Knee Surg Sports Traumatol Arthrosc
DOI 10.1007/s00167-009-1020-9

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Accuracy of high tibial osteotomy: comparison between open- and closed-wedge technique

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Received: 4 November 2008 / Accepted: 2 December 2009

Abstract High tibial osteotomy is an established technique for the treatment of varus malaligned knees. This study analyses the difference between the amount of correction in the preoperative planning and the postoperative result. Furthermore, it compares the difference of the accuracy between open-wedge osteotomy and closed-wedge osteotomy. About 61 patients were either treated with open-wedge or closed-wedge high tibial osteotomy. Preoperative planning and postoperative analysis were performed with a special planning software. The influence of operative technique, aetiology, age, number of previous surgeries, amount of correction and accuracy of the correction compared to the preoperative planning were analysed. The overall postoperative mechanical axis differed form preoperative planning by 2.1° ± 1.7°. The accuracy in the open-wedge group (1.7° ± 1.6°) was significantly higher than in the closed-wedge group (2.6° ± 1.8°; $P = 0.038$). In patients with congenital varus deformity, the accuracy of the correction was significantly higher than in patients with post-traumatic deformity. The authors recommend open-wedge technique in combination with fixed-angle plates for high tibial osteotomy.

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Keywords High tibial osteotomy · Osteoarthritis · Open-wedge osteotomy · Closed-wedge osteotomy · Accuracy

Introduction

Medial osteoarthritis of the knee is a common disease frequently caused by additional load on the medial compartment due to varus deformity. High tibial osteotomy (HTO) is an established technique for symptomatic varus malaligned knees [5, 20, 23, 30], especially for younger and active patients [16, 17]. The aim of HTO is to reduce the load on the medial compartment by shifting the mechanical axis towards the lateral compartment. Overcorrection between 2° and 4° valgus, depending on the extent of cartilage damage, is recommended [25, 26].

Generally, HTO can be performed in an open- or closed-wedge technique. Closed-wedge osteotomy (CWO) has been the treatment of choice for many years [6, 17]. One potential advantage of this technique is bony contact at the osteotomy site. Disadvantages of CWO are the more extensive lateral approach, increased risk of peroneal nerve affection and difficulty of subtle corrections after bone resection.

Advantages of open-wedge osteotomy (OWO) are an operative approach without muscle detachment, no need of fibula osteotomy, reduced risk of nerve damage and subtle corrections by continuous opening the osteotomy. In addition, the stability of the medial collateral ligament can be improved with OWO. Potential disadvantages may be an increased pressure on the patellofemoral joint by patella baja and prolonged bone healing process due to the bone gap. However, bone transplantation is normally not necessary when using fixed-angle plates [9, 13].

Published online: 24 December 2009

Corrective osteotomies need to be precise as under- or overcorrections of the mechanical axis lead to disappointing clinical results [5, 7, 30]. Even small alterations of the mechanical axis cause significant changes of the load distribution of the knee joint [14], which often results in early degenerative changes and dysfunction [29]. The question whether OWO or CWO is more accurate is controversially discussed in the current literature [4]. Many studies have a retrospective design [6, 12, 13, 16, 17, 21, 24, 28, 31], and no studies have analysed the accuracy of correction with a special planning software, which is more accurate in comparison with conventional measurements [10]. The aim of the study was to analyse the accuracy of HTO compared to the preoperative planning with a special planning software. The hypothesis was that HTO with an OWO technique with fixed-angle implants is more accurate than the CWO technique.

Materials and methods

Between January 2001 and December 2005, a total of 87 patients with medial osteoarthritis of the knee were treated with HTO in the authors' institution. Seven Patients were excluded from the study because of corrections of complex deformities, and 19 patients because of imprecise long-leg standing radiographs in internal or external rotation. Therefore, 61 patients (42 male and 19 female) aged 18–74 (48 ± 12) years were included. Thirty-one (51%) patients had primary and thirty (49%) had post-traumatic osteoarthritis. A number of 52 patients (85%) had already undergone one or more previous surgeries.

Preoperative planning and postoperative analysis were based on digitalized, long-leg standing radiographs (Figs. 1, 2) and were performed with special planning software (MediCAD, Hectec, Altfraunhofen, Germany) (Figs. 3, 4). A previous study revealed that the standard deviation of repeated measurements with this special planning software concerning the parameters mLDFA, MPTA, LDTA, JLCA, AMA and MAD was significantly lower compared to conventional analysis [10, 26]. Postoperative radiographs were taken 4.3 months (1–27 months) after surgery.

Between 2001 and 2003, 26 patients (43%) were treated with closed-wedge HTO. A standard anterolateral approach was used. Two Kirschner wires were inserted parallel to the

Fig. 1 Preoperative and postoperative long-leg standing radiographs after open-wedge HTO

Fig. 2 Preoperative and postoperative long-leg standing radiographs after closed-wedge HTO

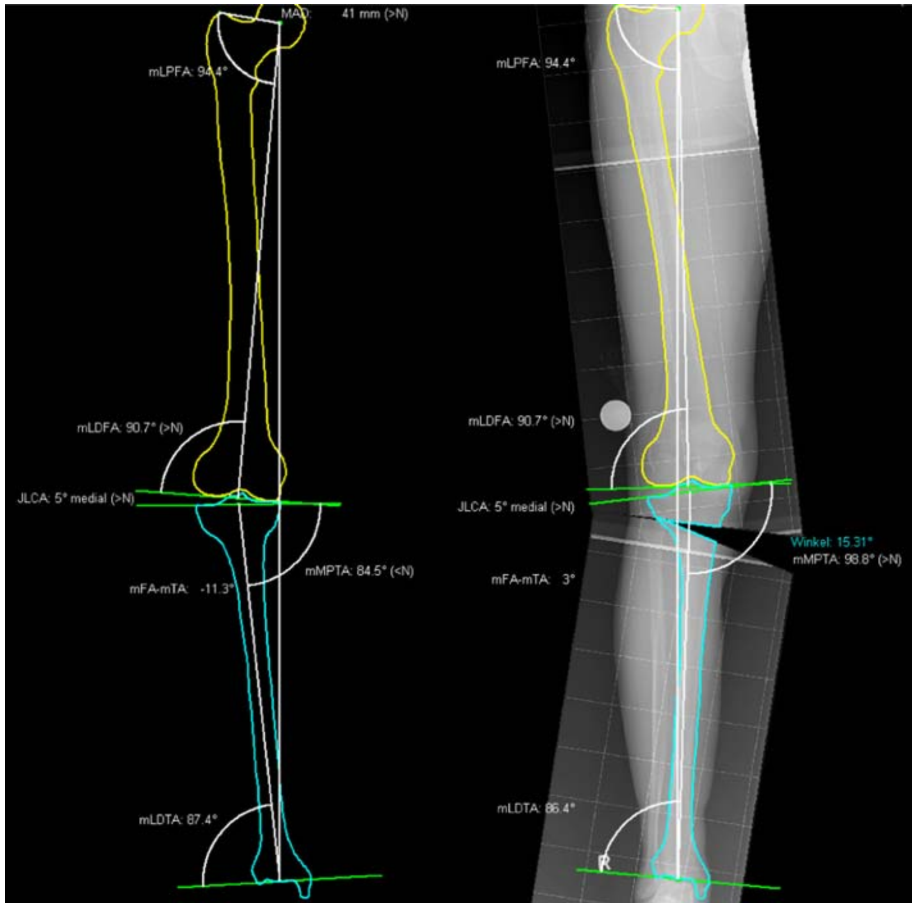

Fig. 3 Preoperative planning of HTO with a special planning software

joint line and two further wires in oblique direction to show the planned osteotomy lines. The osteotomy ended 1 mm lateral to the medial cortex. After removal of the bone, the osteotomy gap was closed and fixed with a conventional screw-plate fixation. The intraoperative mechanical axis was controlled using the cable method [11, 18]. In case of varus deformities of more than 10°, fibular osteotomy was performed.

From 2004 to 2005, 35 patients (57%) received open-wedge HTO. A medial approach was used. Pes anserinus and the superficial medial collateral ligament were shifted dorsally. The osteotomy plane was defined using two parallel Kirschner wires. Along these wires, the osteotomy was performed leaving 1 cm of the lateral cortex intact. With a distraction device, the osteotomy gap was continuously opened and internal fixation was performed using fixed-angle plates (Tomofix or Locking Compression Plate, Synthes, Bettlach, Switzerland). The intraoperative mechanical axis was controlled by the cable method [11, 18]. Bone transplantation from the iliac crest was only performed in corrections of more than 12°.

Age, number of previous surgeries and amount of preoperative varus deformity were comparable in the OWO and CWO group as shown in Table 1. The overall preoperative varus deformity was 7.4° ± 3.8°. In the CWO group, the preoperative varus deformity was 7.9° ± 3.6° and 7.0° ± 3.9° in the OWO group. Furthermore, the percentage of outliners of 3° and more in varus or valgus direction was analysed. Statistical analysis was performed using the software program SPSS for Windows. Results are expressed as mean ± standard error. Comparison between groups was performed using the Student's *t* test and Pearson correlation.

The present study has been approved by the Ethical Committee of the Hanover Medical School, Hanover, Germany. Informed consent was obtained from all patients included in this study.

Results

The overall postoperative mechanical axis measured 2.5° ± 3.2° valgus. The postoperative mechanical axis in the CWO group was 2.2° ± 2.9° valgus and in the OWO group was 2.6° ± 3.3° valgus (Table 2). The amount of correction was 10.1° ± 4.5° in the CWO group and 9.6° ± 3.9° in the OWO group.

The overall postoperative mechanical axis differed from preoperative planning by 2.1° ± 1.7°. The accuracy in the

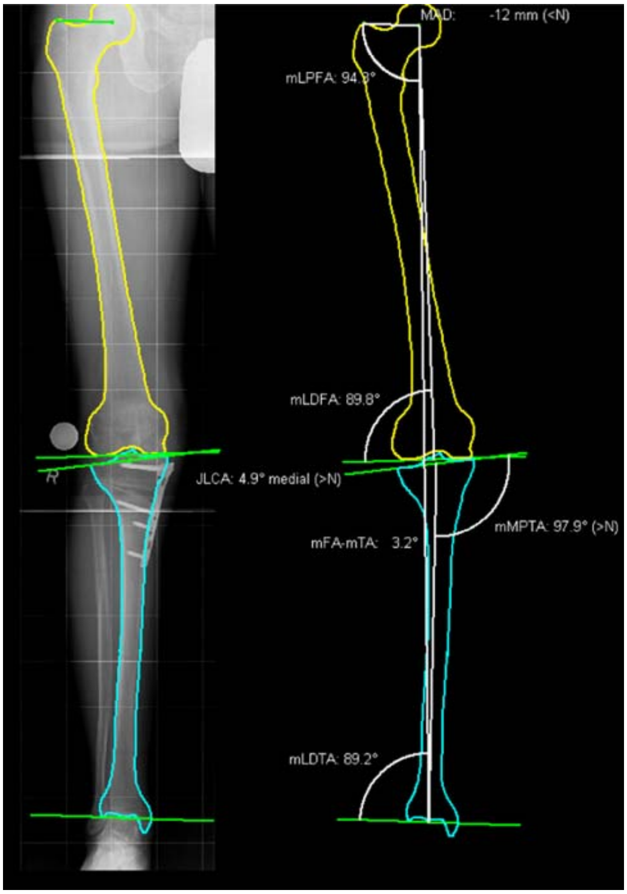

Fig. 4 Postoperative analysis of the mechanical axis

Table 1 Demographic data

	All patients	Patients with CWO	Patients with OWO
Patients	61	26	35
Age (years) (median, range)	48 (18–74)	53 (27–74)	44 (18–68)
Primary varus deformity	31	17	14
Post-traumatic varus deformity	30	9	21
Previous surgeries (median, range)	2 (0–5)	2 (0–5)	2 (0–4)
Preoperative varus deformity	7.4° ± 3.8°	7.9° ± 3.6°	7.0° ± 3.9°

open-wedge group was 1.7° ± 1.6° and significantly higher than in the closed-wedge group, where the difference was 2.6° ± 1.8° ($P = 0.038$). On average, the correction was 0.9° more accurate after OWO compared to CWO.

With a tendency towards undercorrection in both subgroups, accuracy ranged from 5.3° undercorrection up to 4.2° overcorrection in the OWO group. On the other hand, accuracy in the CWO group ranged from 7.0° undercorrection to 4.0° overcorrection. In the OWO group, the difference between postoperative result and preoperative

Table 2 Postoperative results (overall–CWO–OWO)

	All patients	Patients with CWO	Patients with OWO
Postoperative mechanical axis (valgus)	2.5° ± 3.2°	2.2° ± 2.9°	2.6° ± 3.3°
Amount of correction	9.8° ± 4.2°	10.1° ± 4.5°	9.6° ± 3.9°
Accuracy of correction	2.1° ± 1.7°	2.6° ± 1.8°*	1.7° ± 1.6°*

* Statistical significance ($P < 0.05$)

Table 3 Outliners (deviation of 3° and more from the preoperative planning) after CWO and OWO

	All patients	Patients with CWO	Patients with OWO
Outliners (%)	21	31	14
Number of overcorrections after HTO	3	1	2
Number of undercorrections after HTO	10	7	3

planning was 2.4° ± 1.6° in patients with post-traumatic varus deformity, which was significantly more inaccurate than in patients with primary osteoarthritis (1.4° ± 1.2°; $P = 0.029$). In the CWO group, accuracy of HTO did not differ significantly in patients with primary varus deformity ($n = 17$, 2.0° ± 1.4°) compared to those with post-traumatic deformity ($n = 9$, 3.1° ± 2.2°; $P = 0.160$).

Thirteen of the 61 patients had a deviation of the planned correction of 3° or more (21%). In the OWO group, 14% outliners with a deviation of 3° or more were found, whereas 31% outliners were noted in the CWO group. In the OWO group, overcorrections were found in two and undercorrections in three patients. In contrast, only one overcorrection, but seven undercorrections were observed after CWO (Table 3).

Patient age, number of previous surgeries and number of corrections had no significant influence on the accuracy of HTO. Conversion to knee arthroplasty was necessary 51 ± 13 months postoperatively in three patients (12%) after CWO and in one patient (3%) after OWO. No patient developed a non-union or deep infection. Two wound infections requiring revision surgery occurred in both groups. In the CWO group, one persistent peroneal nerve injury was noted. The number of complications was not significantly different between CWO and OWO.

Discussion

The most important findings of this study were a mean difference between preoperative planning and postoperative results of 2.1°, with significantly more accurate corrections after OWO with fixed-angle plates compared to CWO. This is highly important since long-term results of HTO depend on the accuracy of the correction [5, 7, 11, 30]. The relative number of outliers (defined as deviation of three degrees and more compared to the preoperative planning) was more than 100% higher in the CWO group compared to the OWO group.

Only, a few studies have compared the results after OWO and CWO. In a retrospective clinical study of 108 patients with varus deformity, Hoell et al. [13] found no significant difference concerning the postoperative tibiofemoral angle and no significant loss of correction between CWO and OWO. In a prospective, randomized, controlled trial of 92 patients, Brouwer et al. compared CWO and OWO. The authors found more accurate corrections after CWO [4]. Both studies used the Puddu plate, which is less stable compared to fixed-angle plates [1]. However, stability is essential for the open-wedge technique of HTO.

Gaasbeek et al. compared the accuracy of OWO and CWO in an experimental study using five fresh frozen pairs of human cadaver knees and found more precise corrections after OWO. Whereas there was a tendency of undercorrection by OWO, CWO led to overcorrection in their study, although the differences were not statistically significant [8].

Magyar et al. [22] reported about their results after hemicallotasis osteotomy with external fixator, which were more accurate than their results after CWO. Disadvantages of external fixators are less comfort for the patients and the risk of pin tract infections [2]. Higher accuracy after hemicallotasis osteotomy can be explained by the continuous distraction until the desired amount of correction is achieved. In contrast, subtle corrections after bone resection in CWO are difficult.

We noted more precise corrections after OWO in patients with primary compared to post-traumatic deformities. No other studies have been found analysing this parameter. Potential explanations are associated ligament instabilities and joint line incongruencies in the group with post-traumatic deformities.

In this study, accuracy of HTO did not depend on the age of the patient. The influence of age on the accuracy of the correction has not been subject of other studies. However, several studies have shown the negative impact of age on long-term results after HTO [3, 32].

One peroneal nerve lesion occurred after CWO. CWO has a higher risk of peroneal nerve lesions due to the lateral approach and potential fibular osteotomy. In a study of 71 patients with HTO, Leutloff et al. described 5.6% peroneal nerve lesions, 3% wound infection and 1.4% tibial nonunions [19]. Pape et al. found 9.5% peroneal nerve lesions, 7% wound infection and 2.5% secondary operations due to overcorrection in a study of 42 patients with CWO [27]. Galla and Lobenhoffer noted 1.9% wound complications in a retrospective study of 262 open-wedge osteotomies [9]. They observed no secondary loss of correction. Two patients (0.76%) with delayed bone healing received secondary bone grafts.

The non-randomized design is a limitation of the study. Furthermore, the distribution of post-traumatic and primary osteoarthritis was not equal (more patients with post-traumatic osteoarthritis, which had a significantly lower accuracy, were in the OWO group). Moreover, there was a variable interval at the radiologic follow-up examination with long-leg standing radiographs.

Conclusion

Open-wedge osteotomy with fixed-angle plates improves the accuracy of high tibia osteotomy (HTO) significantly and is the recommended technique. The overall difference between preoperative planning and postoperative result was 2.1°. Patients with post-traumatic medial osteoarthritis of the knee seem to have a higher risk of inaccurate corrections. Future studies will have to investigate whether accuracy can be further improved with innovative approaches like intraoperative simulation of weight bearing or the use of navigation modules [11, 15].

Conflict of interest statement The authors declare that they have no conflict of interest. All authors disclose any financial or personal relationship with other people or organizations. The presentation of the issue is independent.

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