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ORIGINAL ARTICLE

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Long-term outcome following high tibial osteotomy with tension bend principle

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Abstract *Background:* High tibial osteotomy has been successfully performed on patients with varus gonarthrosis for many years now. The prospective study presented here serves to verify the long-term outcome of this procedure. *Methods:* A supratuberous high tibial osteotomy was carried out on 100 patients with varus gonarthrosis. Since then, 5 patients have died, and 6 patients could not be traced. The regaining rate was 94%. From a total of 89 patients with 101 operated knee joints, 46 were men and 43 women. The mean age at the time of surgery was 58 years. The patients were clinically and radiologically examined 10 years postoperatively and the knee score and function score ascertained according to the International Knee Society. *Results:* The knee score showed a statistically significant increase from 31 points prior to surgery to 79 points at the time of follow-up; the function score likewise increased from 46 points to 78 points. In addition, 77.5% of patients would undergo the same surgery again, while 79% of patients claimed their condition to have improved following surgery. The preoperative full-length weight-bearing radiograph demonstrated an axis shift in the varus position of on average 9.6° at 10 years postoperatively, an overcompensation in the valgus position of 1° on average. At the time of follow-up, 81% did not require repeat surgery of the knee. *Conclusion:* With a correct diagnosis and accurate surgical techniques, positive clinical and radiological long-term results can be expected. Therefore, high tibial osteotomy may constitute an important contribution to our algorithm in the treatment of varus gonarthrosis.

Keywords High tibial osteotomy · Varus gonarthrosis · Long-term outcome

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Introduction

The concept of displacement osteotomy stems back to McMurray and Pauwels [20, 22], who reported on intertrochanteric osteotomy of the hip joint for the relief of joint parts with damaged cartilage. Axis correction osteotomy is recommended for straightening the axis of the leg, thereby normalizing the function of the affected joint which, in turn, prevents any exacerbation of arthrosis in the overexerted joint segment. High tibial osteotomy was first described by Jackson in 1958 [17]. Many earlier publications refer to subtuberous osteotomy [18, 26, 27]; later, the supratuberous procedure inaugurated by Coventry was universally favoured [2, 4, 21, 29, 30]. Osteotomy performed on this level results in a more rapid bony ingrowth due to the well vascularised cancellous bones in the supratuberous section of the tibial head. It has been established that there is a considerably larger contact surface here compared with the subtuberous division [6]. Furthermore, compression of the quadriceps muscle ventrally over the patellar tendon and dorsally over the ischiocrural musculature occurs, and the juxta-articular osteotomy enables correction at the site of malalignment [6, 23, 30]. For this reason, correction osteotomy should be carried out in the cancellous bone above the tibial tuberosity. Osteosynthesis should guarantee stability on movement in early functional follow-up therapy as well as being technically simple to perform [4]. High tibial osteotomy is indicated for isolated arthrosis of the medial knee joint compartment if no ligament instability or subluxation is present and there is no axis shift over 10° or contracture of more than 10° in the knee joint [9, 10, 11]. The lateral knee joint should be diagnosed as radiologically and clinically free of arthrosis. In our opinion, the age limit for this operation lies between 60 and 70 years, but this depends on the individual capacity of activity.

In the past, the following methods were established for stabilisation of osteotomy surfaces: bone staples [5, 10, 14], one-third tubular plate with cortex screw [9, 29], external fixateur [8, 28] and the blade plate [13]. If the high

tibial osteotomy was performed a long time ago, it would appear that the outcome is less positive for the individual patient [15]. The described complications of this complex operation are in part considerable [2, 12, 14, 23, 27]. Only with the aid of long-term investigations can it be deduced whether or not the aim of long-term functional recovery of the operated knee joint can be achieved. These investigations necessitate a sufficiently high regaining rate in order to make a substantial assessment.

The aim of this study was to evaluate the long-term outcome of patients following high tibial osteotomy and to determine the factors which influence this outcome. This in turn would result in more accurate indications for the surgical procedures, thus leading to more beneficial long-term results.

Patients and methods

One hundred patients took part in this prospective study between 1989 and 1992 at the Orthopaedic Clinic, Hannover Medical School. All presented with varus gonarthrosis and underwent high tibial osteotomy. Since then, 5 patients have died, and 6 patients could not be traced; the retrieval rate was 94%. From the total of 89 patients with 101 operated knee joints, 46 were men and 43 women. The mean age at the time of surgery was 58 years (range 19–79 years).

The operation was carried out according to the procedure of Coventry [4], whereby a laterally based 3/4-wedge was removed from the subtuberous tibia and an overcompensation of 1–2° was aimed for above the physiological vagus position of 7°. Osteosynthesis was done simultaneously in the procedure according to Weber with a 5-hole-one-third tubular plate and a cortex screw [29]. In addition, a second incision was made, the fibula resected and a piece of bone removed (Fig. 1). Postoperative follow-up ensued with 10 kg partial weight-bearing for 6 weeks, then an increase in weight-bearing of 10 kg per week. One year after surgery, the plate and the screw were removed easily by a 1–2-cm incision, once the edge of the plate was properly prepared.

Preoperatively, the knee score and function score were ascertained according to the International Knee Society: 85–100 points were considered excellent, 70–84 good, 60–69 satisfactory and below 60 points poor [16]. Furthermore, an X-ray was taken of the knee along two planes as well as a tangential image of the patella, which were then used for arthrosis classification according to Ahlbäck [1]. The criteria were: narrowing of the joint line space for type I on a full-length weight-bearing radiograph made standing up; obliteration of the joint line space for type II; minor bone attrition for type III; moderate bone attrition for type IV; gross bone attrition with subluxation for type V [1]. In addition, a full-length weight-bearing radiograph anteroposterior (AP) was made standing up in order to access the axis of the lower limb. The follow-up period for all patients was 10 years. At this point in time, the same data were ascertained as before the operation. A questionnaire comprising 24 questions was answered and the patients' subjective opinion ascertained by means of a visual analogue scale.

The Kaplan-Meier survival curve was evaluated for all operated knees at follow-up. Implantation of a unicompartmental joint replacement or a total prosthetic replacement of knee were recognized as a failure [19]. The statistical evaluations were made with the help of the SPSS programme from Windows (version 8.0; SPSS, Chicago, IL). The preoperative and postoperative scores were assessed with aid of Student's *t*-tests, and the correlation analysed according to Pearson. Statistical significance was defined as $p<0.05$.

Fig. 1 **a, b** Postoperative X-rays of a 61-year-old female patient following high tibial osteotomy with one-third tubular plate and cortex screw. The medial cortex is not sawed but broken to approximate the osteotomy. The periosteum remains intact, and primary stability is preserved. **c**, **d** Follow-up images of the same patient 10 years postoperatively

Results

Twelve complications in 10 patients were observed during the postoperative period. A phlebograph demonstrated evidence of 4 cases of deep vein thrombosis, 2 of them proximal and 2 distal without associated pulmonary emboli. There were 3 cases of superficial wound infections which did not require revision. Two lesions of the fibular nerve were confirmed following neurological examination, but both cases were reversible. Bony non-union occurred in 3 patients, while all 3 cases of pseudarthrosis healed up completely after revision including bone grafting and insertion of a T-plate.

The knee score according to the International Knee Society was assessed at 31 points preoperatively and at 79 points on average after 10 years. The function score was 46 points preoperatively and 78 points at follow-up after 10 years. Both scores were statistically significantly im-

Table 1 Subjective comparison of condition prior to operation and at the time of follow-up shown in percent

	Percent
No information	1.7
Much better	66.1
Unchanged	8.5
Worse	11.8

Table 2 The degree of severity of degenerative changes of the medial compartment in the classification according to Ahlbäck preoperatively and at the time of follow-up shown in percent

Ahlbäck classification	Percent of patients
Preoperative:	
I	53
II	24
III	7
IV	13
V	3
Total	100
Follow-up:	
I	14
II	58
III	8
IV	16
V	4
Total	100

proved ($p<0.001$) at the time of follow-up. At follow-up 45% of patients claimed to be able to cover an unlimited distance, and a further 32% were able to walk over 1 km.

A visual analogue scale was used for the subjective assessment of patients with reference to their condition following surgery: 0 points indicated total dissatisfaction, 10 points total satisfaction. The mean value was 7.8 points (range 5–10), and 36% evaluated their result at 10 points.

By means of the questionnaire, the patients were able to compare their condition 10 years following surgery to their condition prior to the operation. Two-thirds of patients remarked on a significant improvement in their condition (Table 1). The correlation assessment revealed that walking distance ($p<0.001$), climbing stairs ($p<0.001$), pain ($p=0.001$) and subjective mobility ($p=0.03$) exerted a significant influence on the patients' satisfaction, whereas passive mobility could not be correlated with their subjective satisfaction. As to the question of whether or not he/she would undergo the same operation again, 77.5% answered in the affirmative. The preoperative full-length weight-bearing radiographs showed an average axis shift of 9.6° in the varus position; 10 years postoperatively there was a shift in the valgus position, an overcompensation of 1° on average. A correlation between the correction angle and the patients' satisfaction could not be deduced. A comparison of the degree of severity of the degenerative changes of the medial knee compartment preoperatively and postoperatively is summarized in Table 2. This essentially shows a shift of Ahlbäck I preoperatively to Ahlbäck II 10 years following surgery.

Evaluation of the success of the high tibial osteotomy was made using the Kaplan-Meier curve. At 10 years postoperatively 81% of the knees were not yet revised (95% confidence limits were 75.2–87.4). Two patients required a unicompartmental joint replacement, and 17 patients underwent implantation of a total prosthetic replacement of the knee (Fig. 2).

Discussion

High tibial osteotomy constitutes one of the choices of treatment for varus gonarthrosis together with unicompartmental joint replacement and total prosthetic replacement of the knee joint. The advantage of displacement osteotomy is that no prosthetic device is required, general preservation of the bone is assured, and unrestricted as

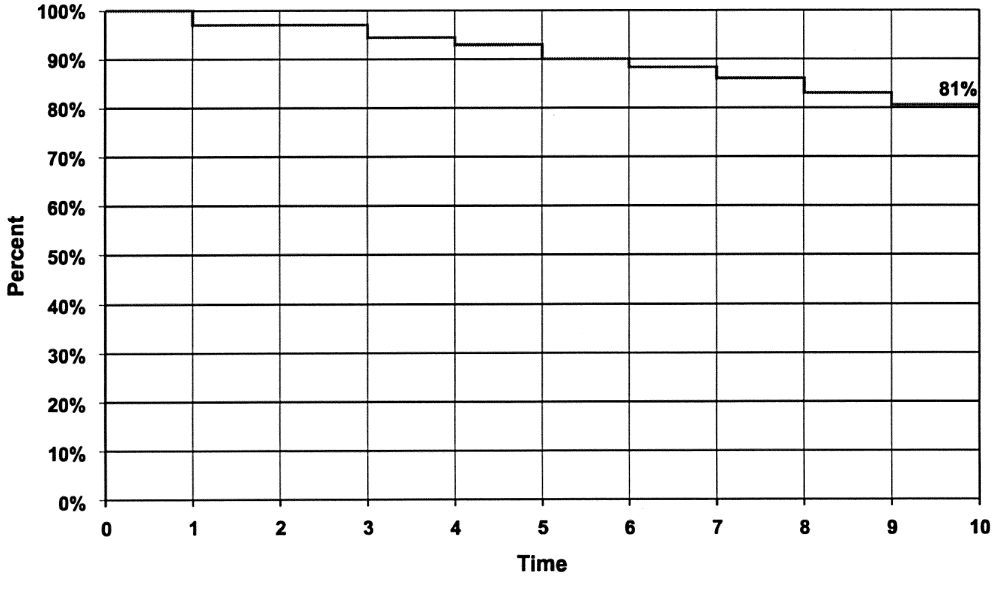

Fig. 2 Kaplan-Meier Survival Curve for tibial osteotomy with revision as a failure endpoint

well as sporting activities may be pursued. However, this particular procedure is technically complex, and complications may arise [7, 12, 14, 24]. A decisive point concerning the rating of such an operation is the long-term outcome, so the 10-year results after high tibial osteotomy will be discussed in the following.

The retrieval rate in long-term studies is most important for the validity of the final evaluation. Comparable studies do not always state this fact, and some demonstrate a considerably lower rate than the one shown here [6, 10, 14, 15, 24, 25].

The surgical techniques used in this study have already been described in detail above. Our previously published biomechanical studies give evidence that the primary stability of this method is comparable with that of other current techniques such as staples or the blade plate [9]. Removal of material can be done with a small skin incision only. However, preservation of the medial corticalis is of great significance, no matter which osteosynthesis is chosen. If this should be inadvertently osteotomized, then an additional medial osteosynthesis is essential in order to avoid a non-union. Furthermore, the method of osteosynthesis used is dynamic and facilitates a lateral sinking. Both factors are beneficial for bone healing and explain the low non-union rate of our studies compared with the rate given in the literature [12, 14, 15]. Also, the neurological complications remain encouragingly low, as the two lesions of the fibular nerve were completely reversible. According to statements made in the literature when performing a necessary fibular osteotomy, it must be taken into account that there is a certain risk of nerve damage [14].

The knee score as well as the function score of the International Knee Society were statistically significantly raised at the time of follow-up compared with the initial condition prior to operation. This is all the more surprising as the patients were 10 years older at follow-up and, on average, 68 years of age and thus more restricted in their activities. The results of the knee and function scores correspond with those in the literature [3, 14, 15] and support the conviction held in the literature that the functional outcome of high tibial osteotomy is superior to that of endoprosthesis.

A particularly important parameter for the evaluation of the outcome of an operation is the patients' subjective opinion. A score of 7.8 points on the visual analogue scale and 78% of patients with improved condition compared with prior to operation give marked evidence of the patients' general satisfaction with their present condition. Hassenpflug reported over 74% satisfied patients, Fuchs over 78% and Insall over 63%.

In order to work out the factors constituting the patients' contentment, we correlated various results with the subjective views of the individual patients. Walking capacity, climbing stairs, pain and subjective mobility showed a statistically significant influence on their contentment, but objective mobility of the knee joint did not feature. This corresponds only partially to the results of Fuchs, who formed a correlation between objective mobility and contentment, but no influence on their contentment was associated with pain [10].

In our clinic, we were in favour of a slight overcompensation of the varus position of 1–2°. We are of the opinion that a full length weight-bearing radiograph in standing position is essential for the preoperative planning and the final assessment of osteotomy in order to give a realistic portrayal of the functional decisive situation. Extensive correction, as sometimes recommended in the literature, can only be tolerated to a certain extent by the male patients in particular. The long-term value of a more pronounced overcorrection has not been proved. While Coventry propagates extensively in favour of overcorrection and bases his clinical success on this procedure, Insall was unable to support his claim [6, 7, 15]. An undercorrection or an exaggerated overcorrection is without doubt connected with poor clinical results [2, 7, 14, 25]. We were unable to form a correlation between the tibiofemoral angle on the full length weight-bearing radiograph and the patients' subjective contentment; other publications confirm this result [12, 14].

The survival analysis was drawn up for the total rating of tibial osteotomy, the final point being the definition of joint replacement. Our long-term results are in this connection more positive than those of Coventry et al. and Insall et al., but poorer than those of Hassenpflug et al. [7, 14, 15].

High tibial osteotomy for the treatment of varus gonarthrosis is a joint-preserving procedure which allows unrestricted function of the knee joint. The relatively high rate of non-union stated in the literature may be reduced by a dynamic osteosynthesis procedure according to Weber. The functional outcome after 10 years is encouraging, but a knee prosthesis was found to be more beneficial for the reduction of pain. Given a correct diagnosis and accurate surgical techniques, this complex procedure may produce good clinical results and satisfied patients. We are of the opinion that high tibial osteotomy offers an important contribution to the algorithm of varus gonarthrosis.

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