Open-wedge HTO with a locking plate (TomoFix®) for treatment **of medial monocompartment osteoarthritis**

Introduction

The combination of malalignment and unicompartmental osteoarthritis, more often encountered on the medial side – also called medial compartment degenerative joint disease – is a common problem which arises in all age groups [1, 2].

Young patients in particular have a high expectancy in regard to regaining their full functional capacity.

Joint-preserving therapies and especially realignment osteotomy are steadily gaining importance.

The following survey covers indications, technique, and results of high tibial osteotomies with an internal plate fixator in cases of varus overload malalignment.

The proximal high tibial osteotomy (HTO) is an established procedure for the treatment of varus osteoarthritis, and can be either of the additive open-wedge type or of the subtractive closed-wedge kind.

A special type of HTO is the dome-osteotomy, a pendular osteotomy of the proximal tibia.

That is considered technically challenging but which, however, has not proved very successful – bone healing is uncertain.

The closed-wedge osteotomy of the high tibia with removal of a lateral bone wedge [3] is still being carried out today.

The closed-wedge technique, which requires removal of a wedge of bone from the lateral aspect of the tibia in the metaphyseal region, necessitates cutting along two planes.

Also, shortening of the fibula is involved. Apart from the leg-shortening that issues, neurological deficits of up to 27% and several shortcomings that include difficulty in intraoperatively controlling the amount of achieved correction, necessity to re-insert the extensor muscle, persistent ligamentous instability, and problems associated with the implantation of an artificial knee at a later date, have been reported [2, 4, 5].

Closed-wedge HTO tends to undercorrection [6].

Because of the above mentioned disadvantages of closed-wedge high-tibial osteotomy, the option of an *open-wedge* technique gained importance.

Particularly interesting were the encouraging results published by Hernigou on open-wedge high-tibial osteotomy (OWHTO) [7].

Stimulated by this, a group of orthopaedic surgeons joined forces as a 'Knee Expert Group' with the support of the AO-Foundation® with the aim of closely examining the advantages and disadvantages of the open-wedge technique, and to further develop this procedure, as required [8].
Generally, the open-wedge osteotomy of the tibia offers several advantages: The technique is simple, the approach causes little trauma and the correction can be evaluated and fine-tuned intraoperatively.

Up to now, the problems of open-wedge osteotomy were the unreliable fixation and the necessity for bone grafting.

There are several options for the fixation of open-wedge osteotomies of the proximal tibia.

In the case of external stabilization by an external fixator one needs to consider the patient's lack of comfort and especially the high risk of pin-track infections due to the lengthy period of time it needs to be worn.

Plates with interfragment metal spacers (spacer plates) are easy to implant but have biomechanical disadvantages and do not stimulate bone healing within the osteotomy gap [9,10].

Larger gaps, however, require autografts (spongiosa plasty) or bone substitutes.

The development of LCP (Locked Compression Plates) with fixed-angle fixation of screws in the threaded holes (so-called internal plate fixators) offers new fixation methods, which, in traumatology, have already proved significantly more stable.

In addition, the controlled elasticity of these implants allows spontaneous osteogenesis, which signifies that generally no autografts are required [8,11].

After first using commonly available osteosynthesis material (AO stainless steel T-plates, 95° titanium blade plates and the 1st generation Puddu plate), with standard surgical procedures as practised by Hernigou et al. in open-wedge HTO, we realised that significant improvement could only be made on two fronts:
a) by use of a more appropriate surgical technique and
b) by promoting osteogenesis through an angular-stable fixation device with just the correct amount of elasticity [9, 11].

Therefore, in 1999, our clinic developed together with the AO KNEG (Knee Expert Group) and the former Mathys Company and later Synthes Company (Oberdorf, Switzerland) a new surgical concept and decided to carry out open-wedge high tibial osteotomies for treatment of unicompartmental osteoarthritis only with fixation by means of special internal locked-compression plate fixators [8, 12-15].

Indications and contraindications

The indication for open-wedge valgisation osteotomy of the proximal tibia is mainly given for unicompartmental medial osteoarthritis and varus malalignment of the lower limb, mainly caused by the proximal tibia. This procedure is ideally suited for patients with a high demand for physical activity.

The corrective osteotomy can be carried out in combination with other reconstructive interventions in the medial compartment, such as osteochondral autologous transfer system (OATS), autologous chondrocyte transplantation (ACT), matrix-associated chondrocyte implantation (MACI), or collagen meniscus implants (CMI) [16].
The preoperative range of motion of the knee joint in extension/flexion should be at least 0/10/120°.

The age of the patient should not exceed 65 years in males or 55 years in females.

Contraindications exist in case of considerable loss of meniscal tissue in the lateral compartment, for third to fourth-degree chondropathy [17], a manifest osteoarthritis of the lateral segment of the joint and restricted mobility of the knee, and especially for extension deficit of more than 20°.

This intervention should not be carried out in cases of precarious soft-tissue conditions at the medial tibial head as well as acute or chronic inflammation.

Due to the significantly impaired bone healing especially in open-wedge osteotomies, nicotine abuse is a contraindication.
The ideal patient for high tibial open-wedge osteotomy is shown in Tab. 1. [8, 16]

Diagnostics

Preoperatively, X-rays of the knee joint are taken in both planes; a tangential image of the patella should be included.

A full-leg weight-bearing x-ray for determining the position of the so-called “mechanical axis” of the leg (Mikulicz’ line) is also required.

The axes of the legs in standing should be examined in both frontal as well as sagittal planes.

In addition to the static examination, the gait pattern has to be evaluated as well.

During the phase of weight-bearing of the leg, a lateral opening, or lateral thrust of the knee joint may be observed.

It is important to take this into account during preoperative planning. This opening of the lateral joint space and the required correction must be entered on the drawing, or calculated, while planning the operation.

Otherwise overcorrection, in terms of valgisation, will result [8,18, 19].

A weight-bearing x-ray of the knee in 45° posteroanterior flexion (so-called Rosenberg image [20]) and MRI can show the extent of damage to the joint compartments.

A bone scan will demonstrate the effect of overload on the affected portion of the joint resulting from enhanced activity.

However, these diagnostic measures are not mandatory.

CT examination is only indicated if the clinical examination gives reason to suspect torsional deformity [18].

With axial CT imaging, femoral and tibial torsion angles of the long bones as well as the distance between the tibial tuberosity and the femoral trochlea, the so-called TTTG (tibia tuberosity trochlear groove) distance can be measured.

Preoperative planning of the correction

Deformity analysis and the planning of the correction – based on the full leg weight-bearing x-ray – are carried out either digitally or are drawn on paper.

The principles for planning are the same for either method, however, the magnification factor of the x-ray should, if necessary, be taken into account.

The extent of the opening required for the osteotomy can now be measured (in mm) on the medial tibial cortex [8, 14, 19].

Fujisawa et al. [21] were able to demonstrate that the best results following valgisation displacement osteotomy were achieved if the mechanical axis postoperatively intersects the joint line at about 62 % of the medial/lateral width of the tibial head.

Agneskirchner et al. [22] were able to confirm this by biomechanical experiments.

The 62 %-point which lies slightly lateral to the intercondylar eminence is accordingly marked on the knee baseline.

Surgical concept

The intervention is carried out in the supine position. A knee bench and a footrest are attached to the operating table.

The full leg – including the iliac crest – is draped free for possible bone-graft harvesting and for intraoperative control of the axis of the leg from the center of the hip to the center of the ankle.

The intervention itself is performed with knee flexion of 45°, the foot resting on the operating table.

A tourniquet is normally not required; optionally, a sterile tourniquet may be used.

Since an image intensifier is required in controlling the surgery, this should be positioned on the opposite side of the table.

At first, always, arthroscopy is carried out in order to evaluate the condition of the cartilage and the menisci, especially within the lateral compartment.

When indicated, this includes resection of the medial meniscus and smoothening of the cartilage or even the ablation of anterior and sometimes medial plateau osteophytes in order to overcome the extension deficit.

The skin and soft-tissue conditions have to be free of irritation and the surgical approach needs to take into account pre-existing surgical scars.

We prefer skin incision of 6-8 cm from the insertion of the pes anserinus dorsocranially upward towards the posteromedial corner of the tibial head, but longitudinal incisions are also possible.

After transection of the subcutis, the tendons of the pes anserinus are retracted posteriorly and distally by a hook.

The distal fibers of the superficial medial collateral ligament are carefully detached and the rear edge of the tibia displayed.

Employing image-intensifier monitoring of the AP plane, two 3.0 mm lancet tipped k-wires, which mark the height and direction of the horizontal osteotomy, are placed exactly parallel to the articular surface.

The AP k-wire marks the center of the joint and is introduced parallel to the tibial slope (Fig. 1).

The point to be aimed at is the proximal end of the tibiofibular joint. The wires end exactly at the edge of the lateral tibial cortex.

For the correct depth of the cut, 10 mm are subtracted from the total depth of transection as measured on the image intensifier.

Osteotomy

The horizontal osteotomy (always with new saw blades) proceeds below the guiding wires in the posterior two-thirds of the tibia.

The anterior ascending osteotomy in the ventral third of the tibia runs upward, cranially, behind the tuberosity and through the entire far cortex, always parallel to the anterior edge of the tibia (Fig. 2).

The two planes form an angle of about 110°. During the entire time of sawing, the oscillating saw is flushed continuously.

After reaching the designated depth of the osteotomy, 2-6 specially designed flat chisels are carefully inserted into the horizontal osteotomy gap, one after the other, opening it slowly after reaching the preoperatively determined opening, the flat chisels are removed, and a bone spreader is inserted intercortically in the far postero-medial corner of the osteotomy.

The leg is extended over a towel roll and the corrected leg axis examined clinically and radiologically with the help of a long especially designed alignment rod (Synthes Inc., Oberdorf, Switzerland).
While spreading the osteotomy open, the inclination of the tibial slope in the sagittal plane must be watched carefully.

In cases of pure varus correction, it should not be changed.

This requires a greater osteotomy gap opening posteriorly than anteriorly, due to the geometry of the metaphyseal tibial!

In cases of varus malalignment with additional extension deficit or/and anterior knee instability, a valgisation-extension displacement osteotomy of the proximal tibia (i.e. a required reduction of tibial slope, but never less than 0°) could lead to a correction of the axis, and coincidentally, to the diminution of the anterior translation in full extension.

In such cases, the asymmetrical opening of the gap must then be accentuated. Conversely, a valgisation-flexion high tibial osteotomy (i.e. a required increase of tibial slope) allows stabilization of posterolateral knee instability and correction to an extent to be expected in morphologically varus knees.

In such cases, the osteotomy is opened rather more anteriorly than posteriorly by using special wedges [8].

Internal plate fixator TomoFix Medial Proximal Tibia

After achieving the preoperatively designated correction of the axis, the internal plate fixator with 8 unidirectional conical and combi-holes (since 2009 the new-generation plate with identical biomechanical properties (Fig. 3)) with pre-mounted spacers is inserted through the subcutaneous tunnel and then the proximal 3 screws are inserted and locked into the proximal top of the T-shaped plate under image-intensifier control.

The next step is to temporarily secure the plate by a lag screw in the first distal hole.

This measure pulls the distal segment of the osteotomy towards the plate fixator and simultaneously compresses the lateral cortex bridge (Fig. 4).

Subsequently, after removal of the pre-mounted spacers, locking screws are inserted mono- or bicortically in the remaining plate holes from distal to proximal.

After tightening all other screws, the lag screw is replaced by a bicortical locking screw.

Finally, the bone spreader is removed. In case of an intact bone bridge and good bone contact of the ascending ventral osteotomy, it is possible to refrain from employing autologous spongiosa grafts for gaps up to about 20 mm In cases of osteoporotic bone or problematic bone healing (e.g. due to nicotine abuse) it is recommended to use autologous bone graft from the iliac crest.

After documentation of the operation results by means of the image intensifier in both planes, the wound is closed layer for layer.

Post-Operative Management

Mobilization starts on day 1 postoperatively using forearm crutches with partial weight-bearing of 15-20 kg bodyweight.

Incremental weight-bearing depends on the level of pain. Generally it is possible to start full weight-bearing without crutches in the fifth postoperative week, which means that by the end of the sixth postoperative week normal weight-bearing capability should have returned.

The range of motion of the knee joint does not need to be restricted, and there is no need for ortheses.

Until return to full weight-bearing, medical antithrombotic prophylaxis by low-molecular-weight heparin should be continued.

X-ray examination of the knee joint and proximal lower limb in both planes is carried out on the third postoperative day and six weeks after the intervention (a full-leg weight-bearing x-ray is made at a later date).

By then, the lateral and the anterior bone bridges should show stable bone healing, the gap itself will naturally still be open.

It is important to emphasize that full weight-bearing and physical activity does not depend on the completion of bone remodelling within the gap, as this process can take up to a year (Fig. 5).

In case of complaints, implant removal might be carried out 12-18 months postoperatively [8, 16, 23].

In our clinic, implants are generally removed in about half the number of patients.

Radiological Results

Open-wedge osteotomy of the medial proximal meta-epiphyseal tibia without filling material is controversial among surgeons.

There is a trend to use filling materials or at least substances which enhance new bone formation in the osteotomy gap.

Solid interpositions alone (autologous, heterologous) are not sufficient enough to withstand the dynamic forces [7, 8, 23].

The effect of solid interpositions to primary and secondary stability has yet to be established.

We have now more the 500 cases operated in our clinic without any interpositions stabilized with the TomoFix implant, and the described surgical technique.

In a retrospective case series study, reviewing the radiological files of 53 consecutive patients for the purpose of describing and quantifying the process of osteotomy gap healing without the use of filling material, with gap openings between 4 mm and 18 mm (average 10 mm), we have seen that ossification of the gap always progressed from the lateral hinge towards the medial side.

The average age of the patients was 50 years.

The standard x-ray evaluation showed in all patients the angle between surfaces was stable over time confirming osteotomy stability.

Bony healing of the osteotomy gap started at the osteotomy surfaces so that the osteotomy gap closes from lateral to medial within 6 to 18 months **(Fig.6).**

Implant removal is therefore not recommended before 12 months.

Fixation stability of open-wedge high tibial osteotomy with TomoFix versus the closed-wedge procedure was examined in a series of 42 patients by a randomized clinical trial using radiostereometry, by Luites et al.

Both give excellent initial stability and remain stable until bone healing is complete i.e. at two years without loss of correction [6].

Clinical Results

Lobenhoffer reported the results of an investigation involving 707 patients treated by a valgisation open-wedge tibial displacement osteotomy [16].

This study was carried out in Lobenhoffers Clinic, Henriettenstift , Hannover, Germany, from October 2000 to February 2006.

The average age of the patients was 40 years.

The average opening height of the osteotomy was 10.6 mm.

There were no cases of secondary loss of correction.

A total of eleven patients needed to be treated by a secondary autograft due to delayed bone healing.

In twelve cases hematoma evacuation was indicated during stationary treatment.

Two patients were reoperated a few days after the first intervention due to overcorrection.

In these cases, the distal locking screws were removed from the plate fixator, the axis of the leg was corrected, and the long side of the plate was again fixed by bicortical locking screws.

The further clinical course was inconspicuous for both patients. All in all, three cases were affected by late infection together with soft-tissue irritation of the implant bed 4 months postoperatively.

After removal of the plate fixator and insertion of antibiotics-impregnated beads the further clinical course for these patients was free of complications.

In cooperation with the AO-CID (AO Foundation, Davos) a multi-center retrospective outcome analysis of 538 patients (Telephone interview: Henriettenstiftung/Hannover, Kantonsspital/Luzern, BG Unfallklinik/Tübingen) with valgisation tibial osteotomy for the years 2004 to 2006 was compiled (publication 2010).

The decisive criterion employed was the Oxford Knee Score.

This score, which is used to evaluate results both for knee unicondylar sled prosthesis as well as for total knee replacement, prevails in international publications.
The twelve questions to be answered by the patient are based on a 5-step scale, so that a minimum of 0 and a maximum of 48 points can be reached.

The average follow-up period is 3.6 (2.4-4.7) years, the average BMI 27, the average opening of the osteotomy 10 mm.

On average an Oxford Score of 40 was achieved, with no significant deviations found within the age groups.

Even in the age group of sixty-year-olds, very good medium-term results could be achieved for patients with correct indications.

The list of all postoperative complications include: 1 implant breakage; 8 with insufficient bone healing diagnosed early, leading to corresponding treatment (reoperation); 11 haematomas; 11 infections; 3 infected haematomas; 2 impaired wound healing.

Recommendations of AO - KNEG 2009: In cases of bone healing delay:

With large gaps or slow bone healing conditions, cancellous bone from the iliac crest should be used, in few cases of delayed unions, a CT scan and the use of cancellous bone in a second surgical intervention is recommended. We have never had to carry out a lateral secondary osteosynthesis [8].

In comparison to results published for prostheses, the functional results can be regarded as very favorable and, together with the low rate of complications, recommendation in favor of this procedure is justified.

Conclusion

Realignment osteotomy holds a central position within the therapeutic spectrum for early and medium-grade varus medial compartment osteoarthritis.

We might state that open-wedge high tibial osteotomy employing optimal surgical techniques (biplanar metaphyseal osteotomy) and the fixation with the internal plate fixator TomoFix® has proved to be successful in treatment of unicompartmental gonarthrosis, even without bone grafts or bone substitute material.

The complication rate is small, and full weight-bearing is achieved quickly with good medium-term results.