002). In a direct comparison of 28 closing wedge osteotomies versus 40 dome osteotomies, the average varus alignment for each was 5.67° and 1.45°, respectively. This correlated with the subjective satisfaction scores where 42.9% patients were unhappy with the closing wedge osteotomy compared with 57.5% with the dome osteotomy with an average follow-up of 8.6 years (Nakamura *et al*., 2001). The reported incidence of infection approximated 1%~2% for opening wedge

techniques using internal plate fixation and less than 1% for closing wedge osteotomies (Rinonapoli *et al*., 1998). Use of internal fixation methods eliminates the potential of pin tract infection and is of greater convenience for patients. An internal fixation plate that incorporates a metal block of fixed size to obtain standard opening wedge has been produced in specified situations. The locking plate in our study provided an internal fixator with increased primary rotational stability in osteotomy site. No loss of correction and delayed union occurred in these serial patients, and the patients were allowed to partially weight-bear early. Development of the fixation technique can improve the rehabilitate process and further contribute to the ultimate outcome.

The particular concerns during opening HTO are the tibial plateau inclination and patellofemoral issues. Inappropriate alteration of the sagittal inclination can compromise the normal knee kinematics (El-Azab *et al*., 2008). Previous data showed that increasing the posterior slope aids in decreasing stress on the posterior cruciate ligament (Lobenhoffer *et al*., 2004). Similarly, decreasing the posterior slope decreases stress on the anterior cruciate ligament. The patellofemoral disease may not be a contraindication to HTO, as one can combine coronal proximal tibial correction with distal fragment anterior displacement (Devgan *et al*., 2003). To apply the regulation precisely in three dimensions, the technique was modified to biplanar osteotomy in this research, which also enhanced the healing process of proximal tibia combined with bone substitutes containing cytokines.

In our clinical experience, proximal opening high tibial osteotomy performed in conjunction with the special rigid locking plate yielded good results in the treatment of pain and dysfunction associated with genu varum. The mid-term data verified the effectiveness of the modified technique with relatively rapid bone healing and earlier rehabilitation. Long-term studies are needed to further develop this procedure.

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