International Orthopaedics (SICOT) 3, 37–45 (1979)

International Orthopaedics

The Effect of High Tibial Osteotomy on Osteoarthritis of the Knee

Clinical and Histological Observations

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Summary. *High tibial osteotomies were performed on 136 osteoarthritic knees for correction of varus deformity. Before osteotomy all patients experienced moderate or severe pain, and the knees showed lateral thrust on weight-bearing. The patients were followed up for one to five years. Marked relief of pain was obtained in 112 knees, and the patients were satisfied with the result of operation in 122. These painless knees showed no lateral thrust, and in the majority the deformity had been adequately corrected, with postoperative femoro-tibial angles (standing) ranging from 165° to 174°. Four of 28 knees with femoro-tibial angles of 175° to 179°, when measured one year after operation, showed recurrence of varus deformity three years after osteotomy. Preoperative ranges of knee motion were well maintained after osteotomy even when arthrotomy had also been undertaken. Intra-articular assessment in two patients, several years after operation, showed that the most degenerated portions of the articular surface were completely covered by a fibrocartilagenous layer, with no bare bone.*

High tibial osteotomy is most effective in osteoarthritic knees with varus deformity, when correction is made to a femoro-tibial angle (standing) of 170° (10° valgus).

Résumé. *Une ostéotomie de l'extrémité supérieure du tibia a été réalisée chez 125 malades (136 genoux) porteurs d'une arthrose sur genu varum. Avant l'intervention, tous les sujets se plaignaient de douleurs plus ou moins importantes et présentaient une augmentation de la déformation lors de l'appui.*

Le recul est de 1 à 5 ans. Une diminution notable des douleurs a été obtenue sur 112 genoux et 122 malades sont satisfaits de l'intervention. Les genoux stables et indolores ne présentent plus de bâillement externe et ont été en majorité corrigés de façon satisfaisante, avec un angle fémoro-tibial compris entre 165° et 174°. Sur les 28 genoux comportant un angle de 175° à 179° un an après l'opération, 4 ont donné lieu à une récidive du varus trois ans après l'ostéotomie. La mobilité pré-opératoire a été conservée, même dans les cas où une arthrotomie a été associée à l'ostéotomie. Un bilan intraarticulaire, effectué chez 2 malades, plusieurs années après l'ostéotomie, a montré que les parties les plus détruites de la surface articulaire étaient complétement recouvertes d'un tissu fibro-cartilagineux.

L'ostéotomie tibiale est efficace dans l'arthrose sur genu varum, surtout si la correction réalise un angle fémoro-tibial de 170°, soit 10° de valgus.

Key words: *Knee, Osteoarthritis, Tibial osteotomy*

Osteoarthritis of the knee is one of the most common orthopaedic diseases affecting the aged in Japan. Late stage osteoarthritic knees with varus or valgus deformity often fail to respond to conservative treatment and, following the paper of Jackson and Waugh in 1961 [11], correction of the deformity by upper tibial osteotomy has become common practice, with section above the tibial tuberosity strongly advocated [6, 7, 17, 4, 9]. The success of the operation has been ascribed to the postoperative realignment of the leg, [4] an improvement in circulation in the bone adjacent to the joint [10], and to a decrease in bone metabolism [14, 15, 16]. This paper describes the clinical results of high tibial osteotomy and discusses the effect of osteotomy upon the healing process in osteoarthritis as seen in the knees of two patients after operation.

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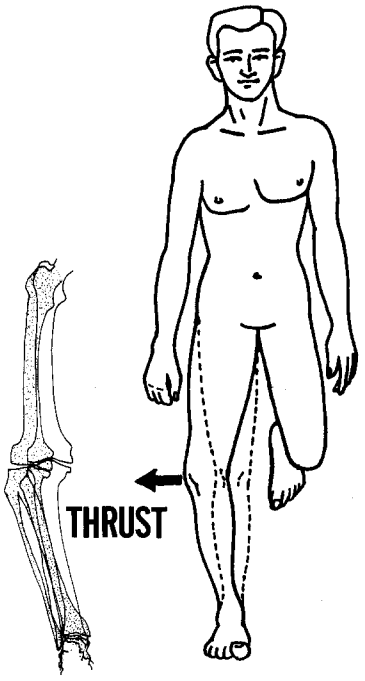


Fig. 1. Lateral thrust of the knee, indicating lateral shift of the knee on weight-bearing, which is seen most frequently in advanced osteo-arthritis with varus deformity

Material and Methods

One hundred and thirty-six osteoarthritic knees in 125 Japanese patients (40 men and 85 women) were treated by high tibial osteotomy for correction of varus deformities. The age of the patients ranged from 43 to 80 years with an average of 63.7 years.

All knees were evaluated pre- and postoperatively with special work sheets itemizing past history, subjective symptoms, objective signs, radiographic findings and laboratory data, including radioisotope scintiscanning. The postoperative follow-up ranged from 12 to 60 months with an average of 34 months.

Clinical Signs and Symptoms

The degree of pain was classified into three categories: no pain or mild pain with no need for analgesia, moderate pain with need for analgesia and decrease of activity and severe pain with disability. Lateral thrust of the knee was used as an indication of instability. A stable knee shows no sideways thrust when bearing weight. Lateral thrust of the knee with medial compartment osteoarthritis was seen on weight-bearing when the varus deformity was increased in radiographs taken of the weight-bearing knee compared with those taken when no weight was borne (Fig. 1). The walking ability was measured as the distance which the patients could walk without resting.

Radiographic Findings

Standing antero-posterior radiographs of the knee were taken while bearing weight on one leg at a time. The femoro-tibial angle [4], was measured in the standing radiograph of each knee before and after osteotomy (Fig. 2a). The mechanical axis of the knee in the frontal plane was deduced, and the deviation of the axis from the centre of the knee was calculated, as shown in Figure 9.

Operative Details and Postoperative Management

The size of the wedge of bone to be removed was calculated, to produce a femoro-tibial angle of 170° after operation, giving 10° of valgus (Fig. 2a). The operative technique partly followed that described by Bauer et al. [4]. The medial half of the fibular head was usually resected to allow the head to slide up freely. Alternatively, osteotomy of the neck of the fibula was performed and the head removed. The laterally based wedge was designed to lie above the insertion of the patellar ligament, but leaving a proximal fragment at least 2.0 cm wide. During the distal osteotomy, a buttress of cortical bone one centimetre in height was left at the tibial tuberosity, to prevent the proximal fragment from migrating anteriorly (Fig. 2b). No internal fixation was used. If

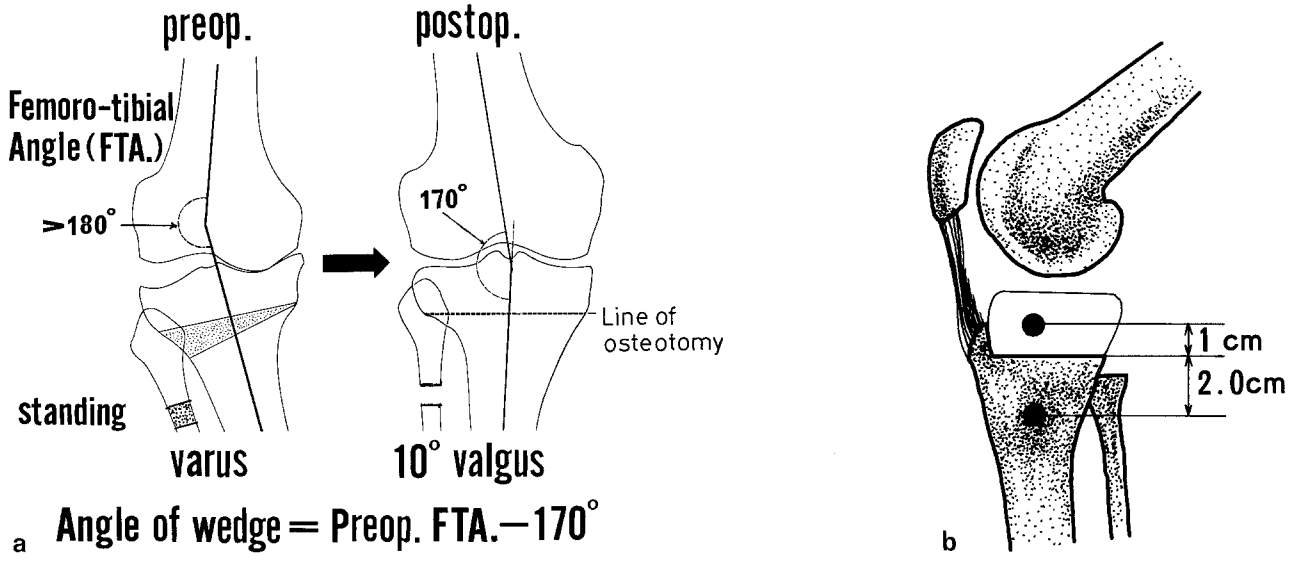


Fig. 2a and b. **a** The femoro-tibial angle and the disign of a laterally based wedge. The femoro-tibial angle is the lateral angle between the femoral axis and the tibial axis as measured on an antero-posterior radiograph. **b** Lateral view of the tibial osteotomy. The cortical bone at the insertion of the patellar ligament is left intact

arthrotomy was required it was carried out first, through a 6 cm parapatellar incision. The tibial osteotomy was then performed and stabilised using the Charnly compression devices. After closure of the skin, a cylinder cast was applied unless the Charnley apparatus was used. Quadriceps exercises and partial weight-bearing were begun after a few days, and full weight-bearing at two weeks. The plaster was removed after six weeks and knee mobilisation commenced.

Results

Preoperative Clinical Findings

All 136 knees had varus deformities and showed lateral thrust on bearing weight. The patients experienced severe or moderate pain and mild joint effusions. Their walking distance was less than 500 m. Thirty-five knees out of 136 had ranges of motion of less than 120° and 62 showed loss of extension of more than 10°. One hundred and ten patients could not sit in the formal Japanese style. The standing antero-posterior radiographs showed narrowing or obliteration of the medial joint space with sclerosis, and the femoro-tibial angles ranged from 180° to 210°.

Evaluation after Osteotomy (Fig. 3)

In knees in which the deformity had been adequately corrected, marked relief of pain was obtained by six months, and pain relief and range of movement had improved further three years after operation. When reviewed, 112 knees out of 136 were painless and stable, with no lateral thrust on weight-bearing, and the patients were able to walk more than 2 km. The patients were satisfied with 122 knees. Most of the unsatisfactory results were due to under-correction of the varus deformity. A range of motion of less than 120° was present in 38 knees, but only five showed loss of extension of more than 10°. An increase in the range of motion of more than 10° was achieved in 60 knees, but 27 lost more than 10° of movement.

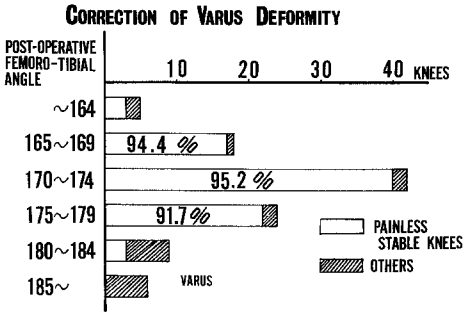


Fig. 3. Clinical results and postoperative femoro-tibial angles (standing) of the first 104 knees. Note that the best results were obtained in the knees with postoperative femoro-tibial angles ranging from 165° to 174°

Fig. 4. A fifty-four year old woman in the formal sitting of Japanese style, taken one year after high tibial osteotomy of the left knee

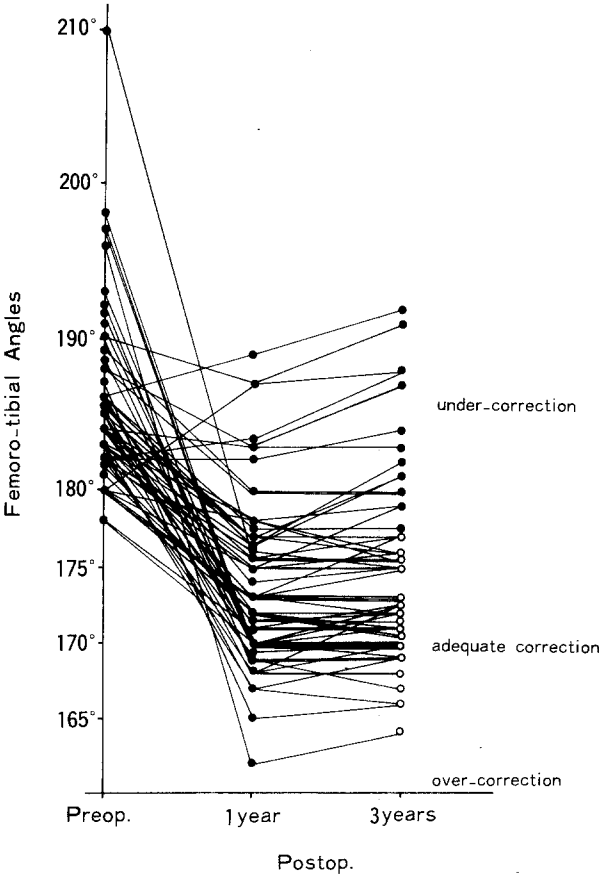
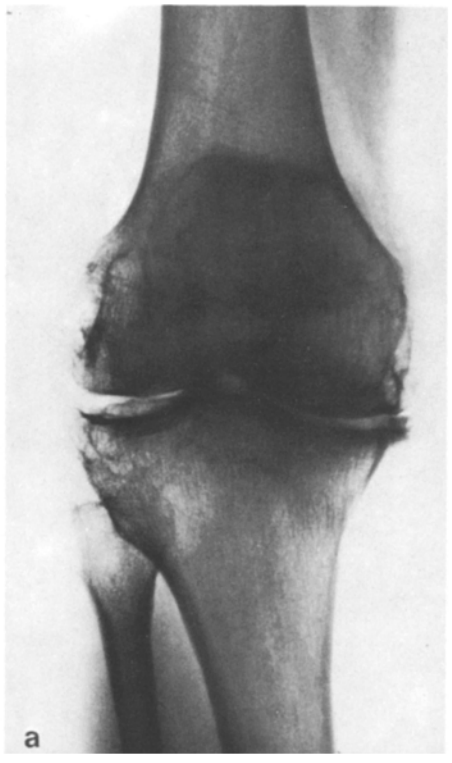


Fig. 5. Changes in the femoro-tibial angles (standing) of 61 knees from before operation to three years after. Note some recurrence of the varus deformity by three years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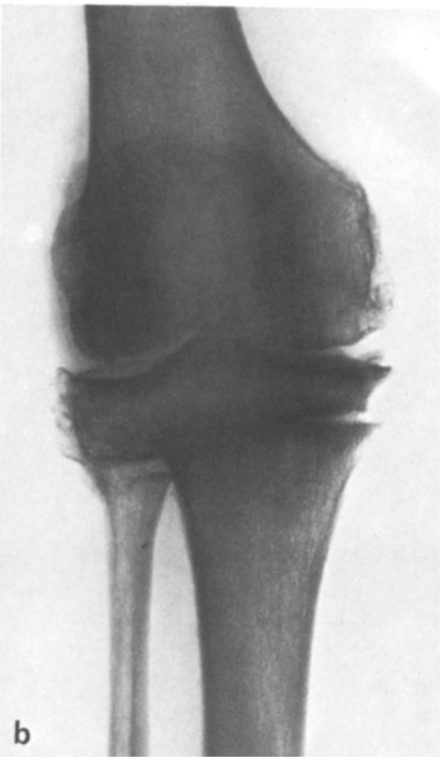
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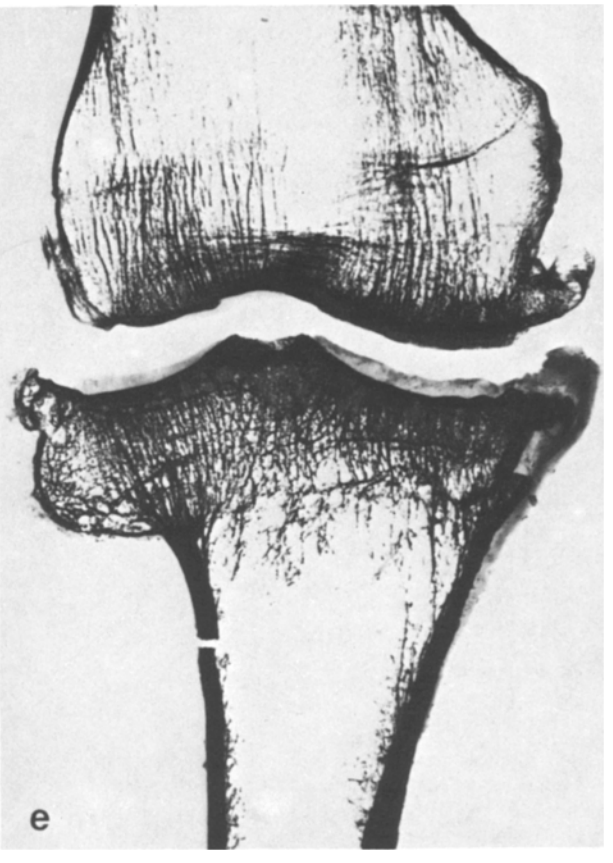
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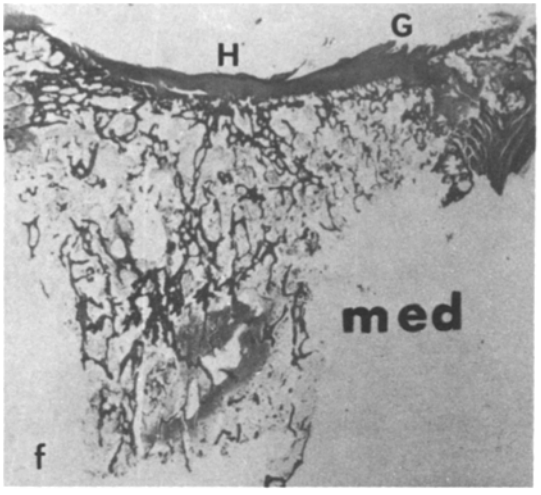

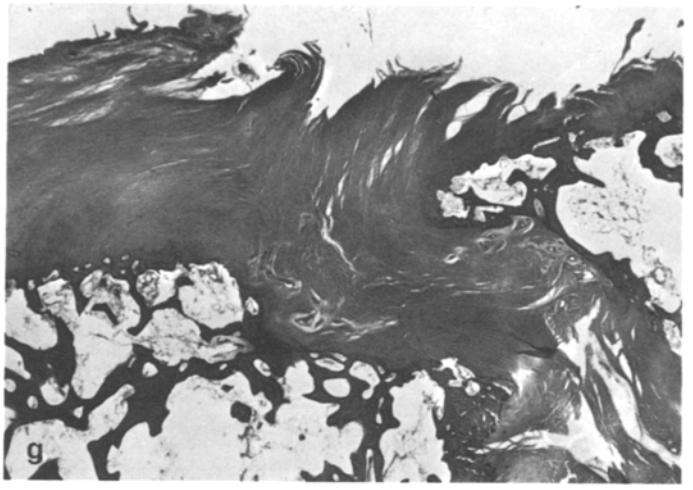

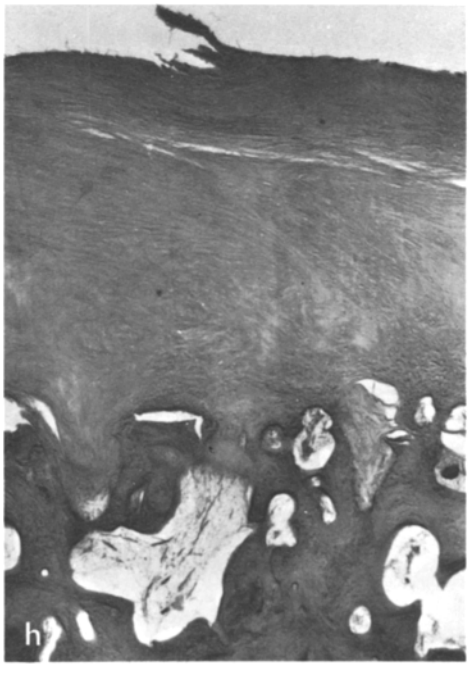

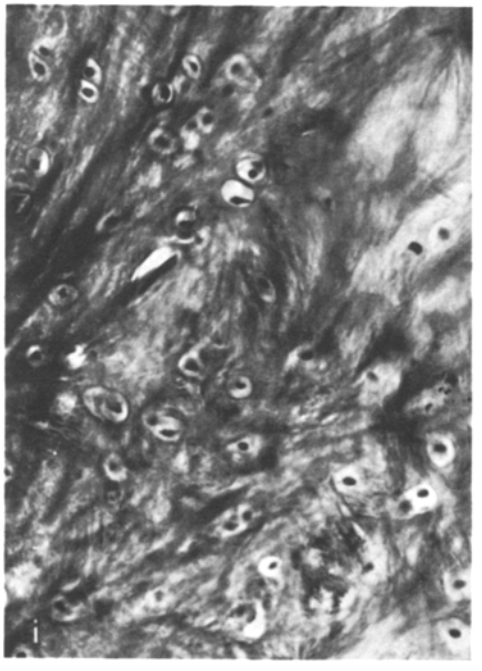

Fig. 6 a – i. a The antero-posterior radiograph of the knee in patient 1, taken in a standing position. Note the osteosclerosis and narrowing of the medial joint space
b The antero-posterior radiograph of the knee of patient 1, four months after osteotomy, taken in a standing position
c The distal end of the femur in patient 1, seen at post-mortem. The weight-bearing part of the medial femoral condyle is covered by white, uneven fibrocartilaginous tissue
d The frontal section of the proximal part of the tibia at post-mortem in the same patient. The medial tibial plateau is covered by a white surface layer
e A radiograph of the same specimen sectioned in the frontal plane
f A histological section of the whole medial tibial condyle in the same patient
g The medial edge of the medial tibial plateau, marked *G* in Figure 6f. The bony tissue on the right side is an osteophyte. The fibrous layer over the articular surface is dividing the osteophyte from the condyle (Haematoxylin and eosin ×30)
h The mid part of the medial tibial plateau, merked *H* in Figure 6f (Haematoxylin and eosin × 30)
i The surface layer on the medial tibial plateau in the same specimen in higher magnification, showing chondrocytes and fibrous bundles. (Haematoxylin and eosin × 200)

Forty-eight patients could sit in the formal way (Fig. 4).

Cylinder casts were applied to 79 legs, and Charnley's compression device was used in 57. There was little difference in the postoperative results between these two methods of fixations. However, loss of more than 10° of movement was found in 20 knees treated in casts, but only in seven in which the Charnley device was used.

Arthrotomy

Arthrotomy was carried out first in 21 knees out of 136 for removal of the medial meniscus, drilling of the articular cartilage, or removal of loose bodies. Eight of these knees gained more than 10° of movement, but five lost this amount.

Postoperative Femoro-Tibial Angle

After operation the femoro-tibial angle, measured in standing, was between 165° and 174° in 82 knees, and these were judged satisfactory by the patients. None of these knees showed lateral thrust and all but one were painless. There was no recurrence of the deformity in this group, but in 28 knees with postoperative femoro-tibial angles between 175° and 179°, the varus deformity had reappeared in four, when seen three years later (Fig. 5). Joint pain was moderate or severe in eight of seventeen knees which had been under-corrected, with postoperative femoro-tibial angles of more than 180°.

Complications

Six patients, four men and two women, had delayed union. Two of them were diabetic. Three of these knees were ended in the under-corrected. One patient complained of painful calcification at the insertion of the patellar ligament. There were no infections and peroneal nerve palsy was not encountered.

The Effect of Osteotomy on the Joint Surface

We were able to examine two knees histologically, one at post-mortem after 25 months, and the other by open biopsy 55 months after osteotomy.

The first patient had a valgus osteotomy at the age of 67 following a 10 year history of increasing pain and disability in his right knee. His pre-operative standing radiographs showed a femoro-tibial angle of 185° (Fig. 6a), which was corrected to 168° after operation (Fig. 6b). When seen 18 months after operation, he had an excellent clinical result, but he died seven months later from an unrelated cause.

When examined at post-mortem, the weight-bearing parts of the medial femoral condyle and the medial tibial plateau of the knee were covered by white, uneven layers of fibro-cartilage, about 3 mm thick, with irregular margins bordered by yellow articular cartilage (Fig. 6c–d). The joint surface of the patella was covered by fibrillated articular cartilage. There were no areas of exposed bone in the joint. Only the anterior portion of the medial meniscus remained. On the lateral side of the joint the articular cartilage was slightly yellow, with a few areas of mild erosion. The lateral meniscus was intact, except for slight fibrillation. A radiograph of the specimen, sectioned in the frontal plane (Fig. 6e), showed dense trabeculae in the medial compartment and irregular trabeculation at the site of osteotomy. Large osteophytes were present at the edges of the medial femoral and tibial condyles, and their size and shape were unchanged from their preoperative appearance. Histological sections from the medial compartment showed a fibrillated surface layer of fibrocartilage over the subchondral bone (Fig. 6f–g). This layer had formed over the previously exposed bone. Horizontally arranged fibres predominated near the joint surface, but adjacent to the subchondral bone plate the structure was more cellular with vertically arranged fibres (Fig. 6h–i). The trabeculae were thick and immature in the subchondral bone of the medial compartment. The articular cartilage of the lateral compartment was hyaline with mild fibrillation at its surface. Thick trabeculae were present at the osteotomy site, mainly on the lateral side, and there was a small cystic lesion at the centre surrounded by a fibrous wall (Fig. 6d).

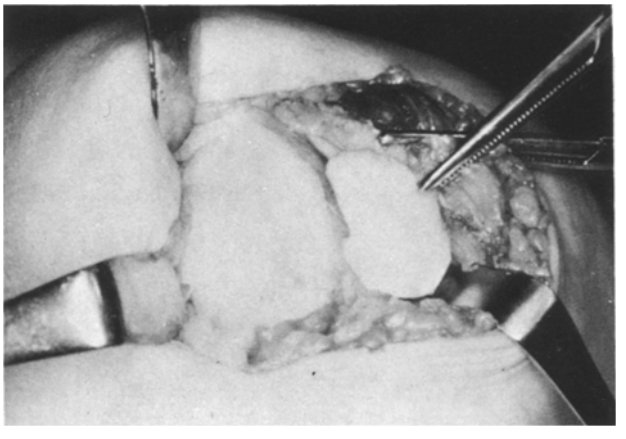

Fig. 7. The appearance at re-operation in patient 2, showing the medial femoral condyle and a loose body. The original defect is completely covered by withe, fibrocartilaginous tissue with no exposed bone

The second patient had a valgus osteotomy of the right knee at the age of 63 for medial compartment pain. Radiographs showed a defect in the articular surface of the medial femoral condyle, with narrowing of the medial joint space. She had an excellent postoperative result, but over four years later developed symptoms due to a loose body in the knee. Fifty-five months after the osteotomy, arthrotomy was performed for removal of the loose body. The weight-bearing surface of the medial femoral condyle was almost intact with no exposed bone. The regenerated tissue covering the previous defect resembled the rest of the articular cartilage (Fig. 7), but was softer and its surface showed fibrillation. On section the histological appearances of the regenerated tissue were identical to those of the fibrocartilage in the first patient.

Discussion

The Pattern of Osteoarthritis of the Knee in Japan

Eight hundred knees with osteoarthritis seen in the Outpatient Clinic of Yokohama City University were classified as described by Ahlbäck [1]. Varus deformity and medial compartment wear were present in 93%. The low incidence of lateral compartment involvement and valgus deformity compares with a 21% incidence seen in American patients [4] (Fig. 8).

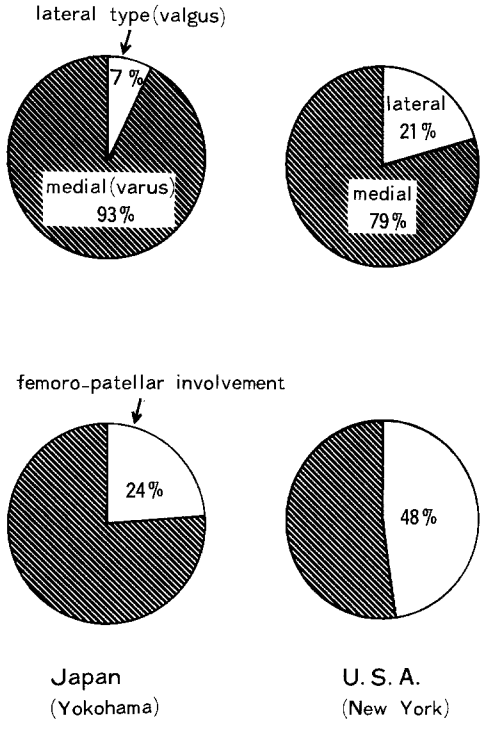

Fig. 8. Comparison of the sites of involvement in osteoarthritis of the knee in Yokohama and New York

However, in Japan, injuries to the meniscus are more common on the lateral than the medial side, suggesting that primary osteoarthritis of the knee is not directly related to meniscal injury. Although Japanese women follow the custom of formal sitting (Fig. 4), which requires the maximum excursion of the patella around the distal end of the femur, osteoarthritis of the patello-femoral joint was seen less often than in the United States. The range of motion of the knee is of great importance to Japanese women, and loss of flexion after osteotomy is of more concern to them than loss of extension.

Angular Deformity

Varus or valgus deformity is seen in the later stages of osteoarthritis of the knee. Increase in varus or valgus angulation occurs on weight-bearing [4, 7, 9, 12], and radiographs of the knee should be taken in a standing position. The deviation of the mechanical axis from the centre of the knee of the affected leg is measured from an antero-posterior view of the whole leg [17, 9, 12]. This axis passes through the medial side in the varus deformed knee, and through the lateral side in the valgus deformed knee. The amount of correction required is calculated by measuring the femoro-tibial angle from the antero-posterior radiographs in a standing position, as emphasized by Bauer et al. [4]. The average femoro-tibial angle of the normal knee when standing is 178° in Japanese men, 176° in Japanese women and 174° in American women. The mechanical axis of the leg passes through the centre of the knee when the femoro-tibial angle is about 172°, as calculated from the regression line of correlation ($Y = 0.364\ X - 62.50$) shown in Figure 9. In the majority of normal knees the mechanical axes of the lower extremities pass through the medial femoro-tibial compartment 5 to 10 mm from the centre of the knee when standing.

Effect of Tibial Osteotomy

Pain is the principal complaint, and patients who experience relief of pain after osteotomy are satisfied with the operation. Instability of the knee when weight-bearing usually produces pain, and most of the patients with angular deformities of the knees showed instability on walking, with lateral or medial thrust. All patients who obtained relief of pain showed no thrust of the knee on weight-bearing after operation, and these knees were found to have a femoro-tibial angle between 165° and 174° (6° to 15° valgus). The best results were obtained with a correction of the tibial angle to about 170°. Scanning with radioactive strontium [3] showed that the

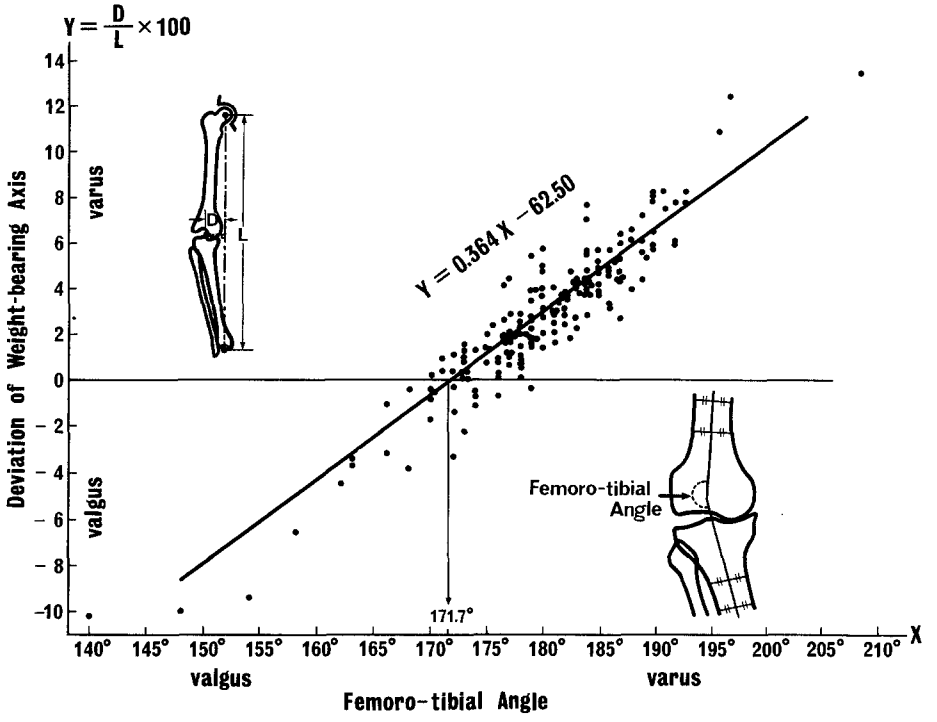

Fig. 9. Correlation between the rate of deviation of the mechanical axis and the femoro-tibial angle among 180 normal and deformed knees, in the standing position. Note that the mechanical axis passes through the centre of the knee when the femoro-tibial angle is 171.7°
D = the distance from the centre of the knee to the mechanical axis of the lower extremity
L = the length of the mechanical axis from the centre of the hip to the centre of the ankle
$D/L \times 100$ = rate of deviation

high mineral turnover in the medial femoro-tibial compartment disappeared after correction of the varus deformity to this degree [14, 16]. Maquet [17] and Kettelkamp and Chao [13] emphasized the importance of overcorrection of the varus deformity by 3 to 5 degrees, but Harris and Kostuik [9] suggested that the mechanical axis should pass through the centre of the knee. We feel that this axis should pass lateral to the centre of the joint after correcting the varus deformity. When the femoro-tibial angle is 170° the weight-bearing axis passes about 5 mm lateral to the centre (Fig. 9). Good clinical results may be obtained in knees which are undercorrected, but the varus deformity tends to recur after a few years.

The histological changes found in the osteoarthritic knee after high tibial osteotomy are similar to those in the hip after high femoral osteotomy reported by Byers [5]. If the deformity of the knee is adequately corrected and the high loading of worn areas is relieved, the degenerative lesions of the articular surface can be gradually replaced. We believe that relief of joint pain depends greatly on the coverage of the degenerated portions of the articular cartilage by a fibrocartilaginous layer.

Indications for Operation

Tibial osteotomy is indicated in the knee with pain on walking, varus deformity and lateral thrust on weight-bearing. Rheumatoid arthritis is not a contra-indication, if synovectomy is performed in conjunction with osteotomy. Ideally, one of the two compartments of the femoro-tibial articulation should be healthy and without bone destruction. Patients with osteo-necrosis of the medial femoral condyle [2] gave the best results following high tibial osteotomy.

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