Arthroscopy-assisted computer navigation in high tibial osteotomy for varus knee deformity

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ABSTRACT

Purpose. To assess the accuracy of knee alignment after high tibial osteotomy (HTO) for varus knee deformity using arthroscopy-assisted computer navigation.

Methods. Six men and 4 women aged 47 to 53 (mean, 49) years underwent medial open wedge HTO for varus knee deformity and medial unicompartmental osteoarthritis using arthroscopy-assisted computer navigation with fluoroscopy. Patients were followed up for a mean of 23 (range, 11–32) months. Intra- and post-operative leg alignments were compared.

Results. The mean postoperative coronal plane alignment was 2.7 (range, 1–4) degree valgus; the mean deviation from intra-operative computer images was one (range, 0.1–1.9) degree; 5 knees had less valgus in the postoperative radiographs than the intra-operative computer images.

Conclusion. Despite being more technically demanding, time consuming, and costly, arthroscopy-assisted computer navigation is safe, accurate, and reliable for HTO.

Key words: knee joint; osteotomy; surgery, computer-assisted; tibia

INTRODUCTION

High tibial osteotomy (HTO) is a common procedure for symptomatic medial unicompartmental osteoarthritis of varus knees. It provides good pain relief and restoration of function.\textsuperscript{1–10} Results are comparable among a variety of techniques, including lateral closing wedge osteotomy, medial open wedge osteotomy, and dome osteotomy. The survival rates of the HTO diminish with time, ranging from 73 to 97\% at 5 years, 51 to 96\% at 10 years, and 39 to 87\% at 15 years.\textsuperscript{3,9–10} Risk factors for failure include insufficient valgus correction, increasing age, osteoarthritis, any lateral tibial thrust, preoperative knee alignment and flexion arc, ligamentous instability, high body mass index, and non-union at the osteotomy site. The only factor that can be controlled intra-operatively is knee alignment, which entails a moderate over-correction of 2º to 6º in the frontal plane.\textsuperscript{3–4} Careful patient selection is essential in achieving good results.

The conventional estimation of about 1º of correction for each mm of the bone wedge removed is an over-simplification. Although fluoroscopic control is used to increase accuracy, a long film for measuring the exact leg alignment is difficult to obtain intra-operatively, as is the application of the Fujisawa intersection method, which is subject to individual variability.\textsuperscript{11} Radiation hazard to patients and medical personnel is another issue. In addition...
to correcting leg alignment in the frontal plane, HTO may unintentionally change the tibial slope in the sagittal plane, and thus alter the tension of the anterior and posterior cruciate ligaments as well as the biomechanical environment inside the knee joint.

Computer navigation is superior to conventional techniques for aligning prosthesis during total knee arthroplasty and HTO. The alignment, level, and orientation of the osteotomy can be determined in real-time intra-operatively. With the addition of arthroscopy, the anatomy and landmarks of the proximal tibia can be fully utilised to determine the frontal plane alignment and tibial slope. Thus, we assessed the accuracy of knee alignment after HTO for varus knees, using arthroscopy-assisted computer navigation.

**MATERIALS AND METHODS**

From October 2004 to August 2006, 6 men and 4 women aged 47 to 53 (mean, 49) years underwent medial open wedge HTO for varus knee deformity and medial unicompartmental osteoarthritis, using arthroscopy-assisted computer navigation with fluoroscopy. Patients were followed up for a mean of 23 (range, 11–32) months. The inclusion criteria were: (1) symptomatic isolated medial knee compartment osteoarthritis of grade III or below, (2) failed conservative treatment, (3) age of <55 years, (4) varus alignment of <10º, (5) flexion contracture of <10º, and (6) flexion range of >90º. Patients with patellofemoral joint symptoms were excluded.

Preoperative leg alignment, range of motion, knee ligaments and menisci were assessed. The mechanical axis was determined using standing long-leg true anteroposterior and lateral scannograms. Knee and functional scores were recorded.

A standard longitudinal incision was made medial to the patellar tendon to expose the proximal and medial tibia subperiosteally. Tracker anchoring pins were inserted into the distal femur and proximal tibia, 2 on each side and through both cortices. Tracker anchoring clamps were then fixed to the pins.

The intra-articular landmarks were registered with arthroscopic guidance (Fig. 1). Standard anterolateral and anteromedial arthroscopic portals were used. The first anatomic landmark—the hip centre—was registered through gentle rotation of the hip to obtain around 100 points throughout the movement. The anterosuperior iliac spines were pressed against the operating table to prevent lifting off and rotation of the pelvis. The most prominent points of the medial and lateral malleoli were then registered to determine the endpoints of the mechanical axis. The medial and lateral borders of the tibial plateau were then registered and the width of the tibial plateau calculated. This defined the medial proximal tibial axis. Along with the mechanical axis, it determined the medial-proximal tibial angle. The tibial anteroposterior direction was then registered and the direction of the tibial slope determined. The medial and lateral femoral epicondyles were registered percutaneously.

The distal point of the femoral mechanical axis was registered. It was about 1 cm anterior to the femoral insertion of the posterior cruciate ligament. The proximal point of the tibial mechanical axis was registered. It was over the tibial insertion of the anterior cruciate ligament. The long-leg mechanical axis, the varus/valgus and flexion/extension alignment of the tibia, and the tibial posterior slope were then determined. The medial and lateral tibial plateaus were registered, followed by the natural tibial slope and the tibial tuberosity. The level of the osteotomy was then determined, and expected to be above the tibial tubercle.

A pre-cut model of the leg with deformity was then generated. The optimal alignment was calculated with the mechanical axis passing through the Fujisawa point (Fig. 2a). The start and end points of the osteotomy determined the initial centre point of rotation on the tibia (hinge of the open wedge). The starting point (medial) was determined through the anteromedial longitudinal incision and the end point (lateral) was determined percutaneously with...
fluoroscopic guidance. The respective entry and exit points from the medial and lateral joint lines were calculated.

An osteotomy plane was generated; 2 guide pins were inserted distal and parallel to the plane to guide the osteotomy, because the saw blade was too soft. The trajectory of the guide pins was parallel to the osteotomy plane and the posterior tibial slope in the sagittal plane. These 2 guide pins determined the level and direction of the coronal/sagittal planes of the osteotomy (Fig. 2b). The guide pins should be as parallel as possible to the tibial slope in the sagittal view to avoid changing the tibial slope. Osteotomy was performed with reference to the guide pins and fluoroscopy. An optimal osteotomy left behind a hinge at the proximal tibiofibular joint.

The wedge was opened using a laminar spreader. The leg axis, the distance of the leg axis from the Fujisawa point, and any change in the tibial slope were calculated while opening the wedge (Fig. 2c). Fluoroscopic examination was also used. The wedge was filled with a matching hydroxyapatite block and the whole construct fixed with screws and plates. The direction of the drill was navigated, and thus minimised the risk of intra-articular screw penetration.

All patients received an identical rehabilitation protocol involving a long-leg hinged brace for 8 weeks. The brace locked in extension while in ambulation and allowed a free range of motion at rest. Partial weight bearing walking was started at day 1, and gradually increased after 4 weeks. Bone healing and leg alignment were assessed using standardised knee radiographs and leg scannograms immediately (Fig. 3), 3 months, 6 months, and one year postoperatively. The coronal plane alignment, tibial slope, and intersection of the mechanical axis over the tibial plateau between intra-operative computer images and postoperative radiographs were compared.

RESULTS

The mean operating time was 135 (range, 115–165) minutes, including the 20 minutes for registration. The mean postoperative coronal plane alignment was 2.7° (range, 1°–4°) valgus; the mean deviation from intra-operative computer images was 1° (range, 0.1°–1.9°); 5 knees had less valgus after operation. The results were comparable to computer navigation HTO without arthroscopic guidance. The mean postoperative tibial slope was 8.1° (range, 2°–15°), with a mean decrease from the preoperative slope of 1.5° (range, 0°–5°). The mean intersection of the mechanical axis over the tibial plateau was 55% (range, 50%–58%), with a mean deviation of 3% (range, 0%–7%) from the
intra-operative images. All patients had good pain relief. There was no short-term complication, loss of alignment, or mechanical failure after a mean follow-up of 23 months.

DISCUSSION

HTO has become more popular because of the increasing number of active, young patients with symptomatic isolated medial knee osteoarthritis, and advances in cartilage resurfacing procedures that require simultaneous correction of leg alignments.

Leg alignment is the most important factor in knee survival after HTO. In our study, the tibial slope was affected by the direction of the tibial anteroposterior alignment, the tibial mechanical axis, and tibial plateau. The exact tibial slope was not navigated because it would have required placement of tracker pins into the proximal tibial osteotomy fragment, which was only 3 cm in width and would hinder placement of the fixation device. Conventional open wedge HTO has been associated with increased posterior tibial slope. When the wedge is placed too anteriorly, the posterior tibial slope increases, and vice versa. The osteotomy and wedge insertion should be from true medial to lateral rather than anteromedial to posterolateral. With computer navigation, alteration of the tibial slope can be eliminated.

The difference in the intersection of the mechanical axis at the knee joint may be affected by the rotation of the leg during registration and/or the presence of osteophytes over the medial proximal tibia. This may shift the intersection toward the medial side resulting in under-correction.

Arthroscopy-assisted computer navigation HTO is more technically demanding and time consuming than conventional HTO. Registration through arthroscopic portals is not easy. The intact cartilage of the tibial plateau is slippery, making it difficult to perform the pivoting action at the start of the registration. The intact cartilage may be scratched and damaged during the procedure. If any “air point” is collected during registration (registration without actual touching of the anatomic landmark), the overall alignment may be affected.

The use of arthroscopy in computer navigation HTO requires extra incisions for the arthroscopic portals and femoral tracker anchoring pins. This increases operating time and costs, especially in the learning period. Nonetheless, the benefit of more accurate leg alignment should outweigh the increased operating time and costs.

In our study, fluoroscopy was used to guide the
REFERENCES