Articles & Publications

Distraction Osteogenesis for
Nonunion After High Tibial Osteotomy

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Abstract

The purpose of this study was to determine whether distraction osteogenesis can be used to treat hypertrophic nonunion associated with angular deformity and shortening after Coventry style high tibial osteotomy. Five consecutive patients were retrospectively reviewed. In all cases, the alignment had collapsed into excessive varus or valgus and leg length discrepancy was present. The leg length discrepancy, mal-alignment, and nonunion were treated simultaneously with distraction.

All cases resulted in union by the time of fixator removal, which averaged 4.4 months. Hospital for Special Surgery knee score significantly improved from 42 to 89. The mechanical axis deviation significantly improved by 5 cm. The coronal plane deformity significantly improved by 13°, and leg length discrepancy improved significantly from 2.3 cm to 0.5 cm. Metaphyseal bone stock increased by 43%, and the Insall-Salvati ratio increased from 1.1 to 1.2 and remained within normal limits. All patients were satisfied with the procedure, and none have had nor need a total knee replacement at an average followup of 4 years. Distraction osteogenesis of nonunion after high tibial osteotomy is a minimally invasive and successful procedure. It leads to bony union with correction of deformity and leg length discrepancy and prevents the need for total knee replacement at intermediate-term followup. The increase in metaphyseal bone stock may make future total knee replacement technically easier.

Introduction

Nonunion after high tibial osteotomy is uncommon. Coventry[4] reported no nonunions in a series of 213 osteotomies. Myrnerts[17] reported one nonunion in 78 proximal tibial osteotomies, an incidence of 1.3%, and Bauer et al[1] reported one nonunion in 66, a 1.5% incidence. Tjornstrand et al[26] reported 10 nonunions in 280 osteotomies, an incidence of 3.6%. In the English language orthopaedic literature, four reports address the treatment of this problem.[2,24,26,28] The numbers of patients in these reports are small, and the treatments variable. Tjornstrand et al[26] advocated open resection of the nonunion followed by Charnley external transfixation and casting in their report of 12 cases. Schatzker et al[24] supported closed compression of the nonunion with external fixation in their report of three cases. Wolff and Krackow[28] advocated open treatment with bone grafting and plating in their report of six cases. Cameron et al[2] reported the use of a double plating technique with bone grafting in their report of 10 cases. Most of these articles focus on the problem of

nonunion and address alignment secondarily. None address the issue of axial length, patella height, or metaphyseal bone stock, which are important considerations for future total knee replacement.[12,16,27]

Ilizarov[9,10] introduced a novel approach for treating hypertrophic nonunions using an external fixator to stimulate osteogenesis by distraction through the nonunion site. There have been four reports in the English language orthopaedic literature in which distraction osteogenesis has been used successfully to treat hypertrophic nonunions with deformity after trauma.[3,10,18,23]

Hypertrophic nonunions are well vascularized, but union is prevented by the lack of stability. The fibrocartilaginous tissue of a hypertrophic nonunion has osteogenic potential, which can be realized once the proper biomechanical environment is established. Contrary to popular belief, compression is not required for healing. When the torsion and shear forces are eliminated, distraction or compression forces applied to the site of the nonunion lead to new bone formation and healing of the nonunion. During this process, limb deformity and shortening can be corrected.[3] This concept of treatment was used in five patients with nonunion after high tibial osteotomy associated with deformity and shortening. This represents a series of cases dealing exclusively with a previously unreported technique of management of this uncommon but challenging problem. It is also the first study of nonunions after high tibial osteotomy to report on leg length discrepancy, in addition to bony union, angular deformity, and functional outcome.

Materials and Methods:
Five patients with nonunion and deformity following high tibial osteotomy were treated with distraction osteogenesis from 1994 to 1998. Four of the five patients were referred for treatment. One patient had the high tibial osteotomy performed at the authors' center. The average patient age was 46.6 years (range, 35-57 years), and the average interval from the index surgery to treatment was 8.4 months (range, 6-9.5 months). All procedures were done percutaneously with application of a circular external fixator or monolateral external fixator. In no case was the nonunion site opened nor was any bone grafting used. Four of the five patients had hardware from the initial high tibial osteotomy. In one patient, the proximal internal fixation screws were removed percutaneously. In a second patient, the hardware was removed through a lateral incision. The hardware was not removed in the other two patients since its presence was not felt to interfere with the planned surgery. The outcomes were evaluated by radiographic analysis and with the Hospital for Special Surgery knee score.

Radiographic analysis included preoperative and postoperative measurements of leg length discrepancy, mechanical axis deviation, medial proximal tibial angle, posterior proximal tibial angle[20] and Insall-Salvati ratios.[11] A point 1.5 cm lateral to the midline was chosen as the mechanical axis deviation goal to calculate the change in mechanical axis deviation and for statistical analysis. This was modified from the concept of Fujisawa et al.[6] Anatomic femorotibial angle was measured, and a goal of 10° of valgus was chosen to calculate the preoperative to postoperative change. This was based on the concept of Insall et al.[12] Additionally, the amount of metaphyseal bone stock was quantified. On the frontal plane radiograph, a direct measurement of the metaphysis was made from the medial tibial plateau joint line to a fixed point in the metaphysis distal to the osteotomy nonunion. The fixed point chosen was a visible landmark, such as a screw thread or hole. Magnification error was corrected to allow comparison of preoperative and postoperative radiographs. The metaphyseal bone stock percent change was calculated as follows:

Difference in metaphyseal height / preoperative metaphyseal height x 100

Clinical outcomes were evaluated with the Hospital for Special Surgery knee score.[21] This

evaluation included pain with walking and at rest, function related to walking, stair climbing, and transfers, knee range of motion (ROM), strength, deformity, and instability.

Statistical analysis was performed using the Student's paired t test.

Surgical Technique:
The Ilizarov device (Smith & Nephew Orthopaedics, Memphis, TN) was used in two patients. Multiple opposed 1.8mm olive wires were inserted into the proximal fragment under careful fluoroscopic control. The rings were assembled onto the wires. Care was taken to avoid placement of intraarticular wires by staying as close to the nonunion as possible. Contact with internal hardware was avoided to help prevent deep infection. The frame was then was assembled and hinges were placed on the bisector line of the center of angulation and rotation at the convex edge of the bone to induce an opening wedge correction.[20]

The Orthofix monolateral fixator (Orthofix Inc., Richardson, TX) was used in 3 patients. Two half-pins (6mm) were inserted into the proximal fragment from the medial side. Care was taken to avoid contact with internal hardware with careful insertion of a 1.8 mm guide wire. A 4.8mm cannulated drill was used to create the drill hole for the solid 6mm half pin. A T-clamp with a variable axis hinge distraction was used to distract the nonunion.

A fibula osteotomy was not performed. If the nonunion was stiff (less than 5° mobility), distraction was started immediately. Distraction rates were adjusted so that the fastest moving edge of the bone lengthened at 1mm per day. If the nonunion was partially mobile (5° to 20° of mobility), distraction was started after an initial period of compression of 1/2mm two times daily for one to two weeks. The bone formation was inspected on the radiograph, and the distraction rate was adjusted accordingly. Weight bearing as tolerated was allowed throughout the treatment.

Results:
The average followup was 4 years (range, 2-6 years). The average time in the external fixator was 4.4 months (range, 2.5-5.5 months). This represented time to bony union. The average knee ROM improved from 0° to 105° to 0° to 116°. The average preoperative leg length discrepancy was 2.3cm (range, 1.8-2.7cm). This improved to an average postoperative leg length discrepancy of 0.5cm (range, 0-1cm) (p = 0.0027). The average mechanical axis deviation improvement in four patients was 5.0cm (p = 0.007). Mechanical axis deviation measurements were not available in one patient.

The average tibial coronal plane deformity correction was 17° (range, 7°-22°). The anatomic femorotibial angle deformity changed from an average of 17.4° deformity (range, 5°-30°) to an average of 4.8° deformity (range, 1°-14°) (p = 0.0031)(Fig 1).

The average preoperative medial proximal tibial angle was 80° (range, 70°-103°). This improved to an average postoperative medial proximal tibial angle of 92° (range, 89°-93°)(Fig 2). In four of the five patients, the nonunion was malaligned in excessive varus with an average medial proximal tibial angle of 75° (range, 70° -83°) and ended treatment with an average medial proximal tibial angle of 91° (range, 89°-93°). In one patient, the nonunion was malaligned in excessive valgus with a medial proximal tibial angle of 103° and ended treatment with a medial proximal tibial angle of 93°. The normal range of the medial proximal tibial angle is 85° to 90°. The average preoperative and postoperative posterior proximal tibial angle was 89.5° and 84° respectively, indicating a correction of procurvatum deformity. The normal range of posterior proximal tibial angle is 77° to 84°.

Insall-Salvati ratio increased from 1.1 to 1.2 (p = 0.057) and remained within normal limits. The average percent increase in metaphyseal bone stock of the proximal tibia was 43% (range, 23%-

63%) (p = 0.00061). The average preoperative Hospital for Special Surgery knee score in four patients was 42 (range, 39-44). This improved to an average postoperative Hospital for Special Surgery knee score of 89 (range, 80-98) (p=0.00038). The Hospital for Special Surgery knee score was not available in one patient. All patients stated that they were satisfied with the procedure and would do it again. After an average followup of 4 years (range, 2 - 6 years), no patient had undergone total knee replacement, nor was total knee replacement planned for any of the patients.

Two patients had superficial pin tract infection develop that responded to oral antibiotics. One patient with pseudogout had a knee effusion develop 1 month after the application of the Orthofix external fixation device. The synovial cell count was 15,000 leukocytes and was positive for birefringent crystals. Synovial fluid cultures were negative for bacterial growth. The patient had an arthroscopic lavage. During this procedure there was a question of arthroscopic fluid egress through one of the proximal pin sites. For this reason, this proximal pin was removed and another one was inserted more distally. The remainder of the time in external fixation was without incident.

One patient had a change in the mechanical axis deviation and anatomic femorotibial angle with time. The mechanical axis deviation progressed from 3.3cm medial to 5.0cm medial and the anatomic femorotibial angle changed from 4° varus to 9° varus during a period of 2 years. The medial proximal tibial angle did not change, and the joint line obliquity angle changed from 0° to 4° varus (This progression of deformity does not reflect a change in the tibial deformity but rather progressive loss of medial compartment cartilage).

Associated factors included posterior horn medial meniscus tears in two patients diagnosed and treated with previous arthroscopy. One patient had had a knee arthrotomy 22 years before the high tibial osteotomy. Three of the five patients had noninsulin dependent diabetes mellitus.

Discussion

This study suggests that nonunion after high tibial osteotomy associated with deformity and shortening can be treated successfully with distraction osteogenesis. This treatment modality has several advantages over previous treatment modalities. Distraction osteogenesis using the Ilizarov method is a percutanous procedure with minimal blood loss. Nonunion takedown and hardware removal are not necessary. Distraction of the nonunion accomplishes simultaneous bony healing, correction of deformity, and lengthening.

The classic approach to nonunion surgery placed great emphasis on compression forces and rigid stabilization with plates or external fixation to achieve union.[7,14,22]

Catagni et al[3] published the first reported series of patients in whom distraction osteogenesis was the mode of treatment for hypertrophic nonunions. They reported 21 hypertrophic nonunions after trauma treated with distraction using the Ilizarov apparatus. Stable union was achieved in all their patients. Angular, axial, and translational deformities were corrected in all of their patients. Leg length discrepancy was corrected in 86% of their patients.

Saleh and Royston[23] presented a series of 10 hypertrophic nonunions after trauma in which bony alignment and length were restored and union induced by external fixation and callus distraction. The mean length increase was 3.5cm and the mean angular correction was 13.5°. There were no refractures or loss of correction or length.

Paley et al[18] included three cases of distraction of hypertrophic nonunions among 25 cases of tibial nonunions with bone loss. In another report, Paley et al[19] included three cases of distraction of hypertrophic nonunions among 29 cases of malunions and nonunions of the femur and tibia. They

characterized nonunions into stiff, partially mobile, and flail types. This technique was not recommended for flail nonunions which are usually atrophic and have greater than 20° mobility. Partially mobile nonunions have 5° to 20° mobility predominantly in one plane with a solid end point to manual stress and usually with some fixed deformity. These were treated with distraction after an initial period of compression. They recommended initial compression of 0.5 to 1.0mm per day for 2 weeks to stimulate osteogenesis followed by gradual distraction. They used compression combined with intermittent distraction at the same rate to stimulate bony consolidation. Stiff nonunions have less than 5° motion and were treated with distraction of the nonunion site at 1.0mm per day. The stiffness of a nonunion is an indirect reflection of the type of tissue between the ununited bone ends. Stiff nonunions have dense fibrocartilaginous tissue. Distraction of this tissue leads to new bone formation with the nonunion site acting as the fibrous interzone.

These studies revealed successful treatment of hypertrophic nonunions with distraction after trauma. Hypertrophic changes at a nonunion site show that callus-forming capacity and biologic healing potential are present. What is required in such cases is appropriate manipulation of the mechanical environment to induce the callus to mature and remodel. Reduction or abolition of shear forces, rather than compression, is needed for successful healing. This can be achieved with mechanically stable external fixation and bony realignment. Linear distraction can be continued to correct shortening and angular distraction may be used to correct angular deformity.[23]

Distraction treatment of hypertrophic nonunions offers a unique opportunity to observe the capacity for bone formation within the nonunion. Additional treatment then can be based on whether bone formation is observed. The appearance of callus confirms the bone healing capacity of the hypertrophic nonunion (Fig 3). Absence of callus formation suggests the need for bone grafting.

The broad surface area and adequate blood supply of the upper tibia provide favorable conditions for healing, and nonunion is uncommon.[26] Tjornstrand et al[26] presented the first series of nonunions after high tibial osteotomy. They advocated open resection of the pseudoarthrosis, bone grafting, Charnley transfixation compression and casting. Schatzker et al[24] reported three cases of nonunion where they did not resect the pseudarthrosis but did perform open bone grafting and applied a transfixation external fixator in compression. Wolff and Krackow[28] reported the results of internal fixation in the treatment of six cases of nonunion after proximal tibial osteotomy. They advised against resection of the pseudarthrosis site in order to preserve metaphyseal bone for future total knee replacement, and they routinely performed open bone grafting. Cameron et al[2] advocated the use of double plates bolted together. Limb alignment and leg length discrepancy were not emphasized in these studies.

Results of total knee replacement in patients after previous high tibial osteotomy have been reported to be less favorable than in patients who did not undergo osteotomy.[13,15,16,27] This has been related to previous skin incisions, patella baja, and bony considerations. Patella baja can lead to difficult soft tissue exposure and patellar eversion during total knee replacement. This could lead to the need for quadricepsplasty during total knee replacement. Multiple skin incisions can compromise skin vascularity and the soft tissue envelope of the knee. Bony abnormalities present after high tibial osteotomy may significantly reduce the bone available for resection during total knee replacement.

In none of the reports on nonunion after high tibial osteotomy, have the authors improved or even measured metaphyseal bone stock and patella baja. An increase in metaphyseal bone stock, and an improvement of patella baja by the Insall-Salvati ratio[11] was seen in the current study. Insall-Salvati ratio[11] increased but remained within normal limits in all patients in the current study. In four of the five patients, no additional incisions were made that would interfere with future arthroplasty.

Retained hardware was observed to deform as the bony deformity corrected ([Fig 4](#)). In one patient, percutaneous screw removal was performed. Routine hardware removal is not necessary. It is important to avoid contact between the external fixation pins and wires and the internal hardware to prevent deep infection. Although there is a theoretical increased risk of infection of total knee replacement in a knee that previously had an external fixator, the authors are unaware of any studies that would support this theory.

Another concern is septic knee arthritis from intraarticular placement of wires.[5,8,25] This is especially true in patients where in whom the proximal nonunion fragment is small. DeCoster et al[5] identified four zones of the knee. The capsule inserts 4 to 14mm below the articular surface in a regular pattern. The anterior half of the circumference is close to the joint line (less than 6mm). They recommended placement of wires and pins greater than 14mm from the subchondral line. If wire placement is needed closer to the joint, this can be done safely in the anterior half at least 6mm from the subchondral line. In the experience of the current authors, the incidence of knee sepsis after proximal tibia external fixation is rare in reconstructive cases. Even in situations of intrarticular wire placement, the synovium seals off rapidly creating a barrier to the knee. In acute trauma, where soft tissue injury and swelling are present, this mechanism may be less effective. Superficial pin tract infections are common and were seen in 2 of 5 patients in the current series. Patients were given an oral antibiotic prescription and instructed to take a one week dose if a pin infection developed. Patients were educated about recognizing a pin infection in order to avoid delay in treatment.

The issues that require consideration in the treatment of these nonunions are bony union, axial alignment, leg length discrepancy, and future total knee replacement. Bony union, restoration of normal axial alignment, correction of leg length discrepancy, increase in metaphyseal bone stock, improvement of patella baja, and improvement of functional outcome as measured with the Hospital for Special Surgery knee score were seen in all patients in the current study. At an average of 4 years followup, none of the patients has required total knee replacement. Distraction osteogenesis in the treatment of nonunion with deformity after high tibial osteotomy is a minimally invasive percutaneous procedure with a successful clinical and radiographic outcome. The nonunion site is not exposed surgically minimizing the risk of infection and no bone graft is required eliminating donor site morbidity. Future total knee replacement, if necessary, may be technically easier as a result of this procedure.

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Legend of Figures

Fig 1. The anatomic femorotibial angle change in five patients.

Fig 2. The medial proximal tibial angle change in five patients.

Fig 3A-D.
(A) Preoperative radiograph showing proximal tibia nonunion with valgus deformity.
(AA) Preoperative clinical picture.
(B) Seven week followup showing correction of deformity and distraction osteogenesis with Ilizarov frame.
(C) Five-month followup (2 weeks after frame removal) showing bony union, correction of deformity, and increased metaphyseal bone stock.
(D) Twenty-eight month postoperative radiograph showing bony remodeling of proximal tibia.
(DD) Clinical picture at twenty-eight months.

Fig 4A-D.
(A) Preoperative radiograph showing nonunion with varus deformity and retained hardware.
(B) Postoperative radiograph showing the application of an Orthofix monolateral frame.
(C) Three month followup showing distraction osteogenesis and correction of deformity. Deformation of the hardware and increased metaphyseal bone stock are evident.
(D) Four month followup showing bony union (day of frame removal).