Osteotomy around young deformed knees: 38-year super-long-term follow-up to detect osteoarthritis

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Received: 20 August 2009 / Revised: 31 August 2009 / Accepted: 31 August 2009 / Published online: 24 September 2009
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Abstract Since 1969 corrective osteotomy has been performed at our institute in young patients (under 40 years) with bowlegs, knock knees and flexion or rotational deformities around the knee. Fifty-seven knees (29 left, 28 right) of 45 patients (19 boys, 26 girls) were followed-up for a period ranging from 30 to 38 years in seven patients with seven knees, from 20 to 29 years in nine patients with 11 knees, and from ten to 19 years in 29 patients with 39 knees. Supracondylar femoral osteotomy was performed on 12 knees (11 patients), high tibial osteotomy above the tibial tuberosity on eight knees (six patients) and below the tuberosity on 37 knees (28 patients). At the final follow-up (age range 42–73 years), all of the deformities were satisfactorily corrected, with no symptoms apart from nine knees, seven of which had dull pain after strenuous sport with osteophytes, etc. in the radiograph. Total knee arthroplasty was performed in the remaining two knees, at ten and 26 years, respectively, after the initial osteotomy. Osteoarthritis developed in the contralateral knee to the initial osteotomy in two patients after 34 years at age 73 and after 33 years at age 67.

Introduction

Long-term follow-up studies have been reported by many institutes, mainly on high tibial osteotomy for osteoarthritis of the knee [1, 2, 5–8, 15, 18]. In spite of few previous

reports, the correction of deformities, especially for bowlegs or knock knees, has been one of the main topics in orthopaedic surgery over the last century. Japan is one of the countries where bowlegs are common as opposed to knock knees. Our previous study [13] suggested that earlier onset of walking might accelerate bowlegs. In our series at the age of 24 months, almost all the babies had bowlegs. Among them, 16 babies with 32 bowlegs with standing limb alignment of more than 15° anatomical varus angulation had started walking at age 10.7±1.0 months, while 13 babies with 26 bowlegs with anatomical varus angulation of less than 14° had started walking at the age of 11.8±1.4 months. The former group definitely had earlier onset of walking ($P<0.05$). It was concluded that in order to prevent bowlegs, parents should not encourage their babies to start walking too early. We report here the super-long-term follow-up of young patients with bowlegs or knock knees who had undergone osteotomy around the knee, which showed quite pleasing results.

Patients and methods

Patients

From 1969 to 1999, at Yokohama City University and its affiliated hospitals, 72 knees of 57 young patients under 40 years of age underwent osteotomy around the knee. There, during the same period, high tibial osteotomy was performed on 1,150 elderly osteoarthritic knees for reference.

The deformities in the young patients in this series included varus, valgus, and flexion deformities and tibial torsion with various aetiologies, including spontaneous bowlegs and knock knees, Blount disease, external tibial torsion, rickets, achondroplasia, Morquio syndrome, Turner syndrome, mal-

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united fractures, osteomyelitis and septic arthritis (Table 1). There were 31 knees of 27 male subjects and 41 knees of 30 female subjects with osteotomy at between six and 39 years of age with a mean of 18.8 ± 8.8 years. Twelve patients with 15 knee operations were not available for more than ten years follow-up (lost to follow-up). Thus, 57 knees (29 left, 28 right) of 45 patients (19 male, 26 female) were available for analysis. The follow-up period (mean 19.5 ± 9.1 years) ranged from 30 to 38 years in seven patients with seven knees, from 20 to 29 years in nine patients with 11 knees, and from ten to 19 years in 29 patients with 39 knees.

Symptoms and abnormal findings of the patients were recorded before osteotomy and on a yearly basis initially and then every four to five years thereafter by direct follow-up examination. The preoperative findings were compared with the postoperative results at the final follow-up.

Operative techniques

Corrective osteotomy around the knee in young patients with various deformities as described above included varus–valgus or derotation type among others. The osteotomy site was the supracondylar region of the femur or above or just below the tibial tuberosity.

Supracondylar femoral osteotomy (SCFO)

In the anterolateral region of the knee, an 8-cm longitudinal skin incision was made from the anterolateral portion of the distal thigh to a point 2 cm lateral to the lateral margin of the patella. Then, the rectus and the vastus lateralis were separated and the periosteum was divided (and elevated) longitudinally, and a laterally-based wedge was marked out for correction of varus deformity (or a medially-based wedge for correction of valgus deformity) 4 cm above a $\phi 3$ mm Kirschner wire inserted 3 cm above the joint line. Osteotomy was performed

by removal of the wedge, and the fragments were fixed with a blade plate (Fig. 1).

Osteotomy above tibial tuberosity, closing wedge (high tibial osteotomy, HTO)

After fibular osteotomy, valgus osteotomy was performed above the tibial tuberosity, with removal of a laterally-based wedge in all cases, aiming for postoperative anatomical valgus angulation of $6-7^\circ$ (varus osteotomy was performed with removal of a medially-based wedge without fibular osteotomy, aiming at anatomical valgus angulation of 4°). The detailed surgical techniques are described in previous reports [3, 10, 12, 14, 15]. The fragments were fixed with Kirschner wires (K-wires) and Charnley's external fixation clamps [10] or with a Koshino blade plate [12] (Fig. 2) or application of a long leg cylinder cast.

Dual plating techniques [12, 15] using a blade plate on the lateral side and a plate on the medial side for fixation of high tibial fragments were employed in some cases. A laterally-based wedge was marked out 22–25 mm below a K-wire inserted along the tibial plateau using a special guide, after segmental resection from the mid-shaft of the fibula and exposure of the anterior part of the knee. Osteotomy was performed, and before completion of osteotomy the blade plate was carefully inserted into Gerdy's tubercle along the K-wire. Osteotomy was completed, and a laterally based wedge was removed. In cases with more than 20° correction, a hemi open wedge was resected (Fig. 2).

Osteotomy below tibial tuberosity (LTO)

This osteotomy was performed in growing children to avoid damaging the growth zone of the upper tibia. Osteotomy was performed just below the tibial tuberosity with removal

Table 1 Osteotomised knee deformities and diseases

Disorders	Number of patients	Boys (knees)	Girls (knees)	Number of knees
Bow legs, primary	14	6 (8)	8 (11)	19
Knock knees, primary	4	1 (1)	3 (3)	4
Blount's disease	4	3 (4)	1 (1)	5
Genu recurvatum	2	0 (0)	2 (2)	2
External tibial torsion	6	3 (3)	3 (6)	9
Rickets	5	1 (2)	4 (7)	9
Achondroplasia	1	0 (0)	1 (2)	2
Morquio syndrome	1	0 (0)	1 (1)	1
Turner syndrome	1	0 (0)	1 (2)	2
Malunited fractures	12	9 (9)	3 (3)	12
Osteomyelitis, septic knee arthritis	7	4 (4)	3 (3)	7
Total	57	27 (31)	30 (41)	72

Fig. 1 Malunited supracondylar fracture of right femur with varus angulation (a). This female patient sustained this fracture at age 25 years. Supracondylar osteotomy of the femur was performed with resection of a medially-based wedge and fixation using an L-shaped blade plate from the lateral side at age 34 years (b). The patient has had no symptoms and no problems. At age 67 years, 33 years after the initial osteotomy, recent final follow-up revealed no pain in the right knee with range of motion from 0° extension to 145° flexion, though osteosclerosis was observed around the lateral femoro-tibial articulation with a femoro-tibial angle of 165° (15° anatomical valgus angulation) in the standing radiograph (c). However, she developed painful osteoarthritis in her left knee with obliteration of the medial joint space and varus deformity in the standing radiograph (d)

of a laterally-based wedge for correction of varus deformity (Fig. 3) (or a medially-based wedge for correction of valgus deformity) to achieve postoperative anatomical valgus angulation of 6–7°. Derotation osteotomy was performed in the horizontal plane with rotation of the distal fragment. The fragments were fixed with either a blade plate, a plate and crossing K-wire fixation (Fig. 4b,d) together with a plaster of Paris splint, K-wires and Charnley's external fixation clamps or a cylinder cast. Before valgus or derotation osteotomy segmental resection of the fibular shaft was performed.

Limb alignment and radiography

Limb alignment was expressed as the standing femoro-tibial angle (FTA) [3, 10, 11], which is the lateral angle between the femoral axis and the tibial axis (around their intersection) measured on an anteroposterior radiograph taken with the patient standing on one leg at a time.

For knees with angulation in the long bone, such as femur varum or tibial vara, the deviation of the mechanical axis from the knee centre was evaluated. A long antero-posterior radiograph of the whole lower extremity was taken with the patient standing on one

Fig. 2 Varus deformity after osteomyelitis of left femur at age 2 years (a). Hemi-open wedge high tibial osteotomy was performed and the fragments were fixed with a Koshino blade plate laterally, together with segmental resection of the fibular shaft (b) at age 28 years. The resected fibular shaft was cut longitudinally and embedded into the medial opening space of the osteotomy (b). The patient has had no symptoms or problems. Recent final follow-up revealed no pain in the left knee, with range of knee motion from 0° extension to 120° flexion. The standing radiograph taken at age 59 years, 31 years after the initial osteotomy, showed satisfactory limb alignment with a femoro-tibial angle of 171° (9° anatomical valgus angulation) (c). As for hemi-open wedge high tibial osteotomy, the horizontal line of osteotomy was marked out 20 mm below the joint line, from the mid point of which a small laterally-based wedge was marked out laterally. After removal of the wedge the lateral side of the osteotomy site was closed and bone grafts were embedded into the medial opened space (d)

Fig. 3 Varus deformity of left knee due to rickets with standing femoro-tibial angle of 194° (14° anatomical varus angulation) in a 21-year-old woman (**a**). Tibial osteotomy was performed to remove a 24° laterally-based wedge just below the tibial tuberosity and the fragments were fixed with crossed Kirschner wires and a long leg plaster splint. The K-wires were drawn out one by one every week from 3 weeks after osteotomy and a long leg cylinder cast was applied. The standing radiograph one year after osteotomy showed a femoro-tibial angle of 170° (10° of anatomical valgus angulation) (**b**). The patient has been doing well with no problems. Recent final follow-up at age 59 years, 38 years after the initial osteotomy, revealed no pain in the left knee with full range of motion and the standing radiograph showed a femoro-tibial angle of 170° (**c**)

leg at a time, and the mechanical axis was drawn and its deviation from the centre of the knee was measured. The femoro-tibial angle can be calculated from the regression line of correlation ($Y=0.364X-62.50$) as shown in Figure 9 of a previous report [10] (Y =rate of deviation: $(D/L) \times 100$, X =FTA; D =distance from centre of knee to mechanical axis of lower extremity, L =length of mechanical axis from centre of hip to centre of ankle. The patellar axial view (sky line view) was taken in 30° , 60° and 90° of knee flexion for evaluation of patellofemoral articulation.

Statistical analysis

Paired t-test was used to compare the preoperative and postoperative clinical scores and range of movement. In all analyses, p -values of less than 0.05 were considered significant. Kaplan-Meier life survival curves with corresponding 95% confidence intervals for all the patients who died before ten years follow-up were horizontal because no death occurred in this series. Kaplan-Meier survival curves with corresponding 95% confidence intervals were calculated, with failure defined according to two end points: (1) revision either by total knee arthroplasty (two knees in this series) or by unicompartamental arthroplasty (no knees in this series) and (2) more than moderate pain persisting at the final follow-up at ten years or more after osteotomy (no knees in this series).

Results

Bowlegs

There were 36 knees (18 left, 18 right) of 29 patients (11 male, 18 female) with bowlegs. The age at osteotomy ranged from 8 to 39 years with a mean of 21.9 ± 8.9 years. Supracondylar femoral osteotomy was performed on six knees of six patients, four with bowlegs due to malunion of fractures and two with bowlegs after osteomyelitis. High tibial osteotomy (HTO) was performed on six knees of five patients (primary bowlegs in one knee of one patient, rickets in three of two, osteomyelitis of the distal femur in one of one, and malunion of tibial fracture in one of one). Osteotomy below the tibial tuberosity (LTO) was performed

Fig. 4 Severe varus deformity of left knee due to Blount's disease (**a**). The preoperative standing radiograph showed depression of the medial proximal epiphysis of the tibia with a femoro-tibial angle of 201° (21° anatomical varus angulation). Trans-epiphyseal opening wedge osteotomy together with hemi-open wedge osteotomy in the region below the tibial tuberosity was performed at age 8 years, the fragments of which were fixed with oblique Kirschner wires and a hook plate laterally (**b**). The postoperative standing radiograph 1 year after the initial osteotomies showed a femoro-tibial angle of 169° (11° anatomical valgus angulation). As for trans-epiphyseal opening wedge osteotomy, transverse osteotomy was performed at a level 1 cm below the medial epiphyseal plate and extended upward vertically around the central portion of the metaphysis through the epiphyseal line (**d**). Bone grafts were embedded into the opened osteotomised space. The fragments were fixed with obliquely inserted Kirschner wires

on the remaining 24 knees of 18 patients. In this group, in one knee with Blount's disease, trans-epiphyseal osteotomy of the medial tibial condyle together with LTO was performed (Fig. 4) and in the other LTO was done. The other three knees, however, could not be followed-up for more than ten years: Stören's epiphyseal osteotomy was performed in two and LTO in one. Further, in this group, in one patient with rickets, the right knee received LTO and the left HTO. The follow-up period ranged from 120 to 456 months with a mean and standard deviation of 226.8 ± 96.9 months.

The preoperative arc of motion (AOM) (maximum angle of flexion minus degree of flexion contracture) ranged from 20° to 160° with a mean of $132.8^\circ \pm 32.5^\circ$, which was greatly improved to 70 – 160° with a mean of $141.1^\circ \pm 21.5^\circ$ at the final follow-up. The preoperative range of knee motion was poor in most of the knees with malunited fractures and those with osteomyelitis or pyogenic arthritis. The Hospital for Special Surgery knee score (HSS score) [16] ranged from 57 to 100 with a mean of 94.5 ± 15.5 preoperatively and from 84 to 100 with a mean of 96.1 ± 6.6 at the final follow-up. The low scores, especially before osteotomy, were mainly due to poor range of motion. The limb alignment was preoperatively varus angulation with standing femorotibial angle (FTA) ranging from 179° to 210° (1° valgus to 30° anatomical varus angulation) with a mean of $188.8^\circ \pm 7.3^\circ$ (18.8 anatomical varus angulation) which was corrected to valgus ranging from 162° to 179° (1 – 18° anatomical valgus angulation) with a mean of $171.5^\circ \pm 5.3^\circ$ (8.5° anatomical valgus angulation) at the final follow-up.

Knock knees

There were 12 knees (seven left, five right) of ten patients (five male, five female) with valgus angulation of the knee. The age at osteotomy ranged from six to 39 years with a mean of 16.6 ± 8.8 years. Supracondylar femoral osteotomy was performed on six knees of five patients, one knee of which was associated with congenital dislocation of the patella and the other by subluxation of the patella. Tibial osteotomy just below the tuberosity was performed on the remaining six knees of five patients, in which the aetiology was rickets in two knees (one patient), Morquio syndrome in one knee, malunion of tibial fractures in two knees (two patients) and pyogenic arthritis in one knee. The follow-up period ranged from 120 to 420 months with a mean of 170.1 ± 96.1 months. AOM ranged from 125° to 160° with a mean of $142.5^\circ \pm 12.0^\circ$ preoperatively and from 130° to 160° with a mean of $148.2^\circ \pm 6.4^\circ$ at the final follow-up. HSS score ranged from 68 to 100 with a mean of 99.0 ± 12.6 preoperatively and from 89 to 100 with mean of 99.4 ± 4.9 at the final follow-up. The preoperative knee score of

68 was in a patient with Morquio syndrome. As for the limb alignment, standing FTA ranged from 147° to 164° (16 – 33° anatomical valgus angulation) with a mean of $156.9^\circ \pm 7.3^\circ$ (23.1° anatomical valgus angulation) preoperatively, which was greatly improved, ranging from 165° to 179° (1 – 15° anatomical valgus angulation) with a mean of $173.9^\circ \pm 5.2^\circ$ (6.1° anatomical valgus angulation) at the final follow-up.

Rotational deformity of knee (leg): external tibial torsion

There were nine knees (four left, five right) of six patients (three male, three female) with externally rotated legs with no symptoms or varus or valgus angulation deformity. The age at osteotomy ranged from eight to 27 years with a mean of 13.7 ± 8.0 years. Tibial osteotomy just below the tuberosity was performed on seven knees of five patients with derotation ranging from 20° to 70° . High tibial osteotomy with 20° derotation was performed on the remaining two knees of a woman (27 years of age). All of the cases were primary, with no cases of fracture malunion. The follow-up period ranged from 120 to 204 months with a mean of 142.7 ± 31.3 months. AOM ranged from 150° to 155° with a mean of $151.7^\circ \pm 2.5^\circ$ preoperatively and from 150° to 155° with a mean of $152.8^\circ \pm 2.6^\circ$ at the final follow-up. Knee score evaluation was not done in this group, since the patients had only external rotational deformity in the legs. In all of them, rotational deformities were well corrected within 15° of external rotation with no symptoms or varus or valgus angulation deformity at the final follow-up.

Complications and patient satisfaction

Postoperative complications rarely occurred; four knees were associated with temporary peroneal palsy which was milder than that reported in the literature [9] and one knee with infection. These complications were treated conservatively with no influence on the final clinical results. There was no case of delayed union of the osteotomy site. Three of four knees with temporary peroneal palsy had correction of valgus angulation and one correction of varus, all of which had osteotomy just below the tibial tuberosity. At the final follow-up, the patients were satisfied with the results of osteotomy in 54 knees (95% of the operated knees). Two patients with three knees answered "unknown" despite a knee score of 100 points. One of these patients mentioned that she had expected the surgical procedures to have been much simpler.

Onset of osteoarthritis at super-long-term follow-up

In two of 57 knees, osteotomy was not definitive one was a 25-year-old woman with varus deformed knee due to

pyogenic arthritis in whom total knee replacement (TKR) was performed at the age of 52 years, 27 years after tibial osteotomy just below the tuberosity, and the other was a 39-year-old woman with a valgus deformed knee due to Morquio syndrome in whom TKR was performed at the age of 49 years, ten years after supracondylar femoral osteotomy. Both knees developed late onset of osteoarthritis because of the initial deformities of the articular surface at the distal end of the femur and in the proximal end of the tibia.

At the final follow-up, seven knees had dull pain after strenuous sport and showed osteophytes in at least one of three compartments (medial and lateral femoro-tibial articulation and patello-femoral articulation) in radiographs (grade 1 in Table 2), in patients whose age ranged from 42 to 71 years at the final follow-up. The other eight knees had no pain or no abnormal clinical findings in spite of at least one compartment with radiographic abnormalities. The remaining 40 knees showed no clinical symptoms nor radiographic abnormalities.

Onset of osteoarthritis in contralateral knee to side of initial osteotomy

It was a quite interesting discovery that in two cases, ordinary osteoarthritis with pain and radiographic osteoarthritic abnormalities were found in the other knee opposite to the initial osteotomy side, which had been completely normal at the time of initial osteotomy. In these cases, one underwent osteotomy at the age of 39 years and final follow-up was 34 years later at the age of 73 years with definite painful osteoarthritis on the contralateral side; the other one (Fig. 1) similarly underwent osteotomy at age 34 years, and final follow-up was 33 years later at age 67 years.

Table 2 Radiographic grading for osteoarthritic knees in a standing position^a (Koshino [15])

Grade	Description
0	Normal
1	Bone sclerosis or osteophyte formation
2	Narrowing of joint space (≤ 3 mm)
3	Obliteration of joint space or subluxation ^b
4	Defect of tibial plateau (< 5 mm)
5	Defect of tibial plateau (≥ 5 mm)

^a An anteroposterior radiograph taken in a standing position was used for grading

^b “Subluxation” indicates the condition in which the medial edge of the medial tibial plateau shows a lateral shift by more than 5 mm against the medial edge of the articular surface of the medial femoral condyle without including osteophyte

Discussion

Correction of varus or valgus angulation around knee in young patients

Osteotomy for bowlegs or knock knees is not the same as high tibial osteotomy for osteoarthritis of the knee. In order to obtain a straight appearance of the lower extremity, the ideal postoperative limb alignment is 6–7° anatomical valgus angulation (173–174° femoro-tibial angle) or the mechanical axis of the lower extremity should pass through a point about 5–10 mm medial to the knee centre, in contrast to that of high tibial osteotomy for knee osteoarthritis which should be 10–11° valgus angulation (169–170° femoro-tibial angle) or so that the axis passes through a point about 10 mm lateral to the knee center [10, 15].

In young subjects, in the super-long-term follow-up results of this series, there was no loss of correction of postoperative limb alignment, and in one case the initial postoperative valgus alignment had been well maintained at 170° even 38 years after osteotomy (Fig. 3b,c). In the elderly, however, with knee osteoarthritis, osteoporosis and degeneration of articulation of the knee joint may cause loss of correction or recurrence of deformity.

Loss of adequate limb alignment may occur in three ways [15]. First, inadequate osteotomy may result in under-corrected alignment. Second, in the case of correction of varus deformity limb alignment may change gradually during the postoperative period because of poor internal (and/or external) fixation. Finally, varus angulation or a tendency to varus may take place even after bone union [4, 6] because of insufficient initial valgus correction of varus deformity and recurrence of degeneration under excessive load bearing.

Billings et al. [4] reported $9.2^\circ \pm 3.69^\circ$ of valgus at six weeks after high tibial osteotomy with rigid fixation, which had changed to $7.4^\circ \pm 4.94^\circ$ of valgus angulation at an average of 8.5 years after osteotomy. Loss of correction, as reported by Stuart et al. [17], should be avoided in order to maintain the best long-term results.

In young patients, bone union is favourable and the bone and surrounding supporting tissues are strong enough to maintain the alignment in addition to no degeneration in the bone and cartilage. As seen in this series, the initial postoperative limb alignment was well maintained in the super-long-term, even with 6–7° anatomical valgus angulation on standing.

Rare development of osteoarthritis in spite of super-long-term postoperative course

In this series, super-long-term follow-up failed to detect ordinary osteoarthritis of the knee, that is, a knee with pain

and osteoarthritic abnormalities in the radiograph, even in subjects aged more than 60 years at the final follow-up. Two particular knees in this series ended in total knee replacement a long time after osteotomy. However, these two cases initially had irregularities and deformities of the articular surfaces because one had varus deformity after pyogenic arthritis and the other had valgus deformity due to Morquio syndrome. Therefore, in these cases the corrective osteotomy had no relation to the later development of knee osteoarthritis.

Correction of bowlegs or knock knees was aimed to obtain 6–7° anatomical valgus angulation in standing (173–174° femoro-tibial angle), which resulted in 171.5°±5.5° for bowlegs and 173.9°±5.2° for knock knees. These were a little more than 169–170° following high tibial osteotomy for medial compartmental osteoarthritis of the knee and a little less than 176° following that for lateral compartmental osteoarthritis as reported previously [11]. However, in this series, the super-long-term follow-up study failed to detect onset of osteoarthritis except in two cases with particular aetiologies. Young patients hardly develop recurrence of deformities as seen in undercorrected cases of high tibial osteotomy for the osteoarthritic knee.

Acknowledgements The author wishes to express his heartfelt appreciation to Prof. T. Saito (Director, Dept. of Orthopaedic Surgery, Yokohama City University School of Medicine) and Assoc. Profs. R. Takeuchi, Y. Inaba, Drs. N. Kurosaka, I. Saito, and R. Hayashi for their kind assistance in accomplishing long-term follow-up in this research.

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