

## ORIGINAL ARTICLE

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## Time-dependent clinical and roentgenographical results of Coventry high tibial valgisation osteotomy

Received: 29 September 1996

**Abstract** We analyzed the time-dependent results after Coventry osteotomy in 118 patients (129 cases) with unicompartamental osteoarthritis of the knee. The median follow-up was 11.6 years (range 0.7–17 years). Data were noted according to the time since surgery. Group I (> 2 years) consisted of all 129 cases, group II (> 4 years) of 41 cases and group III (> 8 years) of 15 cases. The HSS knee score (max. 100 points) improved from  $33.2 \pm 20.4$  (range 17–60) to  $68.3 \pm 25.3$  (range 30–90) in group I, to  $54.7 \pm 18.9$  (range 29–90) in group II and to  $43.7 \pm 20.9$  (range 23–85) in group III. The improvement started  $4.6 \pm 7.8$  months (range 0–60 months) after the operation and persisted for 4 years  $\pm 37.4$  months (range 0–125 months). The functional knee score (max. 100 points) changed from  $61.7 \pm 14.1$  (range 41–70) to  $71.7 \pm 13.1$  (range 53–87) in group I, to  $70.0 \pm 11.8$  (range 54–88) in group II and to  $64.2 \pm 8.0$  (range 42–90) in group III. The initial loss in knee flexion was  $5.6^\circ$  (range  $0^\circ$ – $20^\circ$ ) and for extension  $1.0^\circ$  (range  $-5^\circ$ – $25^\circ$ ). Anteroposterior ligament stability (max. 10 points) decreased from  $9.2 \pm 2.1$  (range 2–10) to  $5.6 \pm 1.7$  (range 2–9) in group III. Lateral ligament stability (max. 15 points) was relatively constant, from  $12.6 \pm 1.9$  (range 4–15) to  $9.7 \pm 1.9$  (range 2–14). Complications included one tibia fracture, one infection, six peroneus pareses, four haematomas and one pseudarthrosis. The mechanical axis was corrected to an average knee valgus of  $5.2^\circ \pm 7.4^\circ$ , which deteriorated over time. Radiographic evidence of arthrosis appeared independent of the operation.

### Introduction

Unicompartamental arthrosis of the knee results in increasing pain and progressive deformity [8, 13, 20]. Once the

collagen fibres of the cartilage have been mechanically exposed, further loss of the intercellular matrix occurs [6]. Conservative treatment by physiotherapy and drugs does not prevent this process [6]. Volkmann initially described an operative treatment [18], in which the weight-bearing axis was shifted by valgisation osteotomy from the destroyed medial to the lateral knee compartment [3, 11, 13]. Debeyre and Patte reported good clinical results for this technique [5]. Coventry et al. stated that pain reduction, improvement of joint function and correction of the weight-bearing axis can be achieved [3, 4]. Other studies postulated that progression of the joint degeneration can be reduced [1, 12]. The aim of our study was to analyse the time-dependent influence of this osteotomy on the clinical and roentgenographical parameters.

### Patients and methods

Since 1978, 141 patients have undergone high tibial osteotomy according to the original method of Coventry at the Orthopedic Department, University of Muenster [3]. In our study, 118 patients (59 men, 59 women) with 129 operations could be completely evaluated. Patients were lost to follow-up because of death (9 cases), long distances to travel (3 cases) and change of address (11 cases). Ninety-seven patients were examined directly and 21 by a standardized questionnaire. The parameters location, duration, severity of pain, level of activity and use of analgesics were documented. Reasons for the varus gonarthrosis were idiopathic (94 patients), post-traumatic (15), congenital (3), rheumatoid (3), osteochondrosis dissecans (1), achondroplasia (1) and phosphate diabetes (1). All patients suffered from therapy-resistant pain that had lasted  $89 \pm 88$  months (range 1–360 months). Intensive conservative treatment (drugs, physiotherapy) had been applied for  $73.5 \pm 79.2$  months (range 1–300 months). The average age at operation was 57.2 years (range 35–81 years). The average body weight was  $76.5 \pm 22.8$  kg (range 54.9–107.5 kg) and height  $169 \pm 9.1$  cm (range 149–189 cm). During follow-up, the body weight rose slightly to  $78.9 \pm 9.1$  kg (range 50–115.5 kg). The median follow-up period was 11.6 years (range 0.7–17 years). In combination with arthroscopy, tibial osteotomy was performed in 31 patients. Fifteen were done for diagnostic reasons, while two were combined with synovectomies. In 16 arthroscopies, a partial or total meniscectomy was performed. The osteotomy was also combined with an arthrotomy in 11 patients. Two of these underwent an additional synovectomy. In 10 arthrotomies, a partial or total meniscectomy was done. Four patients underwent a simultaneous Ma-

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quet-Bandi operation for retropatellar arthrosis. In three patients a tibia cyst was filled by autogenous bone graft. All patients started rehabilitation with immediate passive physiotherapy. After 2 weeks, partial weight-bearing (50% body weight) was allowed in a circular cast. After 6 weeks, active exercises were practised with an increase to full weight-bearing.

To analyse the time-dependent changes, we selected three different follow-up time periods. Group I (> 2 years) consisted of all 129 cases, group II (> 4 years) had 41 cases, and group III (> 8 years) had 15 cases. The clinical evaluation was done according to the knee score of the Knee Society (max. 100 points). The criteria are pain (max. 50), range of motion (max. 25) and stability, anteroposterior (max. 10) and mediolateral (max. 15) [10]. Medioloateral stability was tested by the maximal manual valgus or varus stress. Anteroposterior instability was examined with the Lachmann test. The evaluation of knee function was also done according to the Knee Society for the criteria walking (max. 50) and stair climbing (max. 50) [10].

Radiography was performed first without and then with full weight-bearing. Axial alignment of the mechanical axis at the lower extremity was measured always in full-length radiographs. In each case, neutral rotation and maximal knee extension were checked [16]. The borderline of the medial and lateral tibia condyle was connected by tangents. The tip of the femoral condyle was marked. The joint space was measured three times at the tip of the femoral condyle by three examiners with the micrometer method accurate to 0.05 mm and recorded as an average value (Mitotoyo, Tokyo, Japan). The knee condylus angle was measured by the tangent of the femur and tibia condylus to the midline of the shaft. Arthrosis was classified by three examiners in a modified system according to Ahlbäck and recorded as an average [17]. The criteria were narrowing of the joint space for type I, obliteration of joint space for type II, moderate bone attrition for type III and major bone attrition with subluxation and lateral osteoarthritis for type IV.

## Results

### Clinical examination

An improvement was seen soon after the osteotomy. The total score was mainly influenced by the increase of the postoperative pain values from  $7.5 \pm 5.1$  (range 1–46) to  $33.6 \pm 2.1$  (range 8–48). This improvement started  $4.6 \pm 7.8$  months (range 0–60 months) after the operation and remained constant over  $48 \pm 37.4$  months (range 0–125 months). After 103 operations (79.8%) excellent pain relief was observed. The total HSS score deteriorated in group II, and pain values were the lowest at  $29.3 \pm 1.9$  (range 2–44) in group III (Fig. 1). In group I, the maximal knee flexion decreased by an average of  $5.6^\circ$  (range  $0^\circ$ – $20^\circ$ ), and the point of maximum extension changed at  $1.0^\circ$  (range  $-5^\circ$ – $25^\circ$ ). In group III, the knee flexion further decreased by an average of  $21.2^\circ$  (range  $0^\circ$ – $60^\circ$ ), and the extension changed at  $4.2^\circ$  (range  $-15^\circ$ – $40^\circ$ ). Anteroposterior ligament stability remained relatively constant in groups I and II, and decreased from  $9.2 \pm 2.1$  (range 2–10) to  $5.6 \pm 1.7$  (range 2–9) in group III. Most of these patients demonstrated additional mediolateral instability. The isolated mediolateral stability was not influenced as much and changed from  $12.6 \pm 1.9$  (range 4–15) to  $9.7 \pm 1.9$  (range 2–14) in group III. The lateral collateral ligament was more lax in the long-term group.

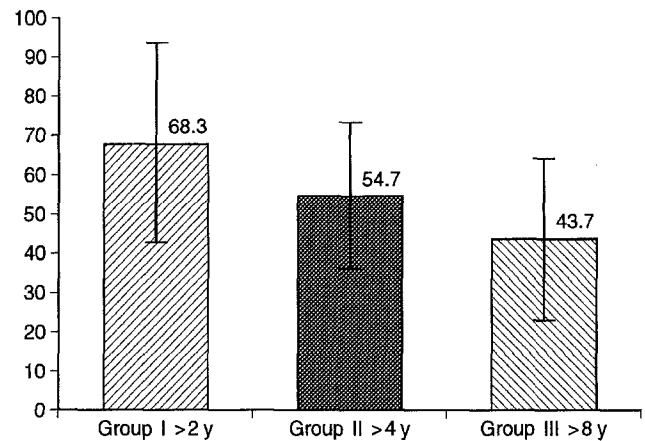


Fig. 1 Results of total HSS score for groups differing in length of follow-up after Coventry osteotomy

### Synovitis

The preoperative incidence of synovitis had been none in 77 patients (59.7%), recurrent moderate in 19 (14.5%), continuously moderate in 20 (16%) and intense in 13 (10%). In group I, the appearance of synovitis improved in 113 patients (87.6%) to none, recurrent moderate in 11 (8.5%) and continuously moderate in 5 (3.8%). This incidence remained constant in group II with no knee effusion in 36 patients (88.2%), recurrent moderate in 4 (9.8%) and continuously moderate in 1 (2%). In group III, no synovitis was noticed.

### Functional examination

The functional status of the patients after the Coventry operation improved and remained more constant than the total knee score (Fig. 2). The walking ability is very low, with preoperatively  $29.3 \pm 10.8$  points (range 10–40 points). In group I, the values improve to  $37.8 \pm 16.5$  (range 23–48). In groups II and III, the walking ability remained constant

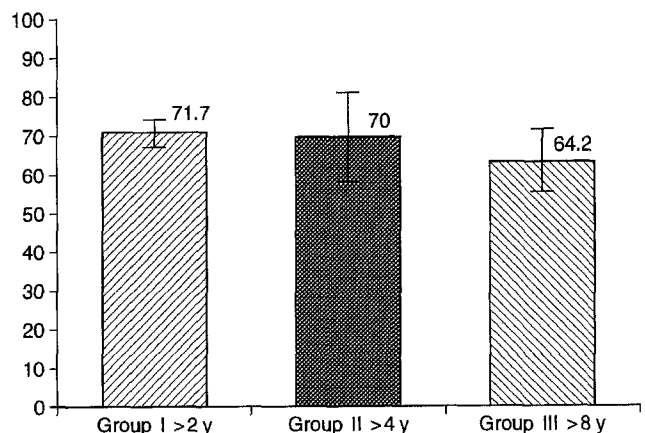


Fig. 2 Functional status after Coventry osteotomy by HSS score according to length of follow-up

with  $37.7 \pm 21.2$  (range 24–47) and  $37.8 \pm 17.9$  (range 25–45), respectively. The preoperative ability for stair climbing was very limited with  $35.8 \pm 10.3$  (range 12–47). After the operation, no striking improvement was seen in group I with  $37.5 \pm 9.5$  (range 12–47). In group II, the functional level was  $35.7 \pm 8.7$  (range 8–41), and it reached the lowest level of  $31.8 \pm 7.9$  (range 8–39) in group III.

### Complications

There were postoperative complications in 21 cases. We noted 3 thromboses with an emboli in 2. As operation-related complications, we observed 3 sensory peroneus lesions and 3 transitory peroneus pareses. In 2 patients, the nerve was successfully operatively revised (1st and 5th day). One patient sustained an intra-articular fracture related to an incorrectly placed osteotomy (< 10 mm) below the joint level. Four patients evidenced haematomas postoperatively, and 3 had seromas. One deep infection (*Staphylococcus aureus*) was successfully treated. One pseudarthrosis was revised at the 6th month with an autogenous bone transplantation. Four patients with persistent synovitis were re-operated by arthroscopic synovectomy. In 12 of 129 operations, a total knee arthroplasty was done. The median time until re-operation was 9.7 years (range 7–15 years).

### Patient's subjective opinion

Eighty of 118 patients (67.8%) would elect to repeat the tibial osteotomy as a treatment for the varus gonarthrosis. This was explained by the good pain relief in 57 (48.3%), improvement of quality of life in 10 (8.5%) and trust in the physician in 7 (5.9%). Seven patients (6%) would only agree if no other alternative method existed. Thirty-five patients (29.6%), however, refused the same operation retrospectively. This could be explained by higher expectations towards the operative results and actual persistent pain in 16 patients (13.6%). Limitations by other diseases which were also important for the decision existed in 4 elderly patients (3.4%). The duration of the rehabilitation time was pointed out by 7 patients (5.9%). Also, negative experiences with the re-operations influenced the opinion in 7 patients (5.9%). Three patients (2.5%) gave no statement.

### Radiographical examination

#### Correction of the alignment

The relationship between the knee joint, femur and tibia was measured by the knee condylar angle. The preoperative femur angle was  $82.3^\circ \pm 3.0^\circ$  (range  $76^\circ$ – $92^\circ$ ) and remained unchanged at  $82.4^\circ \pm 3.0^\circ$  (range  $77^\circ$ – $92^\circ$ ). The tibia angle was corrected by  $9.71^\circ \pm 2.9^\circ$  from preoperatively  $96.28^\circ \pm 4.16^\circ$  (range  $88^\circ$ – $111^\circ$ ) to postoperatively

$86.57^\circ \pm 4.44^\circ$  (range  $76^\circ$ – $96^\circ$ ). Therefore, the resulting knee angulation changed from preoperatively  $8.8^\circ \pm 6.2^\circ$  (range  $-5^\circ$ – $15^\circ$ ) varus to postoperatively  $5.2^\circ \pm 7.4^\circ$  (range  $-10^\circ$ – $20^\circ$ ) valgus. This value decreased slightly in group II to  $2.8^\circ \pm 6.8^\circ$  (range  $-10^\circ$ – $10^\circ$ ) and improved in group III to  $3.5^\circ \pm 6.3^\circ$  (range  $-5^\circ$ – $15^\circ$ ) valgus angulation. Preoperatively, the weight-bearing axis was located  $32.2 \pm 22.6$  mm (range  $-30$ – $78$  mm) medial from the eminentia intercondylaris. This distance was reduced to  $1.1 \pm 22.6$  mm (range  $-37$ – $74$  mm) after the tibia valgisation osteotomy.

### Joint space distance

The measurement of joint space distance under weight-bearing conditions pre- and postoperatively revealed an improvement in the medial (+18.9%) and also in the lateral compartment (+4.2%) (Fig. 3). The operation also changed the variations of the compartment distances with and without weight-bearing. Medially, the difference improved to half of the preoperative situation, and laterally, it was diminished threefold. Comparison of the repeated measurements demonstrated a mean measurement failure by every examiner of 0.13 mm, and similarly between the examiners (Fig. 3).

### Subchondral sclerosis

**Medial compartment.** Sclerosis of the subchondral bone at the tibia plateau or at the femoral condyle were often seen in knee arthrosis as an initial sign of joint degeneration. Preoperatively, a subchondral sclerosis at the medial tibia plateau was seen in 43 cases (33.3%). In 4 cases (3.1%), an additional sclerosis of the femoral condyle was seen. Postoperatively, the sclerosis was only noticed in 26 of 97 cases (26.8%) at the medial tibia plateau. One patient (1%) demonstrated sclerosis at both sides of the knee joint.

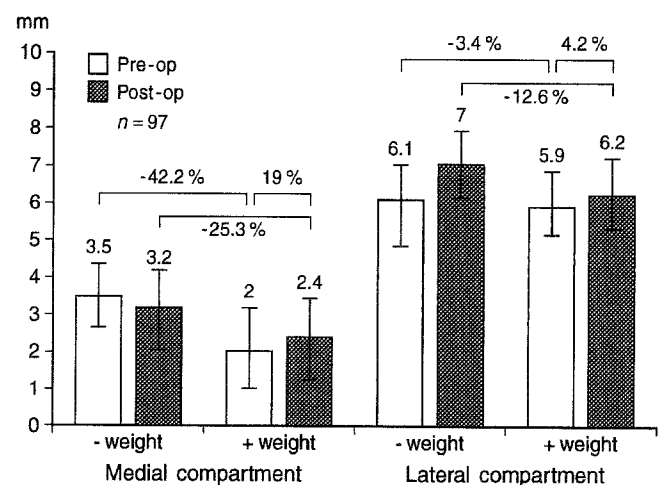


Fig. 3 Measurement of joint space distance under weight-bearing conditions

*Lateral compartment.* Preoperatively, 51 patients (39.6%) demonstrated a subchondral sclerosis at the tibia plateau. The incidence declined to 28 of 97 cases (28.8%) after the operation. No preference for a subchondral sclerosis was seen in the medial or lateral compartment.

### *Arthrosis index*

The degree of joint cartilage degeneration was classified according to Ahlbäck (1968) as modified by Trjörnstrand et al. [17]. The arthrosis index score changed from preoperatively  $1.91 \pm 1.1$  (range 0–5) to postoperatively  $2.3 \pm 1.3$  (range 0–5). The progression of joint degeneration was not stopped by the operation. The incidence of patients with moderate and severe forms of knee arthrosis increased progressively in spite of surgical intervention.

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## **Discussion**

High tibial osteotomy for unicompartmental arthrosis of the knee is a commonly used procedure [4, 11, 13, 20]. Operation-related complications seen as fractures occurred relatively rarely, 0.8%–9.1% [1, 12, 13]. The nervus peroneus lesion is the most common one, 0.8%–8.3% [3, 9, 12]. This could be related to local pressure by the fibular approach and compartmental pressure given extreme corrections. The irritation is mostly transient and appeared in our study in 4.8%. The pseudarthrosis rate varied between 0.8% and 4.7% [1, 3, 12, 20]. Placing the osteotomy above the tuberositas tibia, we always achieved good contact in the cancellous bone, with a low pseudarthrosis rate of 0.7%. Our initial loss of knee motion might be related to the postoperative immobilization time. In the long-term follow-up, the total joint motion and the ligament stability decreased more commonly [1, 17, 20]. It remains unclear whether this can be related to the operation itself or the natural course of the degenerative disease. After the valgisation osteotomy, a stretching of the medial collateral ligament was to be expected. The lateral collateral ligament, however, remained more lax in the long-term group. This might be explained by a functional adaptation process to the postoperative loading in valgus angulation on the medial collateral ligament. We noted additionally an increase of anteroposterior instability over time, which is surprising. We assume that this development could be due to the collagen degeneration in older patients because all of them presented with an additional anteromedial instability. Therefore, a careful patient selection respecting the preoperative joint stability and motion is important. This has also been emphasized in other reports [8, 13].

The good initial pain relief mainly influenced the patients' opinion towards the operation. A failed pain improvement after high tibial osteotomy can be related to an insufficient postoperative angulation of the mechanical axis [9, 13, 19]. Under- or overcorrecting raised the incidence of failure [11, 13, 15]. The optimal angle should be

placed between 5° and 15° valgus angulation. For this range Holden et al. and Rudan and Simurda described improved 'operation survivorship' results [8, 15]. They stated that overcorrection should be more favored than undercorrection with respect to clinical outcome. Coventry et al. reported a more optimal 'survival rate' of 94% for 8° valgus [4]. All of our patients were selected according to the criteria of Coventry, who excluded extreme varus angulation (> 15°) and obesity [3, 4]. In our study, the initial pain-free period lasted only 4 years. Coventry et al. and Yasuda et al. noticed the onset of deterioration after the 5th and the 10th postoperative year [4, 20]. This difference might be explained by our relatively low valgus angle. Below 5° valgus the 5-year 'survival rates' were noted to be relatively poor (63%) [4]. If substantial angulation is lost in the follow-up, the clinical status declines further. Between the 4th and 8th year we noted only 2.4° valgus angulation. The loss of correction varied in other reports between 1° and 4° [4, 11, 17, 20]. This phenomenon is thought to be promoted by systemic osteoporosis or progression of the knee arthrosis [3, 9]. The degree of valgus alignment achieved at surgery is not by itself successful in preventing a recurrent varus deformity [11]. The tibial osteotomy did not stop the progression of the joint degeneration in our study [4, 8, 13]. The measurement of joint space distance under weight-bearing conditions should give information concerning the cartilage thickness. The physiological joint space difference between the medial and lateral compartment ranged between 0.4 and 0.7 mm [16]. In our patients with varus gonarthrosis, the difference was 5–10 times higher, reflecting damage of the medial compartment. After the tibial osteotomy, we noticed an improvement of the joint space distance more medially +18.90% than laterally +4.24%. It remains unclear whether this finding can be related to the cartilage itself or be a consequence of passive opening of the medial compartment by valgus stress related to the shifted axis. Arnold et al. noted that experimentally the normal cartilage initially will be compressed under the load but then the thickness will increase because of the elastic forces [2]. This water-binding capacity and swelling of the cartilage are more evident in the loaded areas [14]. Also, physical activity could increase the joint space distance [16]. Therefore, our results could potentially also be influenced by the improved postoperative functional knee score. Regeneration of the destroyed cartilage could not be verified by our data, although this was described by Coventry and Bowman [3]. Arthroscopy studies that were done before and after a similar osteotomy reported by Fujisawa et al. assessed the ability of articular cartilage to regenerate [7]. Opening of the lateral compartment is surprising and needs further examination, e.g. by magnetic resonance imaging, which is part of an ongoing study in our department. Although the weight-bearing forces are raised in the lateral compartment after the high tibial osteotomy, the incidence of subchondral sclerosis has been diminished in both knee compartments. The phenomenon might be influenced by improved microcirculation after the operation in the subchondral area.

Tibial osteotomy is shown here to be effective in the treatment of medial compartment gonarthrosis. Rigid standardization and a precise operative technique are required as well as accurate radiographic measurements of the mechanical axis of the limb. Our 15% incidence of failed operation resulting in knee arthroplasty is low. For most cases, our intention was to increase the time interval before the implantation of a knee alloarthroplasty, and this was achieved.

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