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ORIGINAL PAPER

Medial open wedge vs. lateral closed wedge high tibial osteotomy - Indications based on the findings of patellar height, leg length, torsional correction and clinical outcome in one hundred cases

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Abstract

Introduction Medial open wedge (MOW) and lateral closed wedge (LCW) osteotomies are established methods to treat medial gonarthritis. Advantages and differences in the outcome of the two techniques have been discussed controversially and there is still no precise recommendation for either technique. We now aimed to assess the effect of each technique on tibial slope (TS), patella height (PH) and leg length discrepancy.

Method In a study of 50 consecutive cases of MOW and 50 of LCW osteotomies were registered. The decision for either technique was made pre-operatively according to an algorithm. Demographic data, operation procedures (time of operation, correction angle, torsional correction) and measurement of patellar height, tibial slope, leg length discrepancy, clinical outcome after one year and bone and wound healing were obtained. Pre- and post-operative values were compared between the two groups.

Results In absence of randomization demographic data demonstrate comparability of the two groups. No difference in bone and wound healing, time of operation and clinical outcome was seen. In the MOW group PH decreased significantly, no relevant alteration of PH was detected in the LCW group. In the latter group a statistically significant decrease of TS compared to a slightly decrease in the MOW group was recorded post-operatively. A significant leg lengthening with the MOW and shortening of the leg with the LCW method can be achieved.

Discussion With respect to similar results in operating procedures, bone and wound healing and clinical outcome decision making factors for either technique should be leg length discrepancy and torsional deformities. Changes of PH and TS have to be known and may influence the technique of osteotomy in cases of patella infera / alta or borderline PH.

Conclusion An algorithm for valgus high tibial osteotomies based on TS, PH and leg length discrepancy may be proposed.

Keywords Gonarthritis · Osteotomy · Varus deformity · Surgical technique

Introduction

Osteotomies around the knee joint for the treatment of gonarthrosis experience a renaissance within the last decade. By the development of a rigid plate fixateur [1] the problem of bone healing after opening osteotomies seemed to be solved. Consequently, medial open wedge (MOW) osteotomy became the most common surgical joint preservating procedure in patients with a high tibial deformity and a medial gonarthritis. The technically easier operative approach medially avoids fibular nerve lesion and fibula osteotomy. But, the lateral closed technique (LCW) still owns its relevance in the treatment of medial gonarthritis. Different studies investigated the advantages and disadvantages of these two different techniques;

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patella height and its change through the osteotomy have been subject to a few previous studies. [2] Does a high tibial valgisation osteotomy really produce a patella baja or does the change of patellar height (PH) and tibial slope (TS) create a problem post-operatively? Controversary results have been published concerning complications after HTO such as delayed or non-union, (deep) infections or nerve lesion. [3] El-Azab claims further investigation on clinical outcome following HTO, especially associated with PH and TS changes. [4]

We therefore now aimed to assess the effect of each technique on TS, PH and leg length discrepancy; furthermore a decision making support / algorithm for either LCW or MOW technique in the treatment of medial gonarthrosis should be established.

Material and methods

Preoperative Planning

Between 2006 and 2014 we investigated 100 consecutive cases of femoro-tibial varus with high tibial deformities. All included patients were treated based on the assessment of patients not included in the current study sample according to clinical and radiographical findings. Clinical investigation consisted of measuring range of motion of the hip and knee joint and torsion of lower leg for detecting torsional deformities. In patients with a torsional deformity a computer tomograph (CT) scan was performed according the protocol of Waidelich and torsional correction was planned. [5] Leg length discrepancy was measured by the senior author (WS) clinically with the patient in supine position; examiner measures leg length discrepancy between the two heels in accordance to method of Strecker et al.. [6] PH was measured on a lateral view radiograph of the knee and Blackburne-Peel-(BPI) [7] and Caton-Deschamps-Index (CDI) [8] were calculated (figure 1). Based on these findings patients were then treated according to our algorithm (figure 2).

Demographic data such as age at operation, body mass index (BMI) and cigarette smoking were registered.

Surgical technique

In this monocentric study all operations were performed or assisted by the same three experienced orthopaedic surgeons (JD, JH, WS) after arthroscopical evaluation of the cartilage and if necessary, arthroscopical treatment.

MOW was performed according to the protocoll of Galla and Lobenhoffer [9] using a rigid internal plate-fixateur (Tomofix®, Synthes, West Chester, USA) (figure 3), LCW according to the protocoll of Strecker [10]. Both cited surgical procedures use a biplanar osteotomy with the vertical osteotomy usually above the insertion of the patellar ligament, which potentially could lead to a change in patella height. The MOW technique does not provide intentional torsional corrections. In LCW without torsional correction medial hinge should not be osteotomied and lateral gap should be slowly closed completely by fixating a 5-whole locking-compression-plate (Synthes, West Chester, USA) laterally (figure 1). Surgical data such as correction angle, torsional correction, time of operation and osteotomy of the fibula in LCW was recorded. The listed operating time contains all arthroscopical procedures.

Fig. 1 Measurement of patella height. Anterior-posterior (left) and lateral (right) radiography of the knee post-operatively after LCW osteotomy. BPI is defined by the quotient of lines 1 (distance between the distal pole of the patella and the expanded tibial joint line) and 3 (length of the articular surface of the patella). CDI is calculated by the quotient of lines 2 (distance between the distal pole of the patella and the frontal upper tibia limit) and 3. (LCW, lateral closed wedge; BPI, Blackburne-Peel index; CDI, Caton-Deschamps index)

Post-operative rehabilitation

Post-operatively, all patients were treated after a standardized protocoll with partial weight bearing with 20 kilogram (kg) for four weeks; then radiographs of the knee were performed and load was increased with 20 kg per week until full weight bearing was achieved. All patients received physiotherapy including continuous passive motion with an unrestricted range of motion adapted to pain level and gait training starting on first post-operative day. Wound healing was assessed clinically and it was recorded as wound-healing disturbance if re-operation due to soft tissue problems had to be performed.

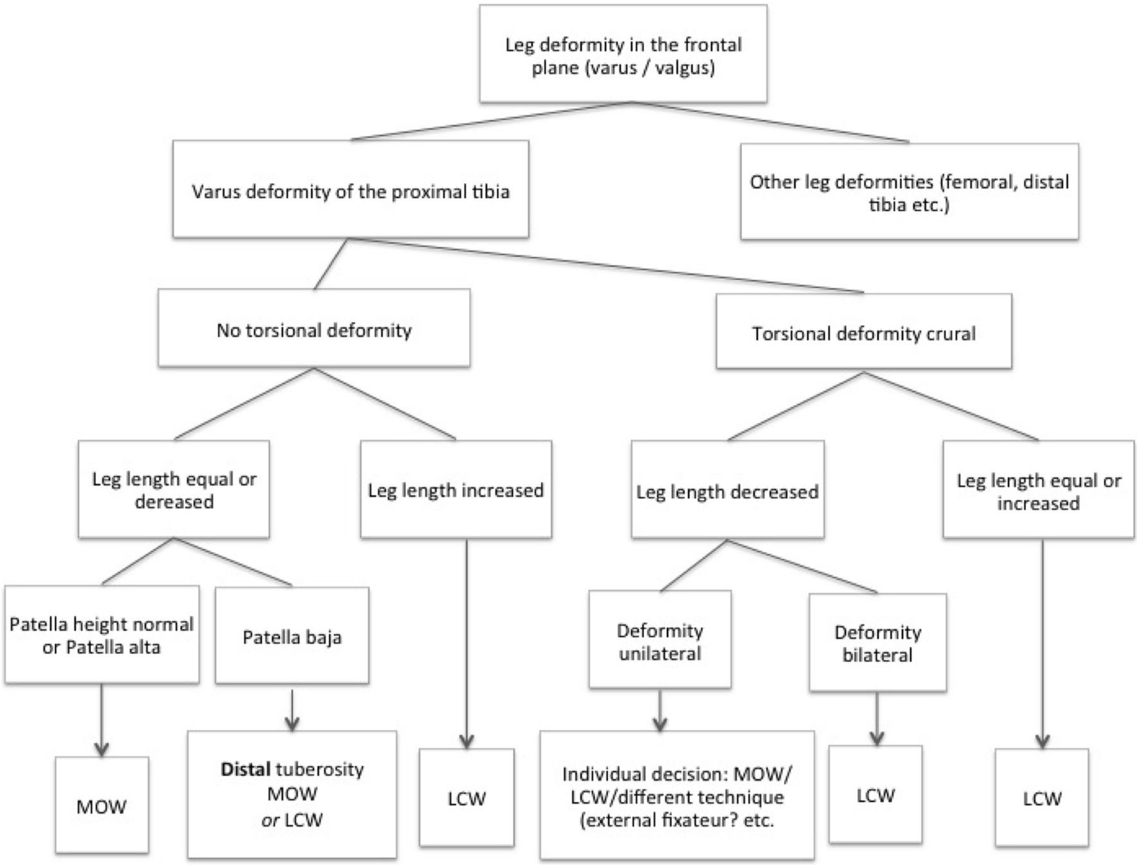

Fig. 2 An algorithm for tibial valgus deformity was developed that guides the surgeon to the right technique of high tibial osteotomy with regard to torsional deformity, patella height, and leg length discrepancy

Post-operative assessment

PH and TS was measured as described by Paley [11] on radiographs pre-operatively and four weeks after surgery (figsures 1 and 3). For evaluation of patellar height BPI and CDI were measured pre/post-operatively and changes were calculated.

Bone healing was assessed clinically and radiographically after four months; if bone healing was not completed after four months, second follow up radiographs were evaluated after eight months. Patients were classified as complete bone healing (after 4 months), delayed union or non-union in cases of incomplete bony healing after eight months. Three orthopaedic surgeons in consent performed the assessment.

For clinical evaluation questionnaires were handed out pre-operatively and one year post-operatively. Severity of pain was registered by a numeric rating scale (NRS). Japanese Knee score (JKS) and Tegner Lysholm Score (TLS) was recorded and compared within the two groups pre- and post-operatively.

Statistical analyses

Microsoft Excel was used for data collection; statistical analyses were performed using SigmaStat software (Systat Software Inc., San Jose, USA). Data were expressed as mean ± standard deviation and p-values <0.05 were considered statistically significant. A Rank-sum test or t-test was used to determine the difference between groups.

The study was approved by the institutional review board and all patients provided written informed consent.

Results

Demographic Data and operating procedures

No statistically significant difference was detected in terms of patients' age at operation, BMI, gender distribution and the percentage of cigarette smokers (table 1).

Due to a large correction angle (>10°) in 14 patients with a LCW osteotomy a fibula osteotomy had to be perfomed. Torsional correction was performed in ten cases of LCW simultaneously to the correction in the frontal plane. [12]

Operation time in LCW was slightly longer, but no statistical difference could be detected (table 1). In both groups, arthroscopy was performed prior to the osteotomy and, if necessary, arthroscopical procedures were performed. The most common procedures were: partial meniscal resection,

Fig. 3 Measurement of tibial slope/proximal posterior tibial angle (PPTA). It is measured on a post-operative anterior-posterior (left) and lateral radiography of the knee after MOW osteotomy. PPTA is defined as the angle between the tibial joint line (asterisk) and the line drawn between a point marking the ventral 4/5 of the tibial plateau and a point bisecting the diameter of the tibia (pound sign) diaphyseally. Some authors measure tibial slope angle, where PPTA has to be subtracted from 90° resulting in an angle of + 2° in the current patient. Negative values indicate an anterior slope (PPTA > 90°)

chondral abrasio, meniscal repair or matrix associated autologous chondral transplantation. Correction angle was slightly larger in the MOW group, but the difference was not significant (table 1).

Bone and wound healing

In terms of bone healing more delayed unions were found in the MOW group, however this finding was not supported by statistical significance. The number of non-unions was equal within both groups. Therefore, complete bone healing was detected after 4 months in 43 (86%) patients after LCW and in 38 (76%) patients after MOW osteotomy, which reveals no statistically significant difference (p=0.4).

No significant difference was seen in regards to wound healing and no deep infection occured (table 2).

Leg length discrepancy, patella height and tibial slope

Leg length decreased by 0.1 cm after LCW osteotomies and increased by 0.5 cm after MOW osteotomies. This difference is seen statistically different resulting in a relevant manipulation of leg length with the different techniques.

Post-operative BPI decreased by -0.1 as compared to pre-operative values within the MOW group, whereas no changes in BPI were found following LCW osteotomies. Accordingly, CDI showed a difference of -0.1 following MOW and no difference (0.0) following LCW osteotomies (table 2). This implies a significant decrease of PH after MOW as compared to LCW and no significant change of PH following LCW osteotomies. Pre-operative tibial slope (TS) did not differ between both groups; while TS decreased in both groups post-operatively, this decrease was significantly higher in the LCW group as compared to the MOW group (table 2).

In figure 4 A-C box plots depict the differences graphically.

Clinical outcome

Questionnaires were complete in 82 cases, three patients (LCW group) died within the follow-up period independently from the surgery resulting in 82 out of 97 (84,5%) completed questionnaires. 41 out of 50 (82%) cases of the MOW and 41 out of 47 (87,2%) of the LCW group were complete.

Neither pre- nor post-operatively, a significant difference was seen between the LCW and MOW group when clinical scores and painlevel were recorded. Improvement of all scores

Table 1 Demographic and operating data within both groups are listed (*BMI*, body mass index; *LCW*, lateral closed wedge; *MOW*, medial open wedge)

		LCW	MOW	*p* value
Demographic data	Age in years*	45 (15–62; 11.4)	45 (20–68; 11.5)	0.77
	Gender	19 female (38%)	16 female (32%)	0.53
	BMI*	27 (19–43; 5.2)	28 (21–37; 4.0)	0.29
	Number of cigarette smokers	15 (30%)	8 (16%)	0.09
Operating data	Correction angle in degree*	8.0 (3.0–15; 3.1)	8.3 (4.0–18; 3.2)	0.77
	Operating time in minutes*	134 (60–338; 50.9)	119 (47–231; 44.0)	0.13

*Mean value (range; standard deviation)

Table 2 Post-operative results: wound and bone healing, change of leg length discrepancy, patellar height, and posterior proximal tibial angle (*MV*, mean value; *SD*, standard deviation; *PPTA*, posterior proximal tibial angle; *BPI*, Blackburne-Peel index; *CDI*, Caton-Deschamps index)

		LCW	MOW	*p* value
Wound healing	Number of wound healing disturbances	2 (4%)	3 (6%)	0.65
Bone healing	Number of delayed unions	5 (10%)	10 (20%)	0.16
	Number of non-unions	2 (4%)	2 (4%)	1.0
Leg length	Change of leg length MV (range; SD)	− 0.1 cm (− 0.5 to + 1.0; 0.3)	+ 0.5 cm (− 0.4 to + 1.2; 0.4)	0.016*
Patellar height	Change of BPI MV (range; SD)	0.0 (− 0.3 to + 0.3; 0.1)	− 0.1 (− 0.3 to + 0.2; 0.1)	0.001*
	Change of CDI MV (range; SD)	0.0 (− 0.2 to + 0.3; 0.1)	− 0.1 (− 0.4 to + 0.2; 0.1)	< 0.001*
Tibial slope	Change of PPTA (MV)	+ 3.9°	+ 1.5°	0.001*

*Statistically significant difference

after surgical treatment was detected to be statistically significant, respectively. Accordingly, pain level decreased significantly within both groups (table 3).

Discussion

Influence on patella height

The current study presents a comparison of the two most common techniques of HTO - LCW and MOW - and confirms that the two techniques are absolutely equal in terms of operating time, wound healing, bone healing and clinical outcome. This finding goes along with the findings of Smith. [3] The most important difference between the two techniques is the change of leg length, PH and TS.

We selected BPI and CDI as measurement tools for the detection of changes of PH, as these measurement techniques provide the ability to identify changes between the patella and the tibial joint line. The relation between BPI/CDI and TS has to be accepted and kept in mind, when overall conclusions concerning PH and TS are drawn.

Although the alteration of PH by valgus HTO has been subject of several previous publications, its definite effect is still discussed controversially. [4, 13, 14] A statistically significant lower PH following MOW compared to LCW osteotomies was described by Smith et. al.. [3] In contrast to the Insall-Salvati Index (ISI), which showed no significant difference, measurements of BPI and CDI revealed a significant decrease of the PH.

In a radiological comparative study on 100 osteotomies El-Azab et. al. found a decrease of PH after MOW measured with BPI, CDI and ISI. [4] The change of PH achieved by surgery turned out to be stable over time until hardware removal. A distalisation of the patella after MOW osteotomy is confirmed by Portner et. al. with a different method of measurement: The authors used the plateau-patella angle as a reliable measurement tool. [13, 15]

The current measurements on 50 consecutive osteotomies acknowledge the lowering of the patella after MOW osteotomy. This change was predicted in a biomechanical cadaver study, where a significant decrease after MOW and increase after LCW osteotomies measured on a continous 3D monitoring of the patella was observed. [16] This biomechanical measurement of a proximalisation of the patella following LCW osteotomies is confirmed in different clinical publications [3, 4, 13], whereas the results of the current study differ from these findings. In their previously mentioned study, El-Azab et. al. showed that PH increased in their group of 50 LCW osteotomies. [4] Comparable to the MOW method, the PH changes persisted until hardware removal. This significant ascent of the patella following LCW procedures is acknowledged by Portner´s measurements of the plateau-patella angle. [15]

In 24 LCW osteotomies Brouwer et. al. calculated BPI and ISI and found a slightly increase of PH and a significant difference to the decrease of PH after 26 MOW osteotomies. [17] The critical use of BPI for PH changes after HTO due to its relation to tibial inclination changes has already been discussed. [17]

Tigani et. al. measured PH changes in 47 LCW osteotomies by CDI and found a tendancy for elevation of the patella especially when correction angle was less than ten degrees; overall the increase of CDI was not statistically significant. [14] The two latter cited publications tend to the findings of the current investigation, where no significant change of PH was observed.

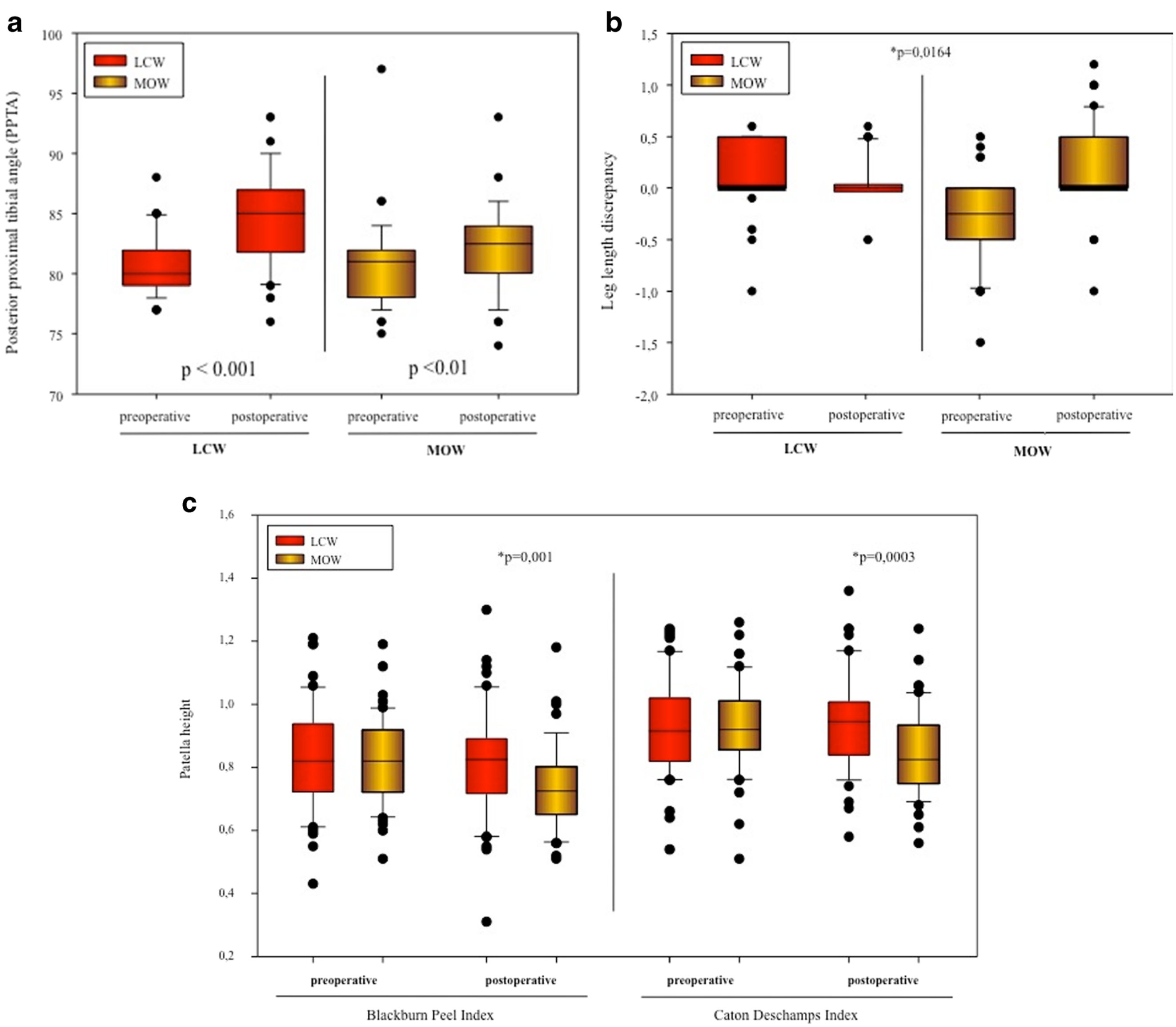

Fig. 4 **a**–**c** Boxplots in **a** depict change of PPTA, in **b** leg length discrepancy, and in **c** patella height—measured by CDI and BPI—is shown. *p* values indicate statistical significance

Table 3 Clinical scores (maximal score is 100 each) and pain level (between no pain, 0, and maximum pain, 10) pre- and postoperatively at 1-year follow-up are compared between the LCW and MOW groups (*LCW*, lateral closed wedge; *MOW*, medial open wedge; *JKS*, Japanese knee score; *TLS*, Tegner-Lysholm score; *NRS*, numeric rating scale; *MV*, mean value; *SD*, standard deviation; *preop*, pre-operative; *postop*, post-operative)

		LCW (MV, range; SD)			MOW (MV, range; SD)		
		preop	postop	*p* value	preop	postop	*p* value
Clinical scores	JKS	65 (37–91; 11)	91 (45–100; 12)	< 0.001*	66 (42–98; 13)	92 (55–100; 11)	< 0.001*
	TLS	45 (10–83; 20)	84 (33–100; 16)	< 0.001*	51 (17–98; 19)	85 (25–100; 19)	< 0.001*
Pain level	NRS	7.6 (3–10; 1.7)	3.1 (1–7; 1.5)	< 0.001*	7.2 (3–10; 2.0)	3.3 (0–10; 2.1)	< 0.001*

*Statistically significant difference

Biomechanically, an increased patellofemoral pressure is caused by MOW osteotomy in the classical technique (proximal the tuberosity) due to a descent of the patella compared to the LCW or distal tuberosity MOW osteotomies. This implicates the recommandation to use LCW or distal tuberosity MOW techniques in cases of (borderline) patella infera or mild symptomatic patellofemoral osteoarthritis.

Tibial slope in relation to patella height

The relation between PH and TS has to be kept in mind. Changes of TS itself after HTO has widely been discussed in the past. In a retrospective study in 67 patients with LCW osteotomy a statistically significant decrease of TS was demonstrated. [18] Reduction of TS by LCW technique correspondends to the findings by different other authors. [4, 19] However, an increase of TS after MOW osteotomies was described in a review analysis by Smith et. al.. [3] The authors summarized four different publications, where TS presented with a significant increase after MOW and decrease after LCW osteotomies. [17, 19] In other studies increase of TS with MOW technique appeared not to be significant. [13]

Taking out one study with a significant increase of TS following MOW osteotomy, El- Azab´s technique as well as their inclusion criteria deviate from those of the current study: The authors excluded patients, where TS was changed intentionally. [4] In the current study, however, those patients were included. The goal of surgical technique in the current cohorte was not to leave an extension deficiency, which in some cases can only be obtained by an intentional decrease of TS. Still, anterior TS (PPTA > 90°) has to be avoided. This difference in the surgical technique might explain the slightly decrease of TS in the MOW group, whereas currently observed TS changes with LCW technique correspond to the cited changes. [20] Range of motion was controlled and documented intraoperatively after correction was completed and full extension (0 degrees) was achieved in all cases.

There is an uncontroversial dependency of BPI and CDI on TS. [2] Decrease of TS results in a change of PH. Measurement of CDI seems to be less affected than BPI. TS and PH therefore can´´t be evaluated seperately in this setting and the exact correlation still remains unclear. According to geometrical considerations the CDI seems to be the most valuable and most unaffected PH measuring tool when it comes to TS following HTO. [21]

According to the normal range of PH two patella infera and six patella alta occured in the current study population preoperatively. Post-operatively, three patella alta and five patella infera were detected. Consequently, patella abnormalities occured in less than 10% of the patients. The technique of the osteotomy influences latter group and borderline values of PH. In any case, disturbances of PH have to be recognized when planning a HTO and it should be recognized that PH and TS might have been altered through HTO when planning a total knee arthroplasty after HTO. [22]

Limitations of the study

Pre-operative planning was performed on long leg radiographs (double-limb stance). [23] Post-operatively, the achieved hip-knee-ankle axis was not measured again to avoid further radiation exposure. Consequently, the exact correction that was achieved and its possible deviation from the pre-operative planning were not determined. Although hip-knee-ankle axis was evaluated clinically post-operatively, the degree of precision of either osteotomy technique cannot be demonstrated in our study.

Clinical outcome and improvement of pain levels after one year was similar with the two described techniques. This is acknowledged by short- and mid-term results. [24] Long-term outcome has to be obtained in the current cohorte.

Mean operation time in both groups was longer than in MOW/LCW procedures due to arthroscopical procedures. The tendancy to a longer operation time may depict the technically more difficult method of LCW technique, which included torsional osteotomies (in ten cases) and additional osteotomy of the fibula (in 14 cases).

Investigation of leg length with the presented method seems to be dependent on the examiner. However, all leg length examinations were performed by the senior author (WS), who is a board certificated and very well experienced surgeon for leg deformities. Secondly, even though very accurate values of leg length can not be measured, tendancies to leg length discrepancy can definetely be detected by the described method of examination. Thirdly, in many cases torsional deformities were suspected clinically and had to be investigated radiographically by torsional CT-scans. This investigation includes measurement of femoral and tibial length. Consequently, an exact value for leg length existed and a correlation to clinical measurement was possible. Strecker et al. has shown a strong correlation between the clinical examination and torsional CT-scan. Magnussen et. al. postulated, that changes in leg length after HTO (LCW versus MOW) are less than mathematical models predicted. [25] However, in their measurements on long leg radiographs pre- and one year post-operatively the authors found a significant change of leg length by the different techniques of osteotomy according to the current findings. Thus, leg length discrepancy should be considered before decision is made to either technique.

If torsional correction is necessary, LCW is the method of choice. Most common desease in this constellation is a (mild) varus deformity associated with an increased external tibial torsion (and sometimes increased internal femoral torsion) leading to patella maltracking (inwardly pointing knee).

Another limitation is the absence of a randomization; of course there is a bias of patient selection for the two groups.

Nevertheless, by demonstrating demographic data and correction angle the comparability of the two groups is ensured.

Conclusion

There is no difference in complications, bone healing, functional outcome or pain level between LCW and MOW technique. Consequently, leg length discrepancy and torsional correction should be the decision making factors for either method. PH has to be considered in pre-operative planing. The correlation of PH and TS and its decrease by either technique has to be kept in mind.

In summary, positive clinical and radiographical results of the patients treated according to our algorithm (figure 2) confirm our therapeutical approach. Based on the current findings our algorithm can be established for the different techniques of valgus HTO. Before final decision is made to either technique demographic conditions such as nicotine abuse, BMI, special medication etc. are subject to careful consideration on the way to an individual customized solution for each patient and problem.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflict of interest.

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