Gonarthrosis in the relatively young and active population causes major daily discomfort and disability. If the arthritic process is mainly limited to the medial compartment, the axis of a varus knee can be realigned laterally with high tibial osteotomy to unload the medial compartment and allow some cartilage regeneration and pain relief. This study describes the outcomes of patients who underwent opening-wedge high tibial osteotomies using Puddu plate (Arthrex, Naples, Florida) fixation. Eighteen patients (22 knees) with genu varum and medial compartment osteoarthritis were followed-up for an average of 6.3±2.3 years after high tibial osteotomy with Puddu plate fixation and iliac crest allograft. Clinical outcome was assessed by the Oxford Knee Score and subjective satisfaction rating. Pre- and postoperative radiographs were evaluated for tibiofemoral angle, Insall-Salvati index, and Kellgren-Lawrence Grading Scale for osteoarthritis. Mean patient age at surgery was 44±13.7 years, and mean body mass index was 29.1±4.7 kg/m². At last follow-up, mean Oxford Knee Score improved from 22.4±13.5 to 37.2±13.7 (P=.002). Average subjective satisfaction rate at last follow-up was 8±3. The measured tibiofemoral angle was corrected to an average genu valgum of 3.3°±4.8° (P=.001). No patient showed severe postoperative osteoarthritis (ie, Kellgren-Lawrence grade 4) at last follow-up. All radiographs showed full incorporation of the bone grafts. At the end of the study, 2 patients underwent total knee replacement.

Opening-wedge high tibial valgus osteotomy with Puddu plate fixation can be a reliable procedure for the treatment of medial-compartment osteoarthritis of the knee associated with varus deformity.

Drs Haviv, Bronak, Kidron, and Thein (Rafael) are from the Arthroscopy and Sports Injuries Unit, Hasharon Hospital, Rabin Medical Center, Petach-Tikva, and Dr Thein (Ran) is from Department of Orthopedics, Sheba Medical Center, Tel-Hashomer, Israel.

Drs Haviv, Bronak, Thein (Ran), Kidron, and Thein (Rafael) have no relevant financial relationships to disclose.

Correspondence should be addressed to: Barak Haviv, MD, Arthroscopy and Sports Injuries Unit, Hasharon Hospital, Rabin Medical Center, 7 Keren Kayemet St, Petach-Tikva, Israel 49372 (barak_haviv69@hotmail.com).

doi: 10.3928/01477447-20120123-08
Opening-Wedge High Tibial Osteotomy | Haviv et al

Gonarthrosis in the relatively young and active population causes major daily discomfort and disability. Until now, an everlasting surgical solution had not been found. If the arthritic process is mainly limited to the medial compartment, the axis of a varus knee can be realigned laterally with high tibial osteotomy. This is achieved with either opening- or closing-wedge osteotomy to unload the medial compartment and allow some cartilage regeneration and pain relief.\(^1\)\(^2\) The advantages of opening- over closing-wedge osteotomy are more technical precision, less muscular dissection, avoidance of damage to the peroneal nerve, and more favorable complication rates.\(^6\)\(^7\) However, although the clinical results at 5 to 10 years after osteotomy are good, they deteriorate with time, and some patients eventually require knee replacement.\(^9\)\(^11\)

In the early 1990s, Franco et al\(^12\) described their technique of opening-wedge osteotomy with new instruments and plates. Following the promising results of Franco et al\(^12\) and others,\(^13\)\(^14\) the current study hypothesis was that high tibial osteotomy improves pain and function in selected patients. The purpose of this study was to evaluate the outcome of patients with symptomatic medial compartment osteoarthritis and genu varum undergoing opening-wedge high tibial osteotomy using the Puddu plate technique.

**Materials and Methods**

Patients included in this study were younger than 65 years with symptomatic osteoarthritis of the medial compartment, intact lateral compartment, genu varum, good range of motion (ROM) (ie, flexion \(\geq 90^\circ\) and flexion contracture \(< 10^\circ\)) and without ligamentous instability. Informed consent was obtained from all patients.

Preoperative planning was performed using standing radiographs of the knee. The tibiofemoral angle\(^15\) was measured as the angle created by the intersection of lines drawn along the anatomical axes of the femur and tibia. In addition to the tibiofemoral angle, pre- and postoperative radiographs were evaluated for the Insall-Salvati index\(^16\) and Kellgren-Lawrence grading scale\(^17\) for osteoarthritis.

All procedures were performed by the senior author (R.T.). An opening-wedge valgus osteotomy was performed in all patients, and a Puddu plate was used for internal fixation. We aimed to shift the tibiofemoral angle to a degree that would place the mechanical axis at the middle of the lateral compartment (Figure 1).

**Surgical Technique**

The opening-wedge high tibial osteotomy technique was performed as described previously by Franco et al\(^12\) using the Puddu plate (Arthrex, Naples, Florida), a butterfly-shaped plate that contained a spacer as a tooth and was available in different sizes, from 5 to 17.5 mm in thickness. The thickness of the spacer coincided with the desired angle of correction. The supine position was used for surgery under general anesthesia. An arthroscopic evaluation and treatment of intra-articular pathologies were undertaken prior to the osteotomy. Patients with advanced arthritis (ie, more than grade 1 according to the International Cartilage Repair Society [ICRS] classification\(^18\)) of the lateral compartment during arthroscopy were considered unsuitable for osteotomy.

We used the longitudinal anteromedial approach to the proximal tibia. With the knee in extension and under fluoroscopic control, a Steinmann guide pin was drilled freehand from the near to the far cortex. This was obliquely oriented, starting ap...
approximately 4 cm distal and directed to 1 cm from the level of the joint line (Figure 2). The osteotomy assembly was mounted on the guide wire. Then, a second pin was introduced at an appropriate angle up to the far cortex. The osteotomy apparatus was removed. An oscillating saw was used to perform an uncompleted cut precisely under the guide wire up to 2 cm away from the far cortex, which served as a hinge. A sharp osteotome was used to finish the osteotomy under fluoroscopic control, confirming that all the cancellous metaphysis were completely interrupted, but preserving a far hinge of approximately 0.5 cm of intact bone.

The wedge opener was introduced and slowly advanced until the osteotomy was opened to obtain the planned realignment of the knee. The surgeon measured the dimension of bone gap directly on the graduated tines of the wedge opener and chose the plate. The plate could then be changed or evaluated, along with quadriceps muscle and hamstring-strengthening exercises. Gradual incremental full weight-bearing exercises were started approximately 3 months postoperatively.

**Follow-up**

All patients were followed-up at 2 and 6 weeks, 6 months, and annually thereafter for radiological and clinical assessment. Clinical assessment was performed prospectively by an independent observer (B.H.) and included an interview, subjective satisfaction rating, Oxford Knee Score, physical examination, and standing radiographs.

The Oxford Knee Score is a rating scale for patients with degenerative knee disorders. It comprises 12 multiple-choice questions, each with 5 responses. It was tested in patients undergoing total knee arthroplasty (TKA) and was found to be reliable, valid, and responsive. Radiographs were evaluated for tibiofemoral angle, Insall-Salvati index, and Kellgren-Lawrence grading scale for osteoarthritis.

Patients requiring revision or replacement surgery were considered failures.

**Statistical Analysis**

Results were expressed as mean ± standard deviation. Student’s *t* test was used to compare paired samples (ie, clinical scores and radiographic measurements). Multivariate analysis was performed to identify independent predictors of the postoperative clinical score, including age, body mass index (BMI), duration of preoperative symptoms, number of prior surgical arthroscopies, radiographic grade of osteoarthritis, and tibiofemoral angle. A *P* value ≤.05 was considered statistically significant.

**RESULTS**

Between 2001 and 2007, twenty-four high tibial osteotomies were performed at our institution. Of these, 2 were excluded because of concomitant anterior cruciate ligament reconstruction (n = 1) and a different type of fixation (n = 1). Overall, 22 knees were included in this study. Preoperative data are shown in Table 1. All procedures were performed by the senior author (R.T.). All patients were relatively young and active. Six patients were involved in a worker’s compensation injury.

Mean duration of preoperative pain and disability was 4.8 ± 5.1 years. Patients were offered surgery if they had a varus knee deformity and their knee symptoms persisted despite conservative treatment. Nine patients had prior surgical arthroscopy. No significant chondral damage (ie, more than grade 1 according to the ICRS classification) to the lateral compartment was present in any of the prior arthroscopies. Of these, 6 had partial medial meniscectomy. In addition, 2 patients who were not operated on before required arthroscopic partial medial meniscectomy at the index operation. No patient had lateral meniscectomy.

All patients included in this study had medial compartment osteoarthritis with an intact lateral compartment verified in the index operation by preceding knee arthroscopy. Ten knees had patellar chondral lesions (ICRS 2). Most patients were otherwise healthy, except for 5 patients with hypertension.

Mean follow-up was 6.3 ± 2.3 years. At last follow-up, mean Oxford Knee Score was 4.8 ± 0.9.
improved from 22.4 ± 13.5 to 37.2 ± 13.7 (Table 2). In 11 of 22 knees, scores were rated as excellent, 3 were good, 4 were fair, and 4 were poor. The final average subjective satisfaction rate was 8 ± 3 points on a scale of 0 to 10.

At last follow-up, the measured tibiofemoral angle was corrected to an average genu valgum of 3.3° ± 4.8° (Table 2) and the mean Insall-Salvati index was 1.0 ± 0.1. No patient showed severe postoperative osteoarthritis (ie, Kellgren-Lawrence grade 4) at last follow-up. All radiographs showed full incorporation of the bone graft.

None of the independent variables (ie, age, BMI, number of prior arthroscopies, duration of preoperative symptoms, radiographic grade of osteoarthritis, and tibiofemoral angle) showed significant prediction of the postoperative outcome score on multivariable regression analysis.

Two patients required hardware removal due to irritation at 1 and 5 years postoperatively. One patient had an asymptomatic broken screw on follow-up. One patient required a surgical arthroscopy 1 year postoperatively due to pain and limited extension. On arthroscopy, a cyclops lesion was found and removed; however, the following clinical score was poor. Two patients underwent TKA due to unresolved pain, 1 aged 56 years and the other aged 62, at 21 and 24 months, respectively, after their original high tibial osteotomy. No major complications (eg, infections, fractures, or thromboembolic events) occurred.

**DISCUSSION**

Our study suggests that opening-wedge high tibial osteotomy using the Puddu plate technique results in a satisfying clinical outcome at a mid-term follow-up of 6.3 ± 2.3 years. The ideal candidate for a high tibial osteotomy is a young patient (younger than 60 years), with isolated medial osteoarthritis and good ROM and without ligamentous instability.1 The patients were mostly young (mean age, 44 years), active patients who failed prolonged conservative treatment (mean symptom duration, 4.8 ± 5.1 years). Half of the patients had prior surgical arthroscopy in the same knee.

Two-thirds of patients reported good to excellent results according to the Oxford Knee Score. Twenty (91%) of 22 knees were not converted to TKA. This is in accordance with other successful results at 5 to 10 years.9 In the literature, survivorship of high tibial osteotomy for the classic closing-wedge method is >90% at 5 years and 70% to 80% at 10 years.11,21-23

In comparison, fewer reports exist on the long-term outcomes of the opening-wedge method. Schallberger et al4 compared opening- and closing-wedge high tibial osteotomy in 71 patients (16 were open) for a range of 13 to 21 years. Survival of both techniques was comparable and reached 92% at 10 years. Hernigou et al24 followed 53 knees treated with proximal tibial opening-wedge osteotomy for large varus deformity and osteoarthritis of the medial compartment for an average of 10 years (range, 8-12 years). They used a buttress plate and a porous beta-tricalcium phosphate wedge. After 10 years, 40 (81%) of 53 knees had an excellent or good result. The best results were obtained in the knees with a hip–knee–ankle angle of 183° to 186°.

The technique used in the current study was previously described by Franco et al.12 All opening-wedge osteotomies were fixed with a Puddu plate and iliac crest bone allograft. We have since abandoned the closing-wedge method because the opening-wedge method results in less muscular dissection and bone stock loss and avoids damage to the peroneal nerve, with more favorable complication rates.6,8 We have found the opening-wedge, specifically the Puddu plate, procedure to be fairly accurate, to result in good bone union, and to cause no loss of correction.23,26 This is supported by a few short-to mid-term reports in the literature. Asik et al13 prospectively followed 65 knees in 60 patients with varus gonarthrosis who underwent high tibial osteotomies with the Puddu plate for an average of 34 months. They found improvement in several knee assessment scores, a postoperative average of 6.5° genu valgum, and a mean Insall-Salvati index of 1.09. These results are comparable to those achieved in the current study. Recently, DeMeo et al27 reported a series of 20 patients treated with a medial opening-wedge high tibial osteotomy using the Puddu plate and allograft bone graft followed for an average of 8.3 years. A 70% survivorship resulted.

**Table 2**

<table>
<thead>
<tr>
<th>Pre- and Postoperative Knee Score and Radiological Measurements</th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Oxford Knee Score</td>
<td>22.4 ± 13.5</td>
<td>37.2 ± 13.7</td>
<td>.002</td>
</tr>
<tr>
<td>Mean tibiofemoral angle, deg</td>
<td>7.7 ± 6.8 (genu varum)</td>
<td>3.3 ± 4.8 (genu valgum)</td>
<td>.001</td>
</tr>
<tr>
<td>Mean Insall-Salvati index</td>
<td>1.0 ± 0.1</td>
<td>1.1 ± 0.1</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Kellgren-Lawrence grading, no.

<table>
<thead>
<tr>
<th></th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>14</td>
<td>2</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>

Abbreviation: deg, degrees.
with 42% of patients rating their knees as good or excellent. Five (25%) patients underwent TKA.

In addition to careful patient selection to attain good results, some negative factors should be considered. We tested various conditions that were previously shown to correlate with poor prognosis, such as age, severe articular destruction, and BMI. Also included were the duration of preoperative symptoms and tibiofemoral angle. None of these independent variables showed significant prediction of the postoperative outcome score on multivariable regression analysis. However, this can be attributed to the low statistical power due to the small cohort of patients.

Plate irritation around the pes anserinus has been reported. It was also observed to the small cohort of patients. This was attributed to the low statistical power due to the small cohort of patients.

Operative outcome score on multivariable showed significant prediction of the postoperative angle. None of these independent variables were considered relatively old compared with the average age of our study population. This surgical technique may be less predictable in older patients.

To our knowledge, no long-term studies exist on opening-wedge high tibial osteotomy with Puddu plate fixation, and a few short- to mid-term studies exist. In addition to mid-term follow-up, the strength of this study is its relatively specific case selection of young, active patients with genu varum and isolated medial osteoarthritis who failed nonoperative treatment. The main limitations of the study are its design as a noncomparative case series and a relatively small cohort of patients. Our preliminary results remain favorable, and we are conducting a longer follow-up on these patients.

REFERENCES