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The advantages of circular external fixation used in high tibial osteotomy (average 6 years follow-up)

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Abstract We evaluated the midterm results of high tibial osteotomy in patients with medial compartment arthritis. This study included 53 patients treated with high tibial osteotomy accompanied by either internal fixation (group A, *n*=26) or Ilizarov-type external fixator (group B, *n*=27). Clinical assessment of patients was performed using Hospital of Special Surgery scoring. Radiography was based on orientation angles of the knee (medial proximal tibial angle, lateral distal femoral angle, posterior proximal tibial angle) and mechanic axis alignment test. We used the Insall-Salvati index to determine patellar height. The mean follow-up in group A was 77 months (range 63–118) and that in group B 72 months (range 61–113). The patients of group B demonstrated better results in terms of Hospital of Special Surgery score, alignment of lower extremity, and preventing of progression of arthritis. We believe that normal alignment and orientation of the knee could be precisely established with a circular external fixator, and that some disadvantages such as patella infera, failed correction, and loss of bone in proximal tibia as observed after classic high tibial osteotomy can be avoided. Furthermore, progression of arthritis can be prevented if the mechanical axis passes through the lateral compartment of the knee.

Keywords Arthritis · Osteotomy · High tibial · Circular fixator

Introduction

The original technique of high tibial osteotomy was first described by Jackson and Waugh [10] in 1961. Coventry et al. [4] later popularized it and presented longer term results on this method [4]. Maquet [13] described his dome osteotomy technique, and in 1992 Paley and Tetsworth [18] introduced new concepts into orthopedic surgery concerning the definition, detection, and treatment of femoral and tibial deformities. Paley et al. [19] then recommended a new method for the treatment of medial compartment arthritis. This dome osteotomy, with the concavity facing the knee joint, is performed below tibial tuberosity. Following osteotomy fixation can be achieved with an Ilizarov type circular external fixator [3, 22].

The purpose of this study was to assess the advantages of circular external fixation comparing to internal fixation utilized for high tibial osteotomy.

Patients and method

This study was carried out between January 1992 and December 1996 and included 53 patients (41 women, 12 men) with medial compartment arthritis. Group A consisted of 26 patients (median age 52.4, range 43–58) who underwent high tibial osteotomy with Coventry technique using internal fixation hardware: buttress plate in 7, Puddu plate in 3, Kirschner wires in 3, and staples in 13. To avoid some disadvantages of the Coventry technique we performed reverse dome osteotomy below the tuberositas tibia with circular external fixator. Group B consisted of 27 consecutive patients (median age 51.7, range 42–59) who underwent high tibial osteotomy

using Ilizarov-type circular external fixator. The same team (M.K., C.S., L.E.) performed surgery in group B.

The our basic criteria for high tibial osteotomy were pain, confined to medial compartment, sufficient muscle strength, no flexion contracture greater than 15°, good range of motion, and no instability [20]. All patients had unilateral involvement (36 left, 17 right). The patients were assessed by Hospital for Special Surgery (HSS) functional scoring, and their mechanical axis deviation of lower extremities and orientation were evaluated by the radiological criteria of Paley and Tetsworth [18]. In addition, The Insall-Salvati index was measured to evaluate pre- and postoperative patellar height. The degree of osteoarthritis was determined according to Ahlback's classification, and stages I, II, and III arthritis were detected in 14, 8, and 4 patients in group A; 12, 13, and 2 patients in group B, respectively. To confirm quality of lateral compartment cartilage diagnostic arthroscopy was performed before the osteotomy for all patients of group B. If a patient's cartilage had damage more than grade I [23], the patient was excluded from this study. Mean follow-up was 77 months (range 63–118) in group A and 72 months (61–113) in group B.

Differences in mean function and radiological measurements were evaluated statistically by Student's *t* test. *P* values less than 0.05 were accepted as statistically significant at a 95% confidence interval.

Preoperative planning

During pre- and postoperative examinations standing anteroposterior and lateral orthoroentgenographies of both hips, knees, and ankles were taken, and malalignment tests in the frontal and sagittal planes were drawn and measured. The fixator frame consists of three rings and is reconstructed preoperatively (Fig. 1). Since the center of rotation angulation (CORA) is at the level of the knee joint, the hinge is placed on the proximal side of the proximal ring at a juxtaarticular position. The two hinges are applied on one or two holes lateral to the central bolt to create an open-up osteotomy. The distraction rod (motor unit) is positioned medially at equal distances from the two hinges.

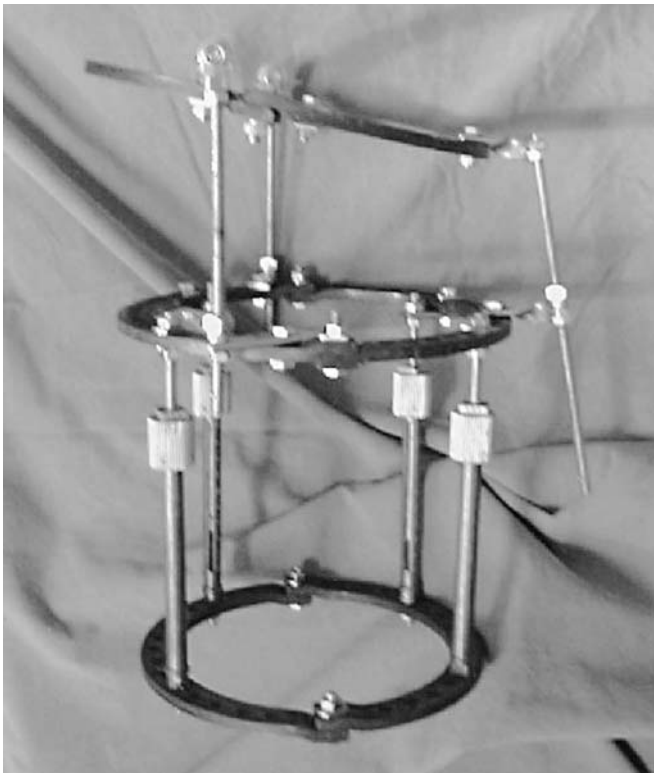

Fig. 1 The view of a prereconstructed frame

Technique

The patients of group A underwent high tibial osteotomy using the Coventry technique. In the patients of group B a middiaphyseal fibular osteotomy was initially performed. The first wire is inserted perpendicular to the mechanical axis of the tibia and fixed to the proximal ring. Afterwards, a second wire is inserted parallel to the ankle joint and fixed to the distal ring, thus the frame is fixed to the leg. At this stage the hinges must be fluoroscopically controlled to be at the level of the CORA. Then 6-mim Schanz pins are inserted through the proximal and middle rings. An olived wire is pierced through fibula and fixed to distal ring. Finally, a percutaneous, reverse dome shaped osteotomy is performed with the help of a template. The distraction rod and both hinges are removed before osteotomy. Lateral translation is achieved by reversing fragments in clock or anticlockwise direction with an osteotome. In this way the axis of both proximal and distal fragments align, hence preventing malrotation of the ankle. Afterwards the distraction rod and hinges are remounted. The fixed angle in the hinges are the same as the "x" angle determined preoperatively.

Results

The mean preoperative and postoperative proximal tibial angle (MPTA), lateral distal femoral angle (LDFA), and posterior proximal tibial angle (PPTA) are presented demonstrated in Table 1 for both groups (Fig. 2). While the mechanical axis passed through the medial compartment of the knee in all patients except 7 in group A, it passed through the lateral compartment of the knee in 22 patients, through the center in 3, and medially in only 2 in group B. The relationship between postoperative mechanical axis and arthritis according to Ahlback is presented Table 2 (Fig. 3). In addition, we observed that preoperatively diagnosed stage III arthrosis in four patients of group A and

Table 1 Functional and radiological mean values in groups A and B (*HSS* Hospital of Special Surgery score, *MPTA* proximal tibial angle, *LDFA* lateral distal femoral angle, *PPTA* posterior proximal tibial angle)

	Group A		Group B	
	Preop	Postop	Preop	Postop
HSS score (points)	73.4	85.6	72.1	91.2
MPTA (degrees)	80	83	82	90
LDFA (degrees)	90	90	88	88
PPTA (degrees)	80	77	80	81
MAD (mm)	30[a]	2[a]	32[a]	12[b]
Insall-Salvati index	0.9	0.8	1	1.1

[a]Medial
[b]Lateral

Fig. 2 **a** Preoperative radiographic view of a patient with severe varus. **b** Postoperative clinical view with maximal flexion after removal of frame. **c** Postoperative standing view after removal of frame. **d**, **e** Good realignment and no sign of arthritis after 88 months

two patients of group B progressed to stage IV during follow-up. These patients had a medial mechanical axis postoperatively.

We put in cast all patients of group A for 6 weeks. Full weight bearing was permitted after 3 months. None of the patients of group B needed an external brace postoperatively. Knee and ankle exercises were initiated on the first postoperative day. Partial weight bearing was permitted with the aid of a crutch on the third postoperative day. The Ilizarov external fixator was removed at a median of 3 months (range 2–4) postoperatively. All osteotomy were healed. Patients in group B were examined more often until osteotomy was healed (on average six times in group B, three in group A). On the other hand, the circular external fixator was more expensive than Kirschner wires, buttress plate, staples, and Puddu plate.

Temporary peroneal nerve palsy was observed in three patients of group A. Deep wound infection requiring débridement and antibiotherapy was detected in two patients and trombophlebitis in two. Thrombophlebitis occurred in 3 patients and pin tract infections in 11 patients of group B. All the complications healed without any sequelae by medical treatment. As a late complication, arthritis progressed to stage IV in four patients of group A and

Table 2 Relationship between postoperative mechanical axis and stage of arthritis according to Ahlback

	Stage I	Stage II	Stage III	Stage IV
Group A				
Lateral compartment	3	–	–	–
Center	2	2	–	–
Medial compartment	2	6	7	4
Group B				
Lateral compartment	22	–	–	–
Center	–	3	–	–
Medial compartment	–	–	–	2

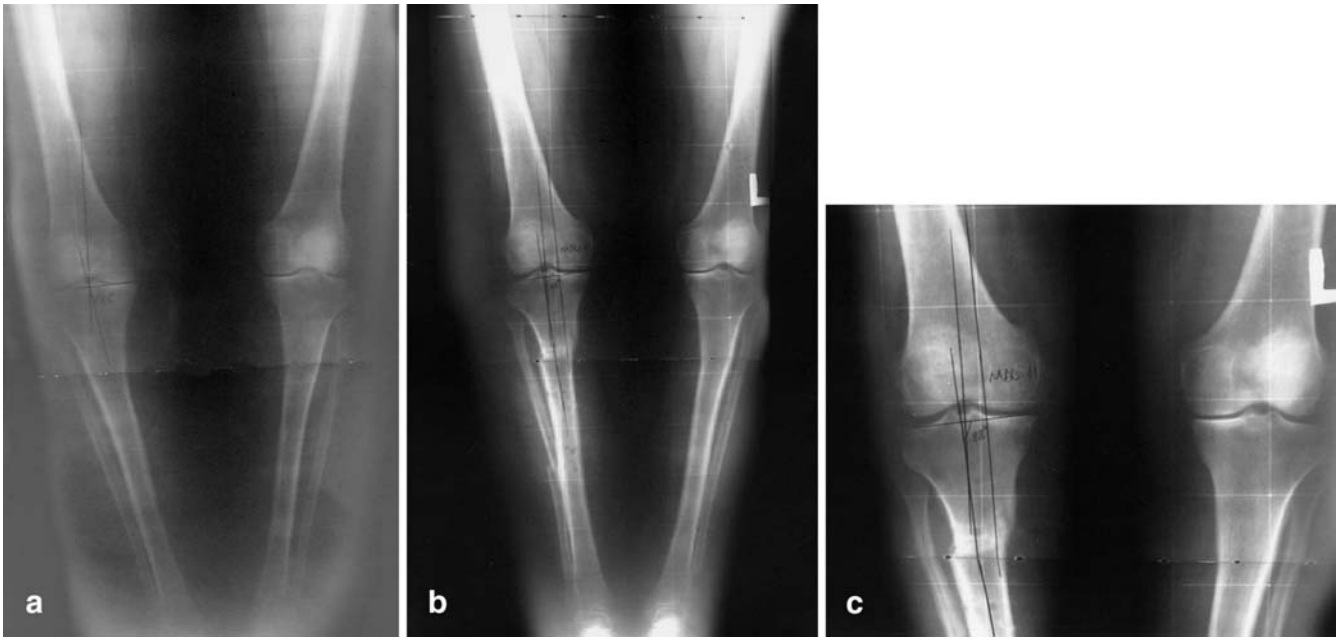

Fig. 3 **a** Preoperative radiographic view of a patient with severe loss of medial joint space. **b** Mechanical axis pass through 11 mm medially and normal MPTA. **c** Notice the widening of medial compartment and no sign arthritis after 84 months

in two patients of group B; these were managed by total knee replacement 5 years after their index operations due to increasing pain.

In contrast to functional results, MPTA and PPTA angles and mechanical axis were determined to be statistically different between groups A and B.

Discussion

Unlike inflammatory diseases, medial compartment arthrosis of the knee is thought to be caused primarily by a mechanical problem. Bony deformities of the tibia or femur and dynamic deformities resulting from lateral collateral ligament laxity may lead to malalignment and arthrosis [3, 19, 20, 22]. In preoperative radiographs of patients we detected malalignment in all cases. In group A the mean preoperative mechanical axis deviation was 30 mm medial, and mean MPTA, LDFA, and PPTA were 80°, 90°, 79°, respectively; while the mean preoperative mechanical axis deviation was 32 mm medial and mean MPTA, LDFA, and PPTA were 82°, 88°, and 81° in group B, respectively.

Two different techniques are utilized for high tibial osteotomy. The classic Coventry technique and high tibial osteotomy carried out with a circular external fixator. These two techniques have important biomechanical differences which may lead to functional and radiological results in the long term. In the classic Coventry technique the osteotomy is performed in form of a closing wedge above the tibial tuberosity [4]. It is still the most commonly preferred method due to its safety [2, 4, 16, 17, 20, 22]. However, complications such as loss of correction, paralysis of peroneal nerve, compartment syndrome, delayed union or nonunion, and intra-articular fractures are reported in 10–60% of cases [2, 8, 9, 13, 16, 19, 20, 28, 29]. Patella infera and patellofemoral malalignment may complicate a future total knee replacement. In addition, as a result of patellar eversion rotation of proximal fragment following osteotomies performed over tibial tuberosity, patellofemoral congruence can be deteriorated, and V-Y quadriceps plasty or osteotomy of tibial tuberosity may be required during the implantation of total knee prosthesis. On the other hand, removal of cancellous bone wedge may also lead to technical problems that can arise during a total knee replacement. Although some authors have stated that they observe no problems during total knee replacement in patients with previous Coventry osteotomies, obstacles in preparing the proximal tibia, the longevity of operation time, increase in bleeding, the requirement of bony graft or special type tibial component prosthesis, and technical difficulties regarding the extensor mechanism are to be accepted [7, 11, 14, 15, 19, 20, 21, 25, 26, 27, 28]. We found patella infera in 12 patients of group A and during knee replacement in 4 patients after Coventry osteotomy; we had to perform V-Y quadriceps plasty and Fulkerson osteotomy due to extensor apparatus problem. Therefore we agree that there is some difficulty during knee replacement after Coventry osteotomy. On the other hand, the Puddu plate technique is an alternative method using a medial open-up osteotomy, but currently there no long-term results are available.

After redefiniton of the concept of lower extremity deformities, Paley et al. [19] introduced a new understand-

ing of the role and technique of high tibial osteotomy in the treatment of medial compartment arthritis. According to this new concept, CORA, which is the apex of deformity in medial compartment arthritis, is localized at the level of the joint line. Therefore the osteotomy should be dome shaped, and the center must overlap with the CORA. Thus the desired amount of correction can be achieved by performing an osteotomy and a normal mechanical axis can be established without creating a second deformity [3, 19, 22]. In addition, erosion of tibial bony plateau, patella infera, and problems related to extensor mechanism do not occur. Nonunion has not been reported as a complication of this technique. In our series there was no patella infera or nonunion. Moreover, we experienced no difficulty during knee replacement in two patients 5 years after high tibial osteotomy performed with circular external fixator.

The Ilizarov circular external fixator has many advantages. The most important one is that precise correction may be adjusted during the postoperative period. Initiation of early weight bearing and range of motion exercises are other advantages. Overall elasticity of the fixator allows micromotions and facilitates union. The device can also correct additional deformities, such as procurvatum, recurvatum, and disproportional extremities [3, 19, 22]. In contrast, there are some disadvantages, including cost, more frequent clinical examination, less comfortable device, pin tract infection, and the need of more experienced hands to apply this fixator [3, 19, 21]. On the other hand, Dahl et al. [5] reported that there is a significant decrease in complications as experience is gained. Twenty-seven patients in our study were operated on by an osteotomy below the tibial tuberosity using an Ilizarov-type circular external fixator. Regarding clinical and radiological assessment we found a mean 12.2-point increase in HSS score and average corrections in mechanical axis and MPTA of 28 mm and 3°, respectively, in group A, while on clinical assessment a mean 19.1-point increase in HSS score was observed. In addition, on radiographic evaluation average corrections in mechanical axis and MPTA were 44 mm and 8°, respectively. HSS score, mechanical axis, and MPTA were significantly better in group B ($P<0.05$, Student's t test). Moreover, we encountered no instance of patella infera in the patients of group B. The better results and lower complication rate in group B may be related to our long experience with the Ilizarov technique, as we have been using this technique over 10 years.

Successful results obtained after treatment for varus gonarthrosis with high tibial osteotomy are time dependent. Many authors accept that success rates of 80 –90% in the first 5 years. After 10 years postoperatively nearly one-half of patients require a total knee prosthesis [4, 8, 9, 16, 20, 28, 29]. These studies emphasize the importance of careful patient selection and surgical technique [4, 8, 9, 16, 20, 28, 29]. Billings et al. [2] recommend an arthroscopic guided high tibial osteotomy, rigid internal fixation, and early ambulation, while Sugita et al. [24] stress the importance of healthy cartilage on lateral tibial compartment. The finding of intact articular cartilage of lateral compartment during diagnostic arthroscopy performed prior to the osteotomy was of paramount importance in group B. We detected a higher success rate in group A after 5 years, while we found no difference between early and late functional results in group B. We believe that this continuing success of function is related to the rigid fixation provided by the Ilizarov fixator, permitting an earlier ambulation, and weight bearing. In addition, maintenance of correction during the postoperative period with the aid of external fixator and the possibility of adjusting precise correction during follow-up examinations is a key factor enabled by the circular external fixator. Moreover, we believe that mechanical axis should pass through the lateral compartment after correction to obtain good results.

We determined the adequacy of the postoperative mechanical axis according to the criteria proposed by Fujisawa et al. [6]. This rating system divides the articular surface of the tibia virtually into 100 U in the horizontal plane; the ideal postoperative mechanical axis should pass through the lateral 30–40 points. Many authors believe that slight overcorrection into valgus position leads to long-term favorable results [2, 3, 8, 9, 17, 19, 20, 21, 28, 29]. In these publications 2–4° of valgus is accepted as efficient. In their investigation Coventry et al. [4] observed satisfactory outcomes in only 63% of patients with varus or neutral alignment, compared to satisfactory function levels as high as 94% in knees with mechanical axes in 4–6° valgus position. Many studies report that a few degrees of overcorrection during high tibial osteotomy can prevent arthrosis. Hernigou et al. [8] reported that satisfactory results were achieved in knees corrected to 3–6° valgus without any progression in arthrosis, while results were not satisfactory in knees with less than 3° valgus accompanied by progression of arthrosis. Majima et al. [12] concluded that overcorrection slows the progression of medial compartment arthrosis and has no harmful effect on the lateral compartment. Antonescu [1] performed 250 high tibial osteotomies and reported 152 cases with excellent and good outcomes after a follow-up of 8–15 years. In this group the arthrosis did not progressed in 105 cases (69%) with a postoperative valgus of 3–6°; in 47 cases (31%) with insufficient correction arthritis progressed.

In our series only three patients in group A achieved a valgus correction of 3–6° while in group B all patients except did so. In both groups arthrosis progressed in the patients who had insufficient valgus correction. Thereafter six of them underwent total knee replacement. Therefore we agree that mechanical axis should pass through the lateral compartment of the knee to obtain good outcomes for the future. Moreover, we believe that valgus correction positively affected functional results in group B as well.

In the treatment of medial compartment arthrosis the desired amount of correction can be precisely achieved with high tibial osteotomy by using an Ilizarov circular exter-

nal fixator in selective cases. Moreover, important complications observed in a classic osteotomy, such as depletion of bone stock, patella infera, and disorders of extensor mechanism, which can hazard a possible future total knee prosthesis, can be avoided. We concluded that this technique can be successfully applied in experienced hands for the treatment of varus gonarthrosis since it has a precise correction ability with a low complication rate.

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