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Radiostereometric analysis of early anatomical changes following medial opening wedge high tibial osteotomy

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ABSTRACT

Background: The objective of this study was to use radiostereometric analysis (RSA) to evaluate the anatomical changes that occur in the tibia immediately after surgical correction with medial opening wedge high tibial osteotomy (HTO), and the changes that occur over the course of the first twelve weeks of osseous union.
Methods: Patients included nine males and one female, with a mean age of 49.0 ± 5.5 years and mean BMI of 28.4 ± 3.8 kg/m^2. The patients underwent HTO using a non-locking plate. RSA marker beads were inserted in the tibia, femur, and patella. RSA exams were first obtained intra-operatively prior to the osteotomy, and subsequently at one, two, four, six, and twelve weeks postoperatively.
Results: Patients were corrected from a mean alignment preoperatively of 8.6 ± 2.5° to 0.3 ± 1.9° postoperatively, with a mean osteotomy of 12.5 ± 3.6 mm. Immediate tibia changes surrounding the osteotomy site included 9.2 ± 2.4° of valgus rotation and 6.2 ± 2.0 mm of distal translation. Secondary motions included 2.5 ± 2.4° of internal rotation of the distal tibia, 1.8 ± 1.4 mm of posterior movement of the femur, and 8.5 ± 3.4 mm of patella baja. Micromotion between the proximal and distal tibial segments decreased over time.
Conclusion: The results suggest that subtle changes to the anatomy occur, beyond what is intended with the procedure, but partial corrections of these phenomena occurred over the twelve weeks. Micromotion surrounding the osteotomy site decreased with osseous union.
Level of evidence: Level IV, case series

1. Introduction

Medial opening wedge high tibial osteotomy (HTO) is an established surgical treatment for osteoarthritis (OA) primarily involving the medial compartment of the tibiofemoral joint. The procedure alters the mechanical axis of the lower limb by realigning the tibia, and redistributes the dynamic load across the knee [1]. Goals of medial opening wedge HTO are to lessen loads on the medial compartment, limit OA progression and improve quality of life [2].

The medial opening wedge procedure relies on adequate fixation of the osteotomy site during bone healing. A number of different osteotomy plates are available, and fixation stability has previously been studied [3–8]. While correcting the varus deformity, other anatomical changes are also possible [9]. Patellar descent with respect to the femur, also referred to as patella baja or patella infera, has been noted to occur with both closing and opening wedge HTO [10–12]. The reason for the change in patellar height is unclear, and may be related to shortening of the patellar tendon, scarring, or adhesions [11]. Increases in the tibial slope following HTO have also been noted, which can lead to anterior translation of the tibia and instability [9].

Radiostereometric analysis (RSA) has been previously used to examine the stability of the fixation following HTO surgery, in both patients and cadavers [3–8,13–15]. However, these studies have focused on the fixation surrounding the tibia (proximal and distal to the osteotomy site) as opposed to the anatomical changes, especially the other, unintended anatomical changes possible with the HTO procedure. The objective of this study was to use RSA to evaluate the anatomical changes that occur in the tibia immediately after surgical correction with medial opening wedge HTO, and the changes that occur over the course of the first twelve weeks of osseous union. It was hypothesized that micromotion surrounding the opening wedge would subside within the fix six weeks post-operation.

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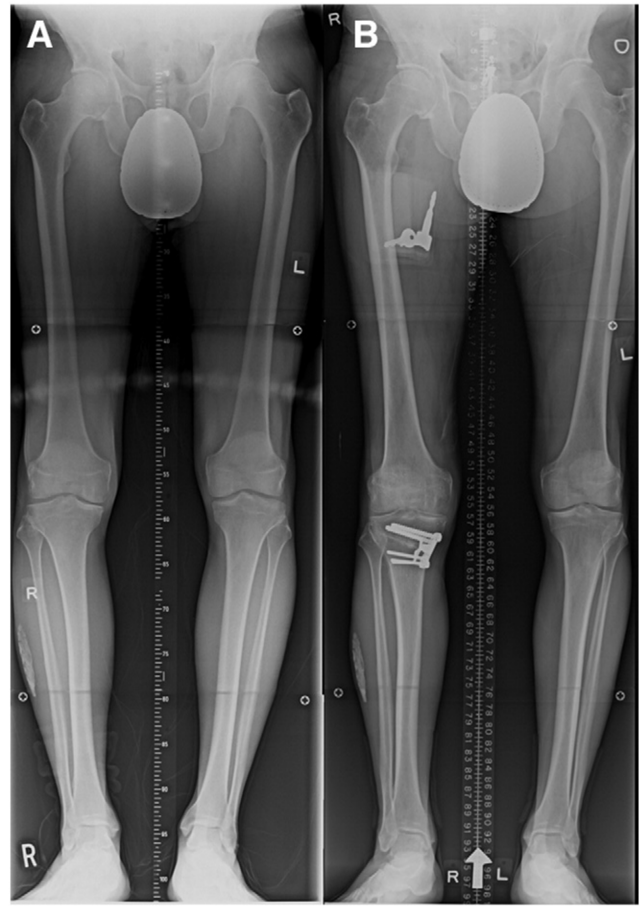

Fig. 2. Full leg radiographs before (A) and after (B) medial opening wedge high tibial osteotomy.

2. Methods

Ten patients scheduled to undergo medial opening wedge HTO were recruited. The study was approved by the Institutional Review Board. Inclusion criteria were ages 30 to 70 years old, activity-related knee pain localized to the medial compartment, varus alignment, medial compartment degenerative OA, no significant patellofemoral symptoms, and a ligamentously stable knee. Patients with advanced patellofemoral or lateral compartment OA, and joint flexion less than 90°, were excluded. The sample included nine males and one female, with a mean age of 49.0 ± 5.5 years, and a mean BMI of 28.4 ± 3.8 kg/m^2. The mean pre-operative mechanical axis angle was 8.6 ± 2.5° varus (range, 5.4 to 11.8° varus).

All patients underwent HTO using an opening wedge osteotomy system (Arthrex, Naples, FL, USA) and a non-locking plate. An oblique osteotomy was performed as a single plane. No tubercle osteotomies were performed for this patient group. Cancellous allograft bone was used in osteotomies greater than 7.5 mm. Partial weight bearing was permitted at six weeks postoperatively, and full weight bearing was permitted at 12 weeks postoperatively. To enable RSA to be performed, tantalum marker beads (0.8 mm diameter) were inserted during the procedure following the placement of the osteotomy guide wire, but before the osteotomy cut was performed. For each patient, four to six beads were inserted above the guide wire (in the proximal tibia, above the osteotomy), and another four to six beads were inserted below the guide wire (in the distal tibia, below the osteotomy). These beads were inserted through the surgical incision. Four beads were inserted into the femur, and three beads were inserted into the patella. These beads were added through small cuts to the skin with a #11 blade.

The first RSA exam was performed intra-operatively, after the guide wire placement and insertion of the beads, but before the opening of the wedge. The examinations were completed using two portable C-arm X-ray systems and a standard calibration cage. The remainder of the operation was then completed, including the osteotomy and plate fixation. Postoperative RSA examinations were performed for all patients at one, two, and six weeks following the operation. The same calibration cage used in the intra-operative exams was used for the postoperative exams. An additional RSA exam was achieved at 12 weeks for seven of the ten patients. The average condition numbers for the distal tibia, proximal tibia, femur, and patella were 59, 44, 67, and 119, respectively. The mean error for rigid body fitting for all segments was below 0.3 mm.

For ease of data analysis, the coordinate system of the RSA measurements was rotated to match the tibial slope at the time of the operation, before the osteotomy cut was performed. This enabled all subsequent measurements to be relative to the original anatomical orientation. In the anterior–posterior image, two low points from both medial and lateral femoral condyles were identified, and a connecting line between these two points was recorded as the anatomical medial–lateral axis (Fig. 1A). The angle of this anatomical axis from the image's horizontal line (i.e. the x axis of the cage coordinate system) was recorded and used for correction. For the lateral image, two midpoints of the outer cortical diameter of the tibia were measured, and a connecting line between the two points was defined to represent the anterior–posterior axis (Fig. 1B). The angle of this line from the image vertical line (i.e. the y axis of the cage coordinate system) was used for correction.

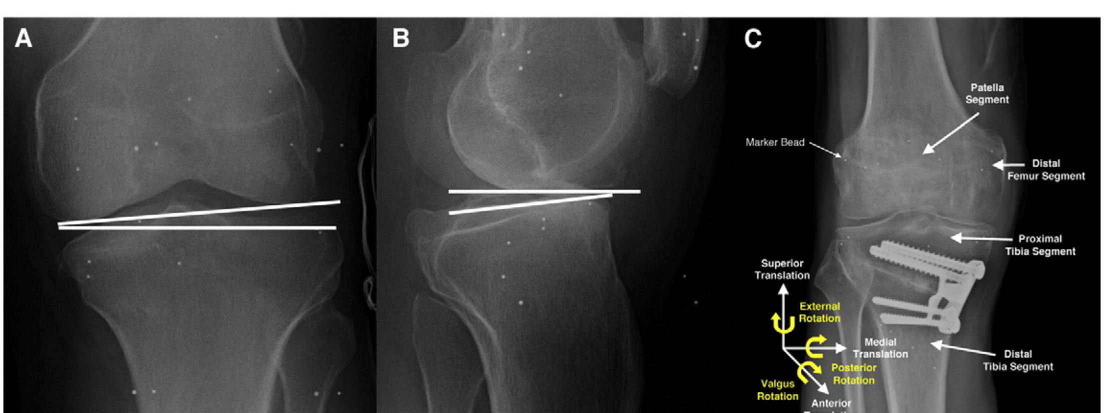

Fig. 1. Coordinate systems and segments used for RSA. A: Selection of anatomical medial–lateral axis (upper line). B: Selection of anatomical anterior–posterior axis (lower line). C: The four anatomical bone segments and directions of translations and rotations.