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ARTHROSCOPY AND SPORTS MEDICINE

Development of the double level osteotomy in severe varus osteoarthritis showed good outcome by preventing oblique joint line

S. Schröter[1] · H. Nakayama[1,2] · S. Yoshiya[2] · U. Stöckle[1] · A. Ateschrang[1] · J. Gruhn[1]

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Abstract

Introduction The purpose of the study was to describe the development of the surgical technique of double level osteotomy in patients with severe varus malalignment and to investigate the clinical and radiological outcome. It was hypothesized that good clinical results without a higher complication rate can be achieved by double level osteotomy to normalize joint angles and avoid joint line obliquity even in cases of progressed osteoarthritis.

Materials and methods Between 2011 and 2014, 33 patients (37 knees) undergoing double level osteotomies (open wedge HTO and closed wedge DFO) were included; of these, 24 patients (28 knees) were available in mean of 18 ± 10 months for the follow-up examination. Indication was symptomatic varus malalignment and medial compartment osteoarthritis. Postoperatively, these patients were assigned to 20 kg partial weight-bearing using two crutches for 6 weeks followed by full weight-bearing. No braces or casts were used. Full weight-bearing long leg anteroposterior radiographs were obtained preoperatively, after 6 weeks and at the time of final follow-up. Mechanical tibiofemoral angle (mTFA), mechanical lateral distal femoral angle (mLDFA) and medial proximal tibia angle (MPTA) were measured. Clinical outcome was evaluated using Lequesne-, Lysholm-, Oxford-, and IKDC-score at the time of follow-up.

Results The preoperative mTFA of − 11 ± 3° increased to 0 ± 2° at final follow-up. The difference between mTFA-planning and final follow-up was − 2 ± 3° ($p < 0.0006$). At final follow-up, MPTA and mLDFA were 89.2 ± 2° and 87 ± 2°, respectively. The Lysholm, Oxford, Lequesne, and IKDC scores were 88 ± 13, 44 ± 3, 2 ± 2, and 77 ± 12, respectively.

Conclusions This study showed that double level osteotomy for the patients with severe varus malalignment and medial compartment osteoarthritis normalises the alignment, joint-angles, avoids joint line obliquity, and leads to good clinical results, despite progressive osteoarthritis.

Level of evidence Case series, Level IV.

Keywords Double level osteotomy · Osteotomy · HTO · DFO · High tibial osteotomy · Joint line obliquity

✉ S. Schröter
schroeter.steffen@t-online.de

H. Nakayama
hiroshi0273@mac.com

S. Yoshiya
yoshiya@hyo-med.ac.jp

U. Stöckle
Ustoeckle@t-online.de

A. Ateschrang
ate21@gmx.de

J. Gruhn
gruhn.julia@gmail.com

[1] Department of Traumatology and Reconstructive Surgery, BG Traumacenter Tübingen, Schnarrenbergstr. 95, 72076 Tübingen, Germany

[2] Department of Orthopaedic Surgery, Hyogo College of Medicine, Nishinomiya, Japan

Introduction

Osteotomy surgery has witnessed a modern resurgence of interest [1] in both Europe and Asia. Osteotomies around the knee shift the load to the intact compartment, with the aim of improving symptoms, to postpone or avoid arthroplasty. Open wedge HTO is routinely performed in patients with varus malalignment and medial compartment osteoarthritis in an increasing number of hospitals. Success in medial open wedge high tibial osteotomy (HTO) depends on pre-operative deformity analysis, osteotomy planning, surgical technique and implant fixation, whereas concurrent cartilage procedures have little beneficial effect on the clinical and radiological outcome [2]. Using digital planning software, high precision in analysis of the deformity and planning the osteotomy is reported [3]. In the past, open wedge HTO was performed independently on the joint angles. In the case of huge deformity, both femur and tibia are usually involved in the deformity. Single osteotomy may result in excessive joint-line obliquity [4], thus increasing the shear stress at the joint surface [5], and finally resulting in a new bony deformity. The aim of the double level osteotomy for varus deformity is to normalise knee joint angles and unload the affected joint compartment [6–8]. The first report of double level osteotomy (DLO) of the knee was reported by Benjamin et al. [9]. In the following years, the encouraging report of DLO could not be confirmed [10–12]. However, there are a few reports of DLO from some selected centres, which again reported good results after DLO in the case of huge varus deformity involving the femur and tibia [4, 6–8]. The survival rate was 96% after 100 months and is superior to most of the long-term results reported after HTO [13] or distal femur osteotomy (DFO) [14]. Restoring the normal anatomy seems to be a forward-looking concept in osteotomies to improve the survival rate. Moreover, if the results deteriorate and revision surgery is necessary after an osteotomy, the normal anatomy of the knee joint will make probably a total knee arthroplasty more easy compared to post HTO [15] or even an unicompartimental knee arthroplasty possible [16]. However, these few reports imply that the surgical technique for DLO is a highly demanding surgery; either the complication rate is high or the majority of the orthopaedic surgeons are not familiar with the principle of double level osteotomy.

Meanwhile, new surgical techniques of osteotomies have been described [17, 18]. In particular, angular stable locking plates have become more popular for the fixation of osteotomies and the biomechanical characteristics are being investigated [19–21]. Because of these developments, DLO has become more popular, especially in Germany, where the number of procedures is increasing continuously; meanwhile, the surgical technique has even spread to Japan.

The purpose of the study was to describe the stepwise development and changes in the surgical technique of DLO and investigate the clinical as well as radiological outcomes. It was hypothesised that a normalised anatomy of the joint angles and avoiding of joint line obliquity is possible and leads to good clinical result even in case of progressed osteoarthritis without a higher complication rate.

Patients and methods

This was a retrospective study from patients undergoing double level osteotomies (open wedge HTO and closed wedge DFO) after approval of the local ethics committee (103/2013BO2). Informed consent was obtained from all individuals participating in the study. Between January 2011 and April 2014, in our department $n = 249$ received an osteotomy in case of varus deformity. Out of these cases $n = 33$ patients (37 knees) received a double level osteotomy by the first author (S.S.) or by A.A. However, $n = 24$ patients (28 knees) were available for the follow-up examination.

Deformity analysis was performed preoperatively and at the time of follow-up using mediCAD digital planning software (Hectec, Landshut, Germany). The Cartesian coordinates of anatomical landmarks determine the mechanical and anatomical axes of the coronal plane to generate conventional alignment angles [22]. According to the deformity analysis, closed wedge and open wedge osteotomy were simulated with mediCAD (Hectec, Landshut, Germany) to generate normalised joint angles, a correction angle, and opening and closing distance, respectively (Fig. 1A-C).

Indication for surgery

Indication for the DLO was symptomatic severe varus malalignment and medial compartment osteoarthritis (Fig. 2). If the simulation of an open wedge HTO resulted in a MPTA of more than 94°, the double level osteotomy was considered—or if there was in the deformity analysis a mLDFA > 90° combined with a MPTA < 87°. The concept of indication was 2011 developed and continuously realized in our department. Therefore, the numbers were increased stepwise. All patients were active, despite their osteoarthritis. Range of motion should be more than 20° extension and more than 100° flexion.

Surgical technique

Surgery was performed under spinal or general anaesthesia. Single dose antibiotics and prophylactic low-dose heparin were administered. Arthroscopy was performed in each

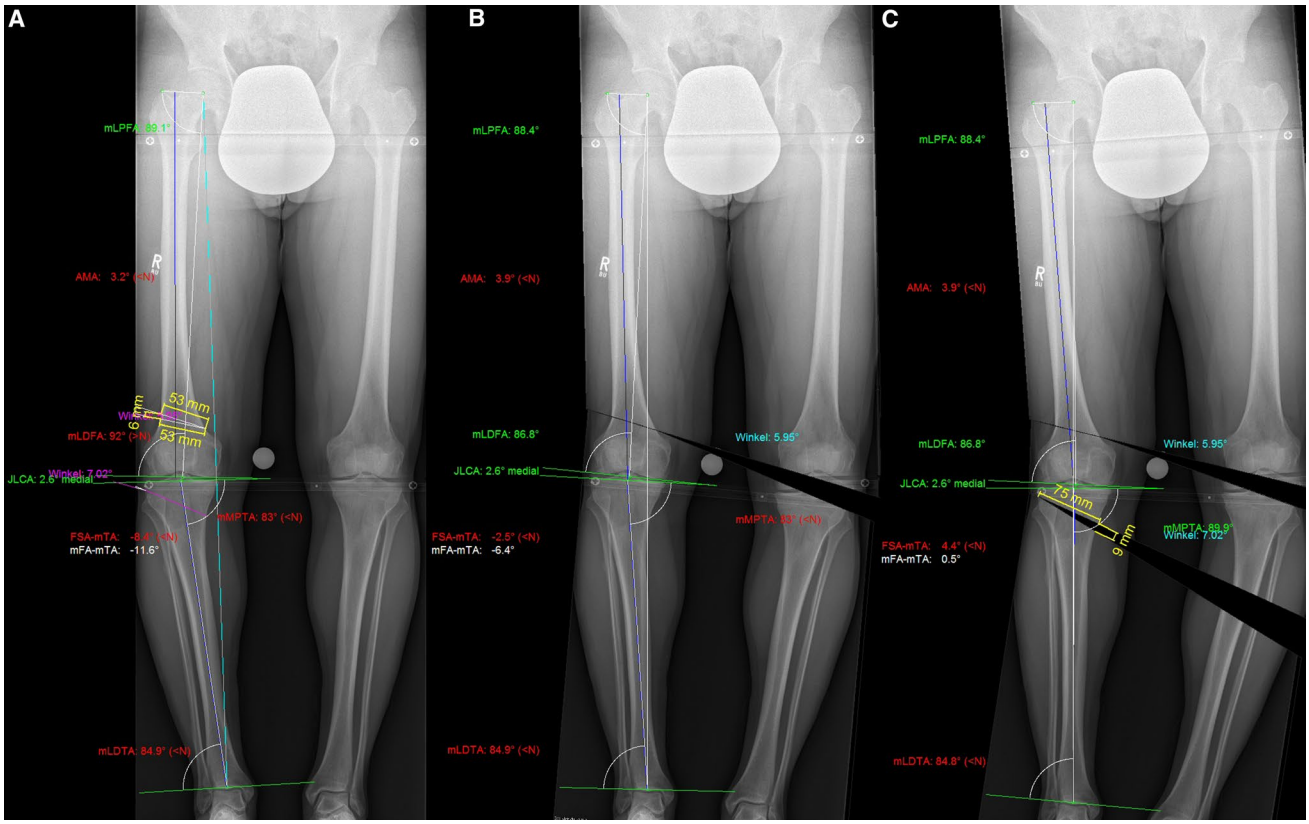

Fig. 1 Deformity analysis and planning of the long leg full weight bearing radiographs using mediCAD digital planning software. *mFA-mTA* Means mechanical tibiofemoral angle. *MPTA* medial proximal tibia angle. *mLDFA* mechanical lateral distal femur angle. *mLDTA* mechanical lateral distal tibia angle. *mLPFA* mechanical lateral proximal femur angle. **a** Deformity analysis according Dror Paly. **b** Simulation of the distal femur osteotomy closed wedge. The height of the wedge base is measured in A with 6 mm. **c** Simulation of the open wedge high tibial osteotomy with an opening of 9 mm

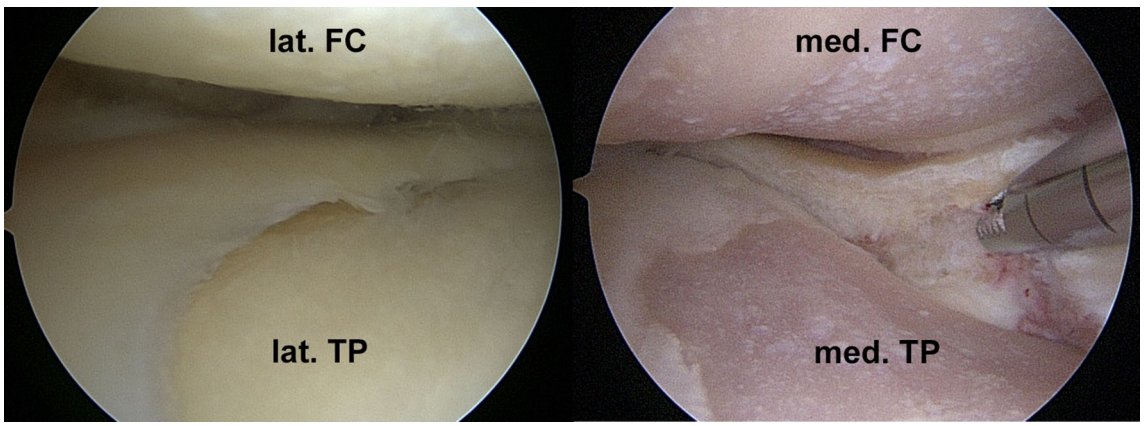

Fig. 2 Arthroscopic findings of the right knee in a patient with the indication for double level osteotomy. Lateral no cartilage lesion and medial grade 4 osteoarthritis. *Lat*. lateral; *med*. medial; *TP* tibiaplateau; *FC* femurcondyl

patient, either simultaneous to the osteotomy or earlier as outpatient surgery, and the findings were documented.

The double level osteotomy procedure always started with the closed wedge DFO. For the first cases, a 20-cm longitudinal incision was used on the lateral side of the femur. The Musculus vastus lateralis was carefully dissected from the intermuscular septum until the metaphysis of the femur was exposed. Afterwards, the blade plate device was

hammered into the femur condyle to define the positioning of the blade plate in a stable bone. K-wires were used to mark the osteotomy according to the planning. The goal of osteotomy was that the length of the proximal and distal cut of the osteotomy should be the same to avoid overstuffing of the lateral cortex. The height of the wedge was measured between the k-wires, which were placed proximally and distally. The single plane closed wedge osteotomy was performed with the aim of an intact hinge point at the medial cortex. The blade plate (DePuySynthes, Solothurn, Switzerland) was inserted in the prepared distal femur and the tension device was mounted proximal to the plate. The tension was increased slowly until the osteotomy was closed and compression of the osteotomy was achieved. The blade plate was fixed with 4.5 bicortical screws and the alignment was controlled using the alignment rod and compared to the digital planning (first step: distal femur osteotomy)(Fig. 3a–d).

After six cases, the fixation technique after DFO was changed from the blade plate to the plate fixator (TomoFix MDF first generation, DePuySynthes). The tension device was still used for the compression of the osteotomy. Alex Staubli from Switzerland invented the biplanar distal femur osteotomy and further developments of the technique were done by the AO Knee Expert Group [23]. Initially, this was used for the medial closed wedge DFO and later for the lateral closed wedge DFO (Fig. 4). With this technique, further development of the approach was possible. A research group

Fig. 4 Postoperative X-ray of a closed wedge biplanar distal femur osteotomy and fixation with the TomoFix MDF

Fig. 3 Intraoperative fluoroscopy of a closed wedge distal femur osteotomy using the blade plate. **a** K-wires to define the wedge, **b** after removal of the wedge; **c** closing the osteotomy using the tension device. **d** Control of the alignment after the closed wedge distal femur osteotomy

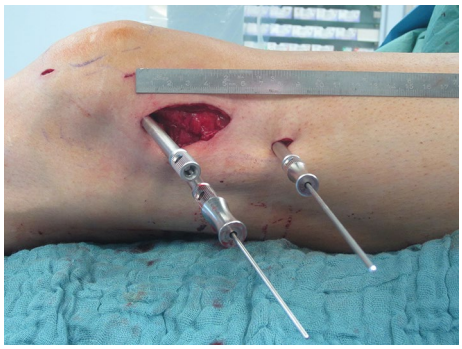

Fig. 5 Intraoperative minimal-invasive approach for the closed wedge distal femur osteotomy

from the Netherlands developed this technique further with a minimally invasive approach [24]. Again, the minimally invasive subvastus-approach for the lateral closed wedge DFO was modified by the AO Joint Preservation and Osteotomy Group, especially Kristian Kley and Philipp Lobenhoffer; this has become the technique which is now used. The approach involves a 5–7 cm longitudinal skin incision (Fig. 5). The musculus vastus lateralis is retracted to the anterior and the dorsal septum is dissected to a length of 3 cm in order to position a radiolucent retractor (Radiolucent retractor pelvic medium 263 mm, No. 03.100.111 DePuySynthes, Solothurn, Switzerland) in the back to protect the neurovascular structures. Four 2 mm k-wires were positioned according to the planning. The distance of the k-wires was measured by a precision calliper (Calliper for corpectomy, short, No 324.060 DePuySynthes, Solothurn, Switzerland). At first the transversal cut was performed and followed by the ascending cut. Afterwards the wedge could be removed. The osteotomy could be closed slowly by valgus stress. The second-generation TomoFix MDF plate (DePuySynthes, Solothurn, Switzerland) from the contralateral side was bent and positioned under the Musculus vastus lateralis. Initially, the 5.0 locking screws fixed the plate to the distal femur. Under valgus stress, a bicortical hole was positioned eccentric in the combi-hole of the TomoFix MDF plate to provide more compression to the osteotomy. Using a 1-cm proximal incision at the level of the proximal holes, the drilling sleeve could be inserted and the 5.0 locking screws could be positioned. At the very least, the bicortical screw was changed to a bicortical angular locking screw. The drain was placed and the layers were closed. The alignment was controlled and compared to the plan. Afterwards, the surgery was completed with the open wedge HTO.

The open wedge HTO was performed using a technique that was similar to previous descriptions [18, 25]. A 5-cm longitudinal incision, sited distal to the medial joint line at the level of the pes anserinus, facilitated dissection to expose the medial tibia. Two guiding k-wires entered the tibia at the metaphyseal flare, parallel to the tibial slope and aimed towards the tibiofibular joint tip. The transverse plane osteotomy was made to within 1 cm of the lateral cortex. The biplanar ascending osteotomy was created under the tibial tuberosity at an angle of 130°. The osteotomy was completed, osteotomes were stacked and the gap was gently spread using a spreader which was positioned at the posterior border. The result was controlled using the alignment rod again. Neither bone graft nor bone substitute was used in the osteotomy gap. The TomoFix™ MHT plate (DePuy Synthes, Solothurn, Switzerland) was placed anteromedially and fixed with 4 proximal 5.0 mm locking screws. To compress the lateral hinge, a bicortical temporary lag screw was inserted in the first plate hole distal to the osteotomy. The remaining distal holes were filled with monocortical 5.0 mm locking screws before the bicortical lag screw was then replaced with a 5.0-mm bicortical locking screw. Finally, the alignment was controlled using the alignment rod (Fig. 6). Soft tissues were closed over a drain.

Postoperative rehabilitation

Postoperatively, the patients were assigned to 20 kg partial weight-bearing using two crutches for 6 weeks followed by full-weight-bearing. No braces or casts were used. Active physiotherapy was started postoperatively after removal of the drain. In addition, the patients used an active motion splint (CAMOped; OPED, Valley/Oberlaindern, Germany) for 6 weeks. The active motion splint is a kind of "bed bike", like a continuous passive motion machine and is used for active therapy rather than for fixation or extra stability.

Radiographs and clinical examination

Radiographs of the knee joint (anteroposterior and lateral view) and full weight-bearing long leg anteroposterior

Fig. 6 Control of the alignment after fixation of the closed wedge distal femur osteotomy (TomoFix MDF) and the open wedge high tibial osteotomy (TomoFix MHT)

radiographs were obtained preoperatively, after 6 weeks and at follow-up examination. Radiographic measurements were assessed using mechanical tibiofemoral angle (mTFA), mechanical lateral distal femoral angle (mLDFA) and medial proximal tibia angle (MPTA). Clinical outcome was evaluated using established instruments (Lequesne-, Lysholm-, Oxford-, and IKDC-score) at the time of follow-up.

Statistical analysis

SPSS for Windows and GraphPad Prism for Mac (GraphPad Software, Inc.; Version 5) were used for statistical analysis and graphical representation, respectively. For statistical analysis, dependent or independent t-tests were used according to the data (normal distribution). $P < 0.05$ was considered significant.

Results

In Table 1, the patient characteristics are presented. The majority of the patients had advanced or severe osteoarthritis (Fig. 7). The preoperative mTFA of $-11 \pm 3°$ increased to $1 \pm 2°$ at weeks and $0 \pm 2°$ at the time of follow-up. The difference between mTFA planning and final follow-up was $-2 \pm 3°$ ($p < 0.0006$) The difference between 6 weeks' follow-up and the final follow-up was $-1 \pm 2°$ ($p < 0.0024$). The difference between the MPTA planning and the MPTA after 6 weeks was $-1 \pm 2°$ (0.0004), while no difference was found between the mLDFA planning and after 6 weeks. The difference for MPTA between 6 weeks follow-up and final follow-up was $-1 \pm 2°$ ($p < 0.0359$). The difference between 6 weeks' follow-up and final follow-up for the mLDFA was just $0.3 \pm 1°$ ($p < 0.0364$). The MPTA was at final follow-up $89° \pm 2°$ and the mLDFA $87° \pm 2°$ (Table 2). Therefore, the joint angles were restored to norm values and a joint line obliquity could be avoided. All osteotomies were healed at final follow-up. Non-union was not observed.

In this retrospective study, clinical results were only analysed at the time of final follow-up. The Lysholm, Oxford, Lequesne, and IKDC score were 88 ± 13, 44 ± 3, 2 ± 2, and 77 ± 12, respectively. No arthroplasty was required and all patients answered yes when asked whether they would like to have the procedure again. The high rate of satisfaction was 4 patients with a DLO at both sides.

Table 1 Patient characteristics

Patient characteristics		
Age (years)	Mean: 50.0 ± 9.7	Range: 30–66
Gender	Female: 5	Male: 23
Body Mass Index (BMI) in kg/m^2	29.9 ± 5.0	Range: 21.2–43.0
Affected side	Right: 15	Left: 13
Follow-up (months)	18 ± 10	Range: 5–43

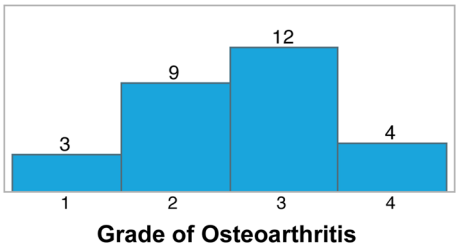

Fig. 7 Distribution of osteoarthritis according Kellgren and Lawrence [26]

Complications

One patient had a complication with a fracture of the medial hinge after distal femur osteotomy; this resulted in an overcorrection, and the problem was solved with a revision surgery. The blade plate was removed and the hinge was protected by a medial approach and a 3.5 locking compression plate. Afterwards, the alignment was adjusted and the osteotomy was fixed by an LISS plate and 5.0 locking screws. The final healing was uneventful.

Table 2 Measurements in the long leg full weight-bearing radiograph

	Mean ± SD	Range
Height of wedge DFO (mm)	6 ± 2	3–11
Height of opening HTO (mm)	9 ± 2	4–16
mTFA preoperative (°)	− 11° ± 3°	− 6° to − 17°
mTFA planning	2° ± 2°	1°–3°
mTFA 6 weeks	1° ± 2°	− 4° to 4°
mTFA time of follow-up	0° ± 2°	− 7° to 5°
MPTA pre-op	84° ± 3°	78°–88°
MPTA planning	91° ± 2°	86°–94°
MPTA 6 weeks	90° ± 2°	87°–95°
MPTA time of follow-up	89° ± 2°	81°–93°
mLDFA pre-op	92° ± 2°	87°–96°
mLDFA planning	86° ± 1°	84°–89°
mLDFA 6 weeks	86° ± 2°	83°–89°
mLDFA time of follow-up	87° ± 2°	83°–90°

DFO Distal femur osteotomy, *HTO* high tibial osteotomy, *mTFA* mechanical tibiofemoral angle, *MPTA* medial proximal femur angle, *mLDFA* mechanical lateral distal femur angle

Discussion

Double level osteotomies were introduced for joint preservation in severe unicompartimental OA to avoid joint line obliquity [6, 27]. Inferior results of high tibial osteotomies were reported in combined (tibia and femur) deformities compared to a deformity just at the proximal tibia [28]. Therefore, the most important finding of the study was to restore the norm joint angles at the distal femur (mLDFA) and the proximal tibia (MPTA) to avoid joint line obliquity and achieve a normal alignment (mTFA) which results in a good clinical outcome. Moreover, further developments of the surgical technique could prevent complications, as observed when using the blade plate. Using the minimally invasive approach, the skin incision could be reduced and the procedure remained safe. Bone healing was achieved in all cases.

Benjamin was the first to report a huge series of $n = 57$ double level osteotomies between 1961 and 1965 which were performed in England [9]. The indications were both rheumatoid osteoarthritis and osteoarthritis. The experience of this case report was similar to the results presented here—satisfaction of the patients was high and some of them requested the surgery on the other side. However, there were some complications and problems (limitation of range of motion and six patients without reduced pain because of severe patellofemoral osteoarthritis), which were connected to the available surgical technique using an intra-articular approach and unstable fixation in a plaster cast, as well as the indication. Despite the good clinical results, analyses of the deformity were not reported.

However, preoperative analysis of the alignment in osteoarthritic knees and varus deformity reported an mLDFA $> 90°$ in 13.5% of cases [4]. Nowadays, digital planning software makes it easy and fast to analyse the deformity with high precision [3] and determine the location of the deformity (femur, tibia or combination of both). In the presented study, preoperative mLDFA and MPTA were $92 \pm 2°$ and $84 \pm 3°$, respectively. Varus deformity of the distal femur is associated with joint line obliquity and may cause a recurrence of varus deformity after high tibial osteotomy [28]. Moreover, in the 3D finite element models of open wedge HTO and high correction angles which results in a joint line obliquity of more than 5° induce detrimental stress to the articular cartilage [5].

Therefore, with respect to the indication, the authors agreed with other groups that an mLDFA $> 90°$ is an indication for distal femur osteotomy [4, 6, 29]. Simulating osteotomy starting with the open wedge HTO, and with the discovery of an MPTA $> 93°$, double level osteotomy was considered.

The aim of double level osteotomy around the knee for varus deformity was to restore normal anatomy or unload an affected joint compartment, while simultaneously normalising knee joint angles and the orientation. Therefore, the aim of the correction was not a huge overcorrection, but rather a slight overcorrection with an mTFA of 0–2° valgus.

Saragaglia et al. reported navigation in a double level osteotomy to adjust the correct alignment [4]. Comparing to the presented results, high precision was found just by using the digital planning software. However, surprisingly, no significant difference was found between the planned mLDFA and the 6 weeks follow-up. In contrast to these findings, a significant difference in the MPTA was found between planning and the 6 weeks follow-up. Therefore, the difference in the mTFA between planning and after 6 weeks follow-up could be explained. Furthermore, the loss of correction between 6 weeks and final follow-up of approximately one degree was also localised in the proximal tibia. There was a further decrease of the MPTA. These findings confirm previous results from our group in respect to the open wedge HTO. However, the closed DFO shows a very high precision when comparing planning, 6 weeks follow-up and final follow-up.

In the presented study, the developments, especially for distal femur osteotomy, could improve the surgical technique. The biplanar technique of the distal femur osteotomy allows the hinge point to be defined more distally and the fat pad between the suprapatellar bursa and the dorsal side of the quadriceps muscles and tendon on the one side and the anterior part of the distal femur on the other side to be protected. Furthermore, the bone loss is reduced [30]. The new plates make the procedure easier to control and reduce the risk of hinge fracture because a hammering of the blade inside the distal femur is not necessary any more. Nevertheless, the blade plate is an angular stable implant that is biomechanically stable [19], but it is surgically demanding. The minimally invasive approach leads to smaller skin incisions. However, no advantage of the minimally-invasive approach for the distal femur osteotomy could be proven with these results. The study design was retrospective and the primary outcome did not include the evaluation of superior results of one to the other surgical technique. Nevertheless, a small skin incision is always an advantage of any procedure. To the experience of the first and senior author the minimal invasive approach results in more early good function of the knee.

All patients were active, despite the progressive osteoarthritis. Comparing the clinical results to findings in other studies, our findings were comparable compared to patients after open wedge HTO [31] or even superior [32–34] despite the higher grade of osteoarthritis. There is more than one reason for this finding. First, in the case of huge varus deformity, the lateral compartment is usually intact and was

unloaded before the surgery. Second, comparing a single level osteotomy to a double level osteotomy in huge varus deformity, the ligaments had less tension after the osteotomy because of the distribution of the correction to the femur and tibia. Third, the double level osteotomy restores the joint angle close norm values and avoid high shear forces which increase to lateral if the MPTA is more than 94° [5]. Fourth, taken into account that a change in the alignment results in 5% load change in the medial compartment [35], the difference regarding load is theoretically more high in huge correction compared to small correction. Fifth, using the recently developed techniques for osteotomy, the procedure has become less invasive and no problems like the limitation of flexion [9] have been observed in the collective. Finally, the correct indication is important.

Limitations

This retrospective study has some limitations. The clinical scores are only available at the time of final follow-up. Therefore, no statement could be given about the amount of improvement. However, a clue that the DLO is very effective is that four patients stated that they would like to have the procedure in both sides, and no patient needed an arthroplasty. In the presented study, there was more than one surgical technique for the DFO. However, whether the results become superior to those presented when using the new minimally invasive technique for the DFO could not be answered. Seven patients were lost to follow-up, which could have influenced the presented results. However, the main reason for the patients failing to attend the study was the distance from their home to the hospital.

Conclusion

This study showed that double level osteotomy for the patients with severe varus malalignment and medial compartment osteoarthritis normalise the alignment, joint-angles, avoid joint line obliquity and leads to good clinical results, despite progressive osteoarthritis.

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