Acta Orthop. Belg., 2009, **75**, 784-791

ORIGINAL STUDY

Ilizarov gradual correction of genu varum deformity in adults

Anis SHIHA, Mohamed ALAM EL-DEEN, Abdel Rahman KHALIFA, Mohamed KENAWEY

From, Sohag Faculty of Medicine, Sohag, Egypt

Valgus producing high tibial osteotomy (HTO) is an effective treatment option for medial compartment osteoarthrosis with varus deformity in young patients. The most common complications of conventional high tibial osteotomy techniques are related to accuracy of correction. Major angle correction of more than 15º with an osteotomy proximal to the tibial tuberosity may cause significant change in patellofemoral mechanics and patellar height. Valgus HTO was performed in 11 lower limbs of 9 patients with gradual correction of the varus deformity using an Ilizarov external fixator, with the osteotomy at the distal border of the tibial tuberosity. The mean age of the patients was 38.5 years. The average correction was 17°. They were followed up for an average of 25 months. The mean preoperative "Hospital for Special Surgery" (HSS) score was 68 and improved to a mean of 90 at follow-up. Nine limbs had excellent or good HSS scores. Disadvantages of this technique were mainly pin tract infection and poor patient acceptance and noncompliance.

Keywords : medial compartment osteoarthritis ; Ilizarov correction ; genu varum ; high tibial osteotomy.

INTRODUCTION

The concept of high tibial osteotomy (HTO) to treat unicompartmental osteoarthritis with varus or valgus deformity is credited to Jackson and Waugh (*19*). They described in 1961 a ball and socket tibial osteotomy just below the tibial tuberosity and osteotomy of the fibula at its middle third for correction of these deformities. Then came the popular Coventry technique, with a lateral closing wedge osteotomy proximal to the tibial tuberosity for treatment of varus gonarthrosis (*7*). This osteotomy was for many years the "knee jerk response" to medial compartment osteoarthrosis (MCOA) (*30*).

Maquet (*26*) described in1976 the barrel vault osteotomy above the tibial tuberosity. This dome osteotomy allowed some postoperative adjustability for the correction. Hernigou *et al* (*16*) described the medial opening wedge osteotomy proximal to the tibial tuberosity. Half closing half opening neutral wedge osteotomy proximal to the tibial tuberosity was also reported (*29*).

The common goal for all HTO techniques is to shift the mechanical axis of the knee from the medial to the lateral compartment. This will unload the medial compartment and redistribute stresses across

■ Anis Shiha, MD, Professor of Orthopaedic Surgery.
■ Mohamed Alam El-Deen, MD, Assistant professor of Orthopaedic Surgery.
■ Abdel Rahman Khalifa, MD, Lecturer of Orthopaedic Surgery.
■ Mohamed Kenawey, MSc, Assistant Lecturer of Orthopaedic Surgery.
Correspondence : Anis Shiha, Orthopaedic Department, Sohag Faculty of Medicine, 82524 Sohag, Egypt. E-mail : anis.shiha@yahoo.com

No benefits or funds were received in support of this study

the knee joint. The most favourable results are obtained with overcorrection into valgus alignment. However the amount of overcorrection is a matter of controversy. Many authors favor overcorrection of 3-6° as the optimal postoperative alignment (*16, 24,26*). Fujisawa *et al* (*11*) recommended that the mechanical axis should pass between 30-40% lateral to the center of tibial spines, a point which is called Fujisawa's point.

The main criticisms against conventional HTO techniques are the uncertain achievement of optimal correction, the effect of osteotomies proximal to the tibial tuberosities on the patellofemoral mechanics, and lastly difficulties with conversion of failed HTO into total knee replacement. We aimed in this study to present advantages and disadvantages of using Ilizarov gradual correction through percutaneous corticotomy distal to the tibial tuberosity in management of varus gonarthrosis.

PATIENTS AND METHODS

During the period from August 2005 to April 2008, 11 lower limbs of 9 patients had a medial opening wedge osteotomy distal to the tibial tuberosity and gradual correction of the genu varum deformity using Ilizarov's device. The mean age of the patients was 38.5 years (16-60 years). Six were males and three females. The mean weight was 78 kg (range : 60-90 kg). The average body mass index (BMI) was 29.8 (range : 22-37.8).

We used the "Hospital for Special Surgery" (HSS) knee scoring system (*18*) for the clinical evaluation of our patients pre- and postoperatively. Ahlbäck's radiographic grading system (*3*) was used to assess the grade of ostearthritis in the medial compartment. Our indications for surgery were either disabling medial compartment osteoarthritis (MCOA) in a patient of 60 years or younger who wishes to continue an active life style, or in a young adult who has disfiguring genu varum deformity without ostearthritic changes.

Preoperative planning was done using full length weight bearing radiographs. Varus stress radiographs were also obtained. For the magnitude of correction, the aim in patients with MCOA was to overcorrect the deformity till the mechanical axis passed through Fujisawa's point. In patients without evidence of MCOA, we planned to correct the deformity till the mechanical axis passed through the center of the knee joint (no overcorrection).

Operative technique

Patients were positioned supine on a standard radiotranslucent operating table. A tourniquet was applied to the thigh but was not inflated during assembly of the Ilizarov frame. Smooth Kirschner wires 1.8 mm in diameter were the only hardware used for frame application.

The first step was to drive a K-wire through the head of the fibula into the tibia parallel to the knee joint line. Rubber stoppers were put at each end of the wire. An Ilizarov ring of suitable diameter was then mounted to that K-wire and secured using two slotted bolts. The wire was tensioned to 110-130 kg using a dynamometer. A second wire was then advanced on the same ring with an angle of about 90º to the first wire and was mounted to the ring and tensioned in the usual way. Using two hinges and a threaded motor rod, a second Ilizarov ring was attached to the first one and then secured to the bone using two tensioned 1.8 mm K-wires. The angle between those two rings was equal to the magnitude of the planned correction. The hinges were adjusted to lie just opposite the lateral tibial border (one anterior and one posterior hinge) to allow for pure correction without lengthening. A third ring was attached to the second one using 4 threaded rods and was adjusted to be just proximal to the ankle joint and was secured to the bone using two tensioned 1.8 mm K-wires.

The tourniquet was then inflated. Through a 1.5-2 cm skin incision, an oblique osteotomy was done in the mid shaft of the fibula. Another small incision of 1.5-2 cm was made at the lower border of the tibial tuberosity. The periosteum of the tibia was incised and raised carefully. Multiple drill holes were made in the tibia with a 3.2 mm drill bit. Using a 10 mm osteotome, the medial and lateral cortices were osteotomised. The threaded rods were then disassembled from the first and second rings. The posterior tibial cortex was fractured indirectly by twisting the proximal two rings. The two rings were attached to each other again and a compression was applied to the corticotomy site to increase its stability. The periosteum was carefully sutured again and subcutaneous tissue and skin were closed in layers.

Postoperative management

Starting from the first postoperative day, patients were allowed weight bearing as tolerated on crutches with full range of motion of the knee and ankle. Straight leg raising and quadriceps strengthening and ankle dorsiflexors and plantar flexors strengthening exercises were

Fig. 1. — The postoperative correction phase.
i : Preoperative planning for the patient with full length standing radiograph.
ii : After 12 days of correction, the mechanical axis passing in the medial compartment.
iii : After 20 days of correction, the mechanical axis passing in the lateral compartment.
iv : Post removal full length weight bearing radiograph showing the new mechanical axis passing lateral to the center of the knee.

encouraged. Patients were discharged on the second postoperative day after careful instruction about daily pin site care.

Correction of the deformity was started gradually on the 7th postoperative day at a rate of 0.25 mm / 6 hours. Follow-up radiographs were obtained weekly during the correction phase. Fine tuning of the correction was achieved by adjusting the positions of the hinges and the motor. Near the end of correction, another full length weight bearing radiograph was ordered to assess the corrected mechanical axis and fine tuning of the correction was again checked with another full length standing radiograph. The construct was then left in place and follow-up radiographs were obtained monthly to follow the consolidation of the new regenerate. With radiographic consolidation, the construct was removed gradually by removing one K-wire from each ring every week. The last 3 K-wires (one on each ring) were removed at once. During this dynamisation, the patients were fully weight bearing on the extremity.

Another full length weight bearing radiograph was obtained following frame removal (fig 1). Vigorous physiotherapy was not usually needed, because patients had already maintained a good range of knee and ankle motion. They were followed up every 6 months for a year, then yearly.

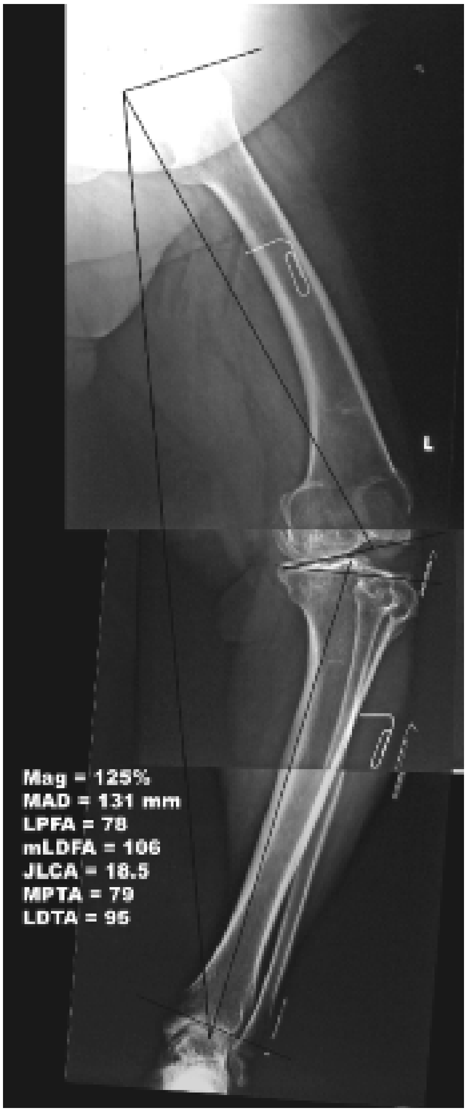

Fig. 2. — Case 4 in this study, the preoperative planning of the left lower limb showing JLCA of 18°.

Statistical Package for the Social Sciences (SPSS v. 9.0, SPSS Inc., Chicage, IL) was used for the statistical analysis. Mann-Whitney U test was used for comparison between HSS pre- and postoperative scores and statistically significant results were considered if p value was < 0.05.

RESULTS

The follow-up period ranged from 10 to 43 months (mean 25 months). The Ilizarov frame was removed at mean of 16 weeks (11-30 weeks). According to Ahlbäck's radiographic grading system, two patients had normal radiographic findings (3 limbs), 2 patients had grade I (narrowing of the joint space), 2 had grade II (obliteration), 2 patients (3 limbs) had grade III (minor attrition) and one had grade IV (major attrition) osteoarthritic changes in the medial compartment.

The average preoperative femorotibial angle FTA was 193° (range : 181-212°). One case (case 4) had hypochondroplasia and associated bilateral lateral collateral ligament laxity with a joint line convergence angles (JLCA) of 27° and 18° for the right and left sides respectively (fig 2). The left side of that patient was under corrected because of non-compliance and loss of follow-up for one month during the correction phase. A postoperative FTA angle of 192° was the result with postoperative JLCA of 16° and overall achieved correction of 18°.

The average postoperative FTA (excluding the patient who was undercorrected) was 171° i.e. 9° of anatomical valgus (165-175°). The magnitude of overall achieved correction ranged from 9° to 25° (mean 17°) (table I).

The mean preoperative HSS score of our patients was 68.2 (range 31-96). Postoperatively the average HSS knee score was 90.1 (67-100). The HSS score was excellent in 7 limbs, good in 2, fair in 1 limb and poor in 1 limb. Excellent or good results were present in 82% of cases and fair or poor results in 18%. HSS score improved by an average of 22 points (range : 4-51 points) and this improvement was statistically significant ($p = 0.01$) (table I).

All patients in this study maintained near full range of motion of the knee and ankle joint during frame application. The range of motion of the knee was not decreased in any patient at the latest follow-up. In case 4, who had the bilateral lateral collateral ligament laxity, preoperative knee flexion was 70 and 90° for the right and left sides respectively. This flexion range was improved to 130° for the right side but the left side had persistent flexion to 90° at the latest follow-up.

Complications in this series were mainly grade 1 pin tract infection (6 limbs) and grade 2 infection (3 limbs) (*31*). All of these pin site problems responded well to local pin site care and oral

Table I. — Patients in this study

Case	Age	Sex	BMI	Grade of OA*	Pre FTA	Post FTA	Pre HSS	Post HSS	Complications
1	23	F	25.7	0	189	175	96	100	G1 pin site infection
1	25	F	25.7	0	189	175	96	100	G1 pin site infection
2	55	F	35.2	2	186	173	60	92	G1 pin site infection
3	52	M	26.1	3	185	167	67	97	
4	43	M	37.8	3	212	172	31	82	G1 pin site infection
4	44	M	37.8	3	212	192	31	73	Undercorrected G1 pin site infection
5	16	M	33.3	1	197	172	96	100	G2 pin site infection
6	18	F	22.0	0	181	172	89	100	G1 pin site infection
7	60	M	24.7	4	189	173	54	67	G2 pin site infection
8	55	M	31.1	2	187	165	63	80	G2 pin site infection
9	32	M	28.4	1	192	167	67	100	

* Grade of osteoarthritic changes in the medial compartment according to Ahlbäck's system (*3*). BMI (Body Mass Index), FTA (Femorotibial Angle), HSS (Hospital for Special Surgery score), G1 (Grade 1) and G2 (Grade 2).

antibiotics. In no instance, did we have to remove or change a K-wire. There were no cases of deep infection or persistent discharge, or infection following frame removal. No cases had iatrogenic neurovascular injury or intra-operative complication.

DISCUSSION

Concerns regarding the conventional HTO techniques proximal to the tibial tuberosity fall mainly under one of three categories ; complications related to HTO, the known fact that the results of HTO deteriorate with time, and difficulties encountered with revision of failed HTO into successful total knee replacement (TKR) (*2,10,20,25,32*). The most frequent complications with HTO are undercorrection, loss of correction resulting in recurrence of varus deformity, and overcorrection (*4,16,17,23,24*). Undercorrection had been linked to the persistence (or early return) of symptoms. Overcorrection can lead to a poor cosmetic result, persistent pain, tilting of the joint line, and considerable loss of bone, a situation which is difficult to treat with another osteotomy or arthroplasty (*13,23*).

Accuracy of correction is therefore an important determinant for the postoperative results and the longevity of pain relief. The accuracy of correction is dependant mainly on the accuracy of preoperative planning and how we will implement that planning intraoperatively (*27*).

Preoperative planning may be a very difficult task in patients with severe lateral collateral ligament laxity and high joint line convergence angle (JLCA) and associated bony varus deformity. The presence of a high JLCA (as in case 4 in our study) makes the calculations for correction a very difficult task and may even be the cause for overcorrection (*8*). Furthermore, manual methods for preoperative planning in lower limb deformity may have significant intra-observer variability (*9,14,28*).

On the other hand, intra-operative assessment of the lower limb mechanical axis is always the most difficult step in tibial osteotomies. Many techniques were used to assess the correction intraoperatively such as visual inspection, cable method, or more recently navigation systems and computer assisted HTO techniques (*15,22,27,29*). Many authors recently described how the navigation can be beneficial in improving the results of HTO (*27*). Reported drawbacks of the navigated HTO techniques include longer operative time, problems related to implantation of the half pins for reference bases, as instability or intra-operative deformation reduces the accuracy or may even stop the navigation procedure, and pin tract infection or fracture through the tracts of the half pins (*15*). Additionally, all techniques of intra-operative assessment of the lower limb mechanical axis ignore the effect of weight bearing on the mechanical axis (*21*).

The effect on patellar height and tracking is also another concern with osteotomies proximal to the tibial tuberosity. Gaasbeek *et al* (*12*) recently emphasized the significant changes in patellar height and tracking, especially with large degrees of correction (more than 15º). They found significant increase in patellar height with closing wedge osteotomy and decrease with opening wedge osteotomy. Both, opening and closing wedge osteotomies led to significant changes in the patellar tracking parameters, tilt and rotation. These effects are more profound after medial opening wedge osteotomy.

Conflicting reports are present in the literature concerning the results of total knee replacement (TKR) done following failed proximal tibial osteotomy. Most authors (*20,23,25,32*) agree that converting failed HTO to TKR may be a technically demanding procedure. Difficulties with revision of failed HTO to TKR are mainly due to higher rates of preoperative limb malalignment, presence of patella infera, and instability. Periarticular scarring, proximal tibial bone deficiency and retained hardware cause difficulties in obtaining adequate exposure. Difficulties with patellar eversion are also encountered and may require tibial tubercle osteotomy.

In the current technique, three Ilizarov rings with 6 smooth 1.8 mm K-wires were the only hardware used for frame application. The gradual postoperative correction protocol, with assessment of the mechanical axis directly by standing full length radiographs results in high accuracy of correction. Correction is also achieved through a corticotomy made distal to the tibial tuberosity ; therefore no effect on the patellar height and tracking parameters is present. Lastly, percutaneous corticotomy and gradual correction following a latency period makes union an eventual expected event in all patients.

Seven patients had pin tract infection which was minimal and responded well to local pin site care and oral antibiotics. For patient satisfaction with the procedure, 9 limbs had an excellent and good postoperative HSS score in the latest follow-up. One patient had poor postoperative HSS score (67) and another patient with bilateral procedures had fair HSS score (73) in the second procedure for his left side. For the one poor result many factors contributed : the osteoarthritis was an Ahlbäck's grade IV with complaints of more than 9 years duration. Regarding the patient with a fair result, undercorrection was probably the cause of his fair HSS score.

Fears about revision to a successful arthroplasty are not present with this technique. The corticotomy is made percutaneously at the lower border of the tibial tubercle and so the area of the proximal part of the tibia is left virgin for a possible revision to TKR. No problems with patellar eversion, scarring, soft tissue balancing, and retained hardware are present.

Schwartsman (*33*) advocated the use of circular external fixation after percutaneous tibial osteotomy distal to the tibial tuberosity and gradual correction so that accurate adjustments can be made postoperatively on the basis of standing weight-bearing roentgenograms. He also cited as advantages, the ability to translate the distal fragment to restore mechanical alignment, improved stability of fixation, and immediate weight-bearing and knee motion of 0° to 90° in the circular frame. For frame application, he used only tensioned 1.8 mm K-wires and olive wires. The goal of treatment was achieved in all cases (30 osteotomies in 27 patients) except one patient with advanced degenerative changes who underwent uncomplicated revision to total knee replacement after 3 years.

Catagni (*5,6*) described a technique for HTO distal to the tibial tuberosity using Ilizarov's method with either acute or gradual correction of genu varum deformity. He concluded that the procedure is simple, safe and well tolerated by the patient and allows rapid return to weight bearing.

Adili *et al* (*1*) compared Ilizarov's method with an osteotomy distal to the tibial tuberosity and Coventry's lateral closing wedge technique in a matched pair of patients with varus gonarthrosis. Patients who underwent Ilizarov HTO had a significantly greater decrease in pain and increase in function at final follow-up.

Good results were similarly reported by Sen *et al* (*34*) when they compared two groups of patients, 26 patients with Coventry HTO technique and 27 patients with a percutaneous reversed dome osteotomy distal to the tibial tuberosity and acute correction using the Ilizarov device. Post-operatively, there was a statistically significant difference between the two groups regarding medial proximal tibial angle (MPTA) and mechanical axis deviation, with increased accuracy of correction in the Ilizarov group.

Reported disadvantages of this technique are mainly related to pin tract infection and pin loosening which may complicate later revision to total knee arthroplasty (*33*). This is not a problem if only 1.8 mm tensioned wires are used with a good surgical technique. We do not use 5 mm half pins in the proximal ring as described by Catagni *et al* (*5,6*), and Adili *et al* (*1*) or 6 mm Schanz screws as in the technique of Sen *et al* (*34*). Tensioned 1.8 mm wires cause minor pin tract infection which resolve rapidly after removal of the construct. Other disadvantages are poor patient acceptance of the bulky external fixator and the need for surgeons experienced in the application of this fixator (*1,33,34*).

In conclusion, Ilizarov HTO is an accurate and reliable technique for correction of genu varum deformity in adults. It is an important option in cases with severe genu varum deformities, where corrections of more than 15° are needed, in complex deformities in more than one plane and finally in cases with an associated severe lateral collateral ligament laxity. The reliability and accuracy of correction, controlled directly by long standing radiographs, is important prior to ligamentous reconstruction. We think, however, that this technique should be reserved for these strict indications, since patients' acceptance and compliance with the frame can be a problem.

REFERENCES

1. **Adili A, Bhandari M, Giffin R, Whately C, Kwok DC.** Valgus high tibial osteotomy. Comparison between an Ilizarov and a Coventry wedge technique for the treatment of medial compartment osteoarthritis of the knee. *Knee Surg Sports Traumatol Arthrosc* 2002 ; 10 : 169-176.
2. **Aglietti P, Buzzi R, Vena LM, Baldini A, Mondaini A.** High tibial valgus osteotomy for medial gonarthrosis : a 10- to 21-year study. *J Knee Surg* 2003 ; 16 : 21-26.
3. **Ahlback S.** Osteoarthrosis of the knee. A radiographic investigation. *Acta Radiol Diagn (Stockh*) 1968 : Suppl 277 : 7-72.
4. **Berman AT, Bosacco SJ, Kirshner S, Avolio A Jr.** Factors influencing long-term results in high tibial osteotomy. *Clin Orthop Relat Res* 1991 ; 272 : 192-198.
5. **Catagni M, Meyers L, Dellacqua D, Guerreschi F.** The role of external fixation in antivarus tibial osteotomy. *Operative Techniques in Sports Medicine* 2000 ; 8 : 39-43.
6. **Catagni MA, Guerreschi F, Ahmad TS, Cattaneo R.** Treatment of genu varum in medial compartment osteoarthritis of the knee using the Ilizarov method. *Orthop Clin North Am* 1994 ; 25 : 509-514.
7. **Coventry MB.** Osteotomy of the upper portion of the tibia for degenerative arthritis of the knee. a preliminary report. *J Bone Joint Surg* 1965 ; 47-A : 984-990.
8. **Dugdale TW, Noyes FR, Styer D.** Preoperative planning for high tibial osteotomy. The effect of lateral tibiofemoral separation and tibiofemoral length. *Clin Orthop Relat Res* 1992 ; 274 : 248-264.
9. **Feldman DS, Henderson ER, Levine HB *et al*.** Interobserver and intraobserver reliability in lower-limb deformity correction measurements. *J Pediatr Orthop* 2007 ; 27 : 204-208.
10. **Flecher X, Parratte S, Aubaniac JM, Argenson JN.** A 12-28-year followup study of closing wedge high tibial osteotomy. *Clin Orthop Relat Res* 2006 ; 452 : 91-96.
11. **Fujisawa Y, Masuhara K, Shiomi S.** The effect of high tibial osteotomy on osteoarthritis of the knee. An arthroscopic study of 54 knee joints. *Orthop Clin North Am* 1979 ; 10 : 585-608.
12. **Gaasbeek R, Welsing R, Barink M, Verdonschot N, van Kampen A.** The influence of open and closed high tibial osteotomy on dynamic patellar tracking : a biomechanical study. *Knee Surg Sports Traumatol Arthrosc* 2007 ; 15 : 978-984.
13. **Grelsamer RP.** Unicompartmental osteoarthrosis of the knee. *J Bone Joint Surg Am* 1995 ; 77 : 278-292.
14. **Hankemeier S, Gosling T, Richter M *et al*.** Computer-assisted analysis of lower limb geometry : higher intra-observer reliability compared to conventional method. *Comput Aided Surg* 2006 ; 11 : 81-86.
15. **Hankemeier S, Hufner T, Wang G *et al*.** Navigated open-wedge high tibial osteotomy : advantages and disadvantages compared to the conventional technique in a cadaver study. *Knee Surg Sports Traumatol Arthrosc* 2006 ; 14 : 917-921.
16. **Hernigou P, Medevielle D, Debeyre J, Goutallier D.** Proximal tibial osteotomy for osteoarthritis with varus deformity. A ten to thirteen-year follow-up study. *J Bone Joint Surg* 1987 ; 69-A : 332-354.
17. **Insall JN, Joseph DM, Msika C.** High tibial osteotomy for varus gonarthrosis. A long-term follow-up study. *J Bone Joint Surg* 1984 ; 66-A : 1040-1048.

18. **Insall JN, Ranawat CS, Aglietti P, Shine J.** A comparison of four models of total knee-replacement prostheses. *J Bone Joint Surg* 1976 ; 58-A : 754-765.
19. **Jackson JP, Waugh W.** Tibial osteotomy for osteoarthritis of the knee. *J Bone Joint Surg* 1961 ; 43-B : 746-751.
20. **Katz MM, Hungerford DS, Krackow KA, Lennox DW.** Results of total knee arthroplasty after failed proximal tibial osteotomy for osteoarthritis. *J Bone Joint Surg* 1987 ; 69-A : 225-233.
21. **Kendoff D, Board TN, Citak M *et al.*** Navigated lower limb axis measurements : influence of mechanical weight-bearing simulation. *J Orthop Res* 2008 ; 26 : 553-561.
22. **Kendoff D, Citak M, Pearle A *et al.*** Influence of lower limb rotation in navigated alignment analysis : implications for high tibial osteotomies. *Knee Surg Sports Traumatol Arthrosc* 2007 ; 15 : 1003-1008.
23. **Krackow KA, Holtgrewe JL.** Experience with a new technique for managing severely overcorrected valgus high tibial osteotomy at total knee arthroplasty. *Clin Orthop Relat Res* 1990 ; 258 : 213-24.
24. **Krempen JF, Silver RA.** Experience with the Maquet barrel-vault osteotomy. *Clin Orthop Relat Res* 1982 ; 168 : 86-96.
25. **Madan S, Ranjith RK, Fiddian NJ.** Total knee replacement following high tibial osteotomy. *Bull Hosp Jt Dis* 2002 ; 61 : 5-10.
26. **Maquet P.** Valgus osteotomy for osteoarthritis of the knee. *Clin Orthop Relat Res* 1976 ; 120 : 143-148.
27. **Maurer F, Wassmer G.** High tibial osteotomy : does navigation improve results ? *Orthopedics* 2006 ; 29 Suppl : 130-132.
28. **Myers TG, Fishman MK, McCarthy JJ, Davidson RS, Gaughan J.** Incidence of distal femoral and distal tibial deformities in infantile and adolescent Blount disease. *J Pediatr Orthop* 2005 ; 25 : 215-218.
29. **Nagi ON, Kumar S, Aggarwal S.** Combined lateral closing and medial opening-wedge high tibial osteotomy. *J Bone Joint Surg* 2007 ; 89-A : 542-549.
30. **Paley D.** *Principles of Deformity Correction*. 1st edition. Springer-Verlag, Heidelberg, 2002, pp 479-507.
31. **Paley D.** Problems, obstacles, and complications of limb lengthening by the Ilizarov technique. *Clin Orthop Relat Res* 1990 ; 250 : 81-104.
32. **Parvizi J, Hanssen AD, Spangehl MJ.** Total knee arthroplasty following proximal tibial osteotomy : risk factors for failure. *J Bone Joint Surg* 2004 ; 86-A : 474-479.
33. **Schwartsman V.** Circular external fixation in high tibial osteotomy. *Instr Course Lect* 1995 ; 44 : 469-474.
34. **Sen C, Kocaoglu M, Eralp L.** The advantages of circular external fixation used in high tibial osteotomy (average 6 years follow-up). *Knee Surg Sports Traumatol Arthrosc* 2003 ; 11 : 139-144.