ORIGINAL ARTICLE

Dome-shaped High Tibial Osteotomy: A Long-term Follow-up Study

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Background: High tibial osteotomy (HTO) is a well-established treatment for unicompartmental gonarthrosis of the knee, but its durability and complications remain controversial. We previously introduced a novel dome-shaped HTO, and the long-term follow-up results using this technique are analyzed in this study.
Methods: We treated 25 varus knees in 22 patients with medial gonarthrosis, using a specially designed calibrated cutting jig along with rigid external fixation and early joint motion postoperatively. A total of 16 patients (19 knees) completed the study protocol and were followed up for 13–16 years (mean, 15 years).
Results: The surgery attempted to obtain 8° valgus; the actual postoperative alignment averaged 12.4° valgus, which decreased significantly to 7.8° valgus after 5 years. The outcome as assessed by the Hospital for Special Surgery knee score was excellent or good in 18 knees at 5 years postoperatively, and in 13 knees at the final follow-up, showing a significant deterioration with time. Loss of correction with time was not correlated with the postoperative alignment achieved: at 5 years, loss greater than 2° was found in 12 knees, but their mean corrected angle (11.8° valgus) was not significantly different from that of the others (13.3° valgus). Nor was the loss of correction correlated with the knee scores. The mean amount of joint motion after surgery did not change significantly with time: 124° preoperatively and 114° at the final follow-up. The patellar position also did not change from preoperative values during postoperative follow-up: mean Insall-Salvati index was 0.88 before and 0.90 5 years after surgery, neither showing patella baja.
Conclusion: Dome-shaped HTO is a durable time-buying procedure for patients with unicompartmental medial gonarthrosis, and can avoid subsequent development of patella baja that may complicate further prosthetic arthroplasty. [*J Formos Med Assoc* 2006;105(3):214–219]

Key Words: osteoarthritis, osteotomy

Deformity of the knee results in asymmetric load on one compartment and leads to degeneration of the joint. High tibial osteotomy (HTO) was developed to treat unicompartmental gonarthrosis of the knee, and aims to relieve pain and improve function by correcting deformity.[1,2] The osteotomy realigns the anatomic axis of the knee to 8–10° valgus, and transfers the mechanical axis to the center or lateral to the joint to reduce the medial stress, thus preventing progression of arthritis.[2–7] Widening of a previously narrow joint space may lead to regression of the subchondral cysts and sclerosis if stress is sufficiently reduced,[8,9] and the degenerative articular cartilage in the medial compartment may regenerate after surgery.[10]

Various models of HTO have been proposed since Jackson and Waugh introduced the concept in 1961.[11] Coventry first popularized the HTO by using a medial closing-wedge osteotomy proximal to the tibial tuberosity.[12] This conventional

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method, being a demanding procedure with potential complications such as compartment syndrome and peroneal nerve palsy, was, more recently, replaced by the medial opening-wedge osteotomy using the hemicallotasis technique.[13,14] However, HTO-associated problems continue to be reported, including the difficulty in achieving an accurate or adequate correction of malalignment, the recurrence of malalignment, which, in turn, would shorten the durability of effectiveness, and postoperative patella baja that would complicate subsequent prosthetic replacement surgery.[15,16]

Evolution of surgical techniques has continued, tending to reduce complications and improve results. Among the various surgical methods, dome-shaped osteotomy provides good results by accurate angular correction.[17] However, shortening of the patellar tendon still occurs after Maquet barrel-vault type dome-shaped osteotomy.[18] We designed a calibrated osteotomy jig and used it to refine the surgery, as previously described,[19] with an easily applicable technique: the angle of correction was accurately set by the jig, and no additional internal fixation was needed. The purpose of this study was to investigate the results of this surgical method with a long-term follow-up period of a mean of 15 years.

Methods

The study was conducted following approval from the institutional review board. Inclusion criteria included degenerative joint disease involving the medial compartment of the knee (medial gonarthrosis), varus malalignment with pain on the medial side of the knee that limited activities and decreased quality of life, and the desire to remain active. The amount of remaining medial joint space was considered to be irrelevant. Patients with posttraumatic arthritis of the affected knee, and previous fracture of the proximal tibia that might affect further bone healing, were excluded. The study was explained to patients, and written consent was obtained from each patient before surgery. During the years 1984–1986, dome-shaped HTO was performed in 25 knees of 22 patients (7 men, 15 women); patients' mean age was 58 years (range, 40–67 years).

All subjected knee joints were evaluated before surgery, including range of motion (ROM), function as determined by the Hospital for Special Surgery (HSS) knee score,[1] and patellar position as indicated by the Insall-Salvati Index measured on a lateral radiograph of the knee in 30° flexion.[20] A stress anteroposterior radiograph was taken with the patient standing. The preoperative strategy was mapped on this film by determining the extent of varus, and calculating the amount of angular correction needed to obtain a postoperative angle of 8° valgus.

The operation was performed as previously described.[19] Briefly, the anesthetized patient was positioned supine and routine sterile procedures were used. Exsanguine field was maintained with a pneumatic tourniquet. Fibular osteotomy was done through a direct longitudinal incision to remove 1 cm of fibula from 3 fingers' breadth beneath the top of the fibular head, with protection of the peroneal nerves and veins. Another 5-cm midline longitudinal incision was made anteriorly to expose the proximal tibia and identify the borders of patellar tendon. A curved drill-guide was placed beneath the patellar tendon and fixed with a middle-thread Steinmann pin driven on the proximal tibia above the tibial tuberosity and perpendicular to the longitudinal tibial axis. The barrel-vault osteotomy was outlined by multiple pre-drilling through the guide. The guide was dismounted and the proximal arm of the jig was assembled onto the retained pin with medial placement of the goniometer, on which the preoperatively schemed angular correction was dialed (Figure 1). Another Steinmann pin was set on the tibia along the distal arm of the jig. The jig was then removed, leaving two pins on the bone, and the osteotomy was completed with a curve-tip osteotome. The tibia was rotatory realigned by paralleling the two pins, with a concurrent 1-cm anterior shift of the distal fragment. External compression clamps were assembled to the pins

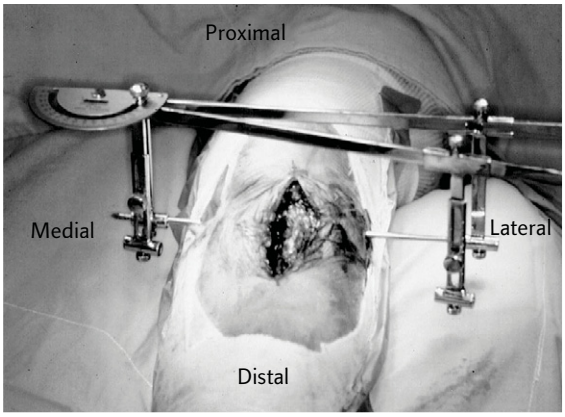

Figure 1. A Steinmann pin was set at the proximal tibial metaphysis, approximately 2 cm beneath and parallel to the joint surface. The jig was assembled on the pin; its goniometer was then set to the angle of correction as planned preoperatively. A second pin (not shown in this figure) was drilled along the distal arm.

to fix the reduced osteotomy, and the wounds were closed.

Patients resumed free motion of the knee joint immediately after surgery, as well as partial weight bearing on the operated leg with the aid of a walker. The compressive clamps were checked weekly and tightened as necessary until they were removed with the pins at 8 weeks, providing acceptable bone healing. Postoperative alignment of the knee was measured on a radiograph at this time.

All patients were reevaluated 5 years postoperatively to determine ROM, HSS knee score, Insall-Salvati Index, and knee alignment. During the subsequent follow-up, the osteotomy was considered to have failed if intractable pain with weight bearing on the operated knee necessitated conversion to prosthetic arthroplasty. A final evaluation was done before the conversion surgery or at the end of this study, with a mean follow-up period of 15 years (range, 13–16 years). Data were analyzed with Students' t test unless otherwise specified, with the significance level set at $p < 0.05$.

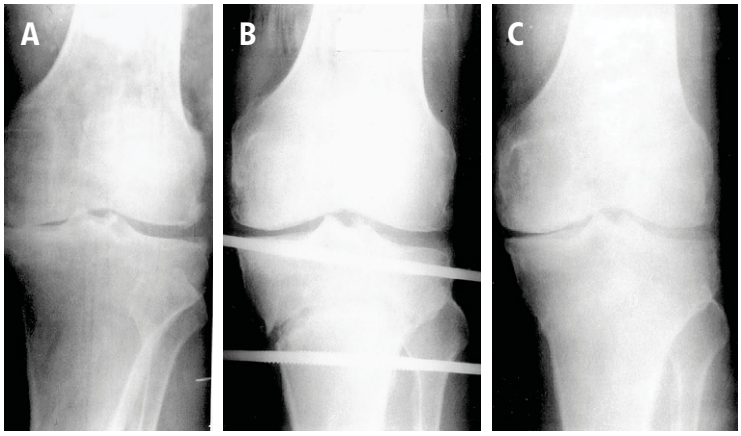

Figure 2. Radiographs of the medial compartment of the left knee of a 68-year-old osteoarthritic woman: (A) with 8° varus; (B) corrected to 7° valgus by the osteotomy and fixed with the external fixator, showing good bone healing, which enabled the patient to walk freely; and (C) at the follow-up 14 years postoperatively.

Results

During follow-up, two patients (2 knees) lost contact, three patients died, and one was unevaluable due to a stroke. The remaining 16 patients (19 knees) completed the study protocol, including five men (5 knees) and 11 women (14 knees). Immediate postoperative complications included loss of fixation in one knee, which required a repetition of surgery. No infection, peroneal nerve palsy, compartment syndrome, or thrombophlebitis was found. All osteotomies had united by 8 weeks. Generally, the medial joint spaces were preserved during the entire follow-up period (Figure 2).

All knees were varus preoperatively with a mean angle of 3.4°. The corrected alignment when the pins were removed was valgus with a mean angle of 12.4° (range, 0–20°). This angle decreased to 7.8° valgus at 5 years, showing a significant loss of correction with time. During follow-up, 12 knees (12 patients) had lost > 2° of correction at 5 years postoperatively, but their corrected alignment (mean, 11.8° valgus) was not significantly different from that of the other knees (mean, 13.3° valgus, $p = 0.51$). Osteotomy was regarded to have failed in three knees (2 patients) at 157, 163, and 168 months, respectively, and was converted to total knee arthroplasty. All of these three knees had had loss of correction > 2°.

Knee function also deteriorated with time. The mean HSS knee score was 68 ± 6 preoperatively, 88 ± 9 at 5 years postoperatively, and 84 ± 7 at the final evaluation. The scores were classified as excellent or good in 18 knees (15 patients) at 5 years postoperatively, and in 13 knees (12 patients) at the final evaluation, a significant decrease. Clinical outcome was not correlated with loss of correction: at 5 years postoperatively, the mean score

of the 12 knees with loss > 2° was not significantly different from that of the other knees ($p = 0.58$, Wilcoxon rank-sum test). The mean ROM was 124° preoperatively and 114° at the final evaluation, which was not a significant difference.

The Insall-Salvati Index was 0.88 ± 0.15 preoperatively, and 0.90 ± 0.19 at 5 years postoperatively. This difference was not significant, indicating limited alteration in the patellar position.

Discussion

Studies comparing the outcome of HTO with that of the modern unicompartment knee replacement show that osteotomy remains a valuable tool in current clinical practice,[21–23] with excellent or good results in 60–90% of cases.[5,6,17,24–27] The dome-shaped osteotomy was first introduced by Blaimont et al[28] and popularized by Maquet.[29] Our method was a modification of Maquet's method by using a new osteotomy jig and compression clamps.

The results of HTO tend to deteriorate with time,[30,31] as also seen in this study. Recurrence of the deformity is associated with the return of pain and a less satisfactory clinical outcome,[30] therefore, the degree of correction achieved is considered to be critical to successful follow-up results.[32–34] Overcorrection by 5° beyond normal valgus was advocated to make space for loss of correction.[12] However, this study did not find a good correlation between postoperative alignment and loss of correction, nor between loss of correction and clinical outcome. The latter finding is similar to Aglietti et al's observations.[35] An extraordinary valgus knee may have a deformed appearance, the anatomy is altered and the subsequent prosthetic arthroplasty is more difficult due to balancing problems.[36] Data from this study suggested that correction to the normal 7–9° valgus was most likely to provide a successful long-term result.

Accurate achievement of corrected alignment is important, yet is much dependent on the operative technique.[29,37–41] Various jigs have been designed,[40,42,43] but their accuracy has not been confirmed.[15] Some calibrated designs estimate angular correction by the distance of distraction at the osteotomy site, but require the use of intraoperative radiographs or fluoroscopy to ensure the accuracy.[44,45] Our calibrated osteotomy jig provided concise and direct control of alignment for HTO. The required amount of correction was determined on the preoperative radiograph and achieved using the goniometer during surgery. Similar to other methods of HTO, our method referred the angular deviation of the lower leg to the coronal plane determined by the proximal tibia. Nevertheless, the postoperative alignment between femur and tibia would be affected by the soft tissues connecting these two bones, i.e. across the knee joint, therefore, the postoperative result might differ from the preoperative anticipation and planning. In this study, we attempted to achieve a surgical outcome of 8° valgus, and the obtained postoperative alignment averaged 12.4° valgus.

The classic lateral closing-wedge osteotomy has been replaced by the medial opening-wedge hemicallotasis to reduce the risk of neurovascular complications.[14] However, this leads to the necessity of filling the osteotomy gap with bone graft or other synthetic material,[46,47] and the problems of fixation and union.[42] In cases where prolonged postoperative immobilization is necessary, patella baja may develop.[22,35] Dome-shaped osteotomy results in good contact of osseous surfaces after realignment, which facilitates bone healing. In our design, the pins set on the bone during the osteotomy were retained as part of an external fixator. After dismounting the jig, clamps were assembled onto the pins to apply compressive force to ensure rigid fixation and allow early joint motion.

The high rate of patella baja after HTO can make subsequent conversion to prosthetic arthroplasty difficult.[20,48,49] In wedge-shaped osteotomy proximal to the tibial tuberosity, the distance between the tuberosity and the joint line is changed because angular correction is achieved by linear displacement. The opening-wedge osteotomy brings the patella inferiorly; the closing-wedge

osteotomy shifts the tuberosity toward the joint line, creating a redundant patellar ligament that may contract by subsequent scarring of the surrounding tissue. Patella baja may, therefore, follow both alternatives of wedge osteotomy. The dome-shaped osteotomy removes a negligible amount of bone and results in rotation rather than linear displacement; therefore, it may minimize the distance change between the tibial tuberosity and the joint line, and avoid patella baja. Although a previous study using dome-shaped osteotomy, external fixator and early motion reported unavoidable shortening of the patellar tendon,[18] this did not develop in our patients.

Although it has largely been replaced by modern prosthetic arthroplasty, HTO is still valuable for selected patients who are ≤ 70 years old, are physically active, and consider artificial joint replacement less desirable. Its shortcomings such as postoperative complications and inadequate time-effectiveness can be overcome by proper modification of the surgical design. Dome-shaped osteotomy, in combination with external fixator and early joint motion, can provide a good clinical outcome.[17] Our instrument further simplified the surgical technique, carried a low complication rate, and provided durable results. Subsequent prosthetic arthroplasty, if needed, was not difficult in this series.

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