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A new navigation-based technique for lateral distalizing condylar osteotomy in patients undergoing total knee arthroplasty with fixed valgus deformity

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Abstract
Purpose In a prospective, consecutive study, a navigation-based technique for calculating the sliding distance of the lateral epicondyle prior to osteotomy in TKA surgery of fixed valgus deformity has been developed, and early results have been evaluated.
Materials and methods Twenty-seven knees with a fixed valgus deformity undergoing TKA received this new treatment. Clinical scores and radiograph evaluation were performed preoperatively and 1-year postoperatively. Static and dynamic kinematic data were obtained from navigation at the beginning and at the end of surgery.
Results The calculated amount of sliding distance varied between 5 and 16 mm. No complications regarding this technique occurred. All clinical scores showed a significant improvement, and radiological evaluation showed a correction of all parameters in 100 % of patients.
Conclusion With this navigation-based technique, it is possible to calculate the amount of sliding distance prior to osteotomy and obtain excellent early results. All axes have been corrected completely, and flexion and extension gaps were balanced. No specific complications of this technique have occurred so far.
Level of evidence II.

Keywords Valgus · Knee · Lateral osteotomy · Navigation · TKA

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Introduction

A preoperatively fixed valgus deformity is often a problem regarding functional outcome and long-term survivorship of TKA [20, 26]. From a surgical standpoint, correction of this deformity is often a challenge, and correct bone resections are one essential aspect for correcting the mechanical axis in these knees [29]. Recent literature has shown that regardless of the degree of preoperative deformity, the percentage of a persisting deformity larger than 3° from the mechanical axis can be found between 20–30 % of knees without navigation [21]. In severe valgus knees, the rate of a persisting postoperative deformity of more than 3° degrees can be even higher [16]. This problem may be one reason for the inferior outcome in these knees, especially when the effect of axis deterioration over time is taken into account [7, 11]. To minimize the number of outliers, navigation can be a useful tool for performing the bone cuts precisely [19, 28] and might therefore be extremely helpful especially in severe valgus deformities.

In addition to performing the correct bone cuts, the most challenging part of correcting fixed valgus deformities is soft-tissue balancing. Most balancing techniques rely on different releasing steps of the lateral and/or posterior-lateral structures of the knee [17]. Some authors attempted to rebalance the knee by retensioning the elongated medial collateral ligament [13]. In most techniques, the soft-tissue balancing has been described as a stepwise procedure [17, 24, 25, 29, 30]. Lüring et al. [18] showed that all of the lateral structures (e.g. popliteus, lateral collateral ligament) have a stabilizing effect throughout the entire range of motion except for the iliotibial band which stabilizes the knee laterally only in extension. The stabilizing effect of these lateral structures is even more pronounced in flexion. Taking into consideration that many valgus knees are in valgus alignment in extension only, a release of these lateral stabilizing structures helps to create an equal gap in extension but simultaneously loosens the knee in flexion. As a consequence, constrained implants are often needed. Another factor for the use of a semiconstraint implant can be the laxity of the medial collateral ligament [10]. Although these implants show good long-term results especially in elderly patients [6], the amount of constraint should be minimized.

In knees with fixed valgus deformities, an isolated release of the iliotibial band is often insufficient to completely balance the knee in extension. In such a scenario, the sliding osteotomy of the lateral femoral condyle has been described as a promising technique [3, 4, 12]. However, until now, the results of this technique have been described only in a small series of patients [22]. Published as a technical note, the amount of sliding distance needed for correction and whether it can be reproducibly quantified remains unclear.

Objectives of this study, therefore, were (1) to develop a new navigation-based technique for quantification of the sliding osteotomy distance of the lateral condyle in fixed valgus deformities and (2) to evaluate the early results of this new surgical technique. Of particular interest was the fact whether this new technique is able to restore joint stability and patello-femoral kinematics during the entire range of motion. The hypothesis of the study was that the sliding osteotomy in a navigated technique is not only able to restore the leg axis but also to balance the medial and lateral gap throughout the entire range of motion.

Materials and methods

Between 2008 and 2009, 410 consecutive TKA were performed in the institution of the S.A. Thirty-nine of them were clinically and by radiography categorized as valgus knees; 37 of those categorized as having an intraarticular deformity. Ten of these patients had a non-fixed valgus deformity that could be balanced with an isolated release of the iliotibial band only. The other 27 of these showed in the clinical examination preoperatively a fixed valgus deformity in extension only. In long leg radiographs, the mechanical axis was determined. A median of 191° HKA was found (186°–202°). No specific stress radiographs were made before surgery. During navigation, the type of valgus deformity was analysed in extension and during flexion. To find out whether the deformity was fixed, additional stress testing during surgery was performed. All of these 27 knees showed a fixed valgus deformity in extension only. In these cases, the mediolateral gap difference during dynamic ROM analysis becomes almost 0 mm around 90° of flexion (Fig. 1). Intraoperatively, an isolated release of the iliotibial band was not sufficient to balance the knee. Therefore, a distalizing osteotomy of the lateral condyle was performed to balance the knee in this specific group. Patients' age in this specific subgroup was 69.5 ± 13.2 years at surgery.

Extraarticular deformities or additional deformities from the hip were excluding criteria. All knees were cemented PFC (cruciate retaining) MBT TKA (DePuy Warsaw Inc.). Written consent was obtained by all patients prior to surgery, and the local ethics committee approved the study design.

All patients were assessed prior to surgery and 1-year postoperatively to test the early postoperative result. This study was not designed as a long-term survivorship study. Our protocol included clinical scores (WOMAC [2], American Knee Society Score [14], Patella Score [9]) and a radiographic analysis. This radiographic analysis included measurement of HKA, femorotibial angle, ADLF (anatomic distal lateral femur angle) and MPTA (medial proximal tibia angle) in the ap view; tibial slope and femoral posterior offset in the lateral view and patella shift and tilt in the skyline view. The same assessment was performed postoperatively. Radiographic measurements were performed using digital templates (Gemed Pacs, Ulm Germany) allowing one decimal of accuracy for angles and millimetres.

Biomechanical analysis of the knee was done at the beginning of surgery and at the end of surgery with the CI Knee unlimited 2.1.1 module of the navigation system (Brain Lab: Vector Vision Sky, Feldkirchen, Germany). The medial and lateral flexion and extension gap was measured statically at 0° and 90° of flexion and dynamically throughout the entire range of motion. The navigated leg axis prior and postsurgery was measured. The navigation software provides measurement accuracy of 0.5 degrees for angles and 0.5 mm for distances or gaps.

Surgical technique

In all valgus knees, a lateral parapatellar approach was applied. After capsular opening, resection of the lateral meniscus and the ACL was done, and the patella was translated over the medial condyle. Eversion of the patella was neither intended nor performed.

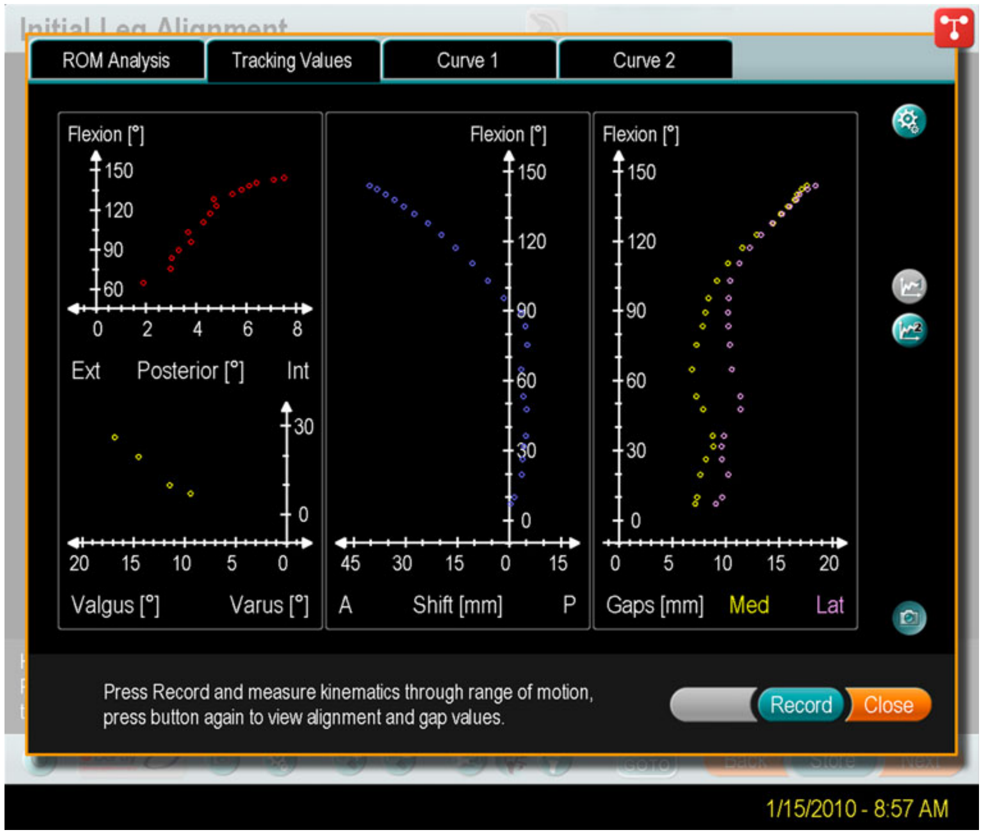

Fig. 1 This figure shows a screenshot of the navigation software. The graphs show the valgus alignment and the mediolateral gap difference throughout the range of motion

For navigation, the Steinman pins were placed on the tibia and femur, respectively, and the anatomical landmarks were palpated in order to create an individual anatomical model of each patient knee.

In addition to the static parameters (extension gap and flexion leg axis), the dynamic measurements of the width of the medial and lateral joint space were obtained throughout the entire range of motion. The typical data of a fixed valgus deformity are displayed in Fig. 1, showing an unbalanced gap in extension and a nearly equal gap at 90° of flexion. The aim of the balancing technique is that the lateral gap is equal with the medial gap after the releasing steps and that the extension gap and the flexion gap are also equal. If there is a difference in extension, it is first treated with a release of the iliotibial band. In some cases with a non-fixed deformity, this release is sufficient to balance the knee. In almost all fixed valgus deformities, a difference of more than 3 mm and a secondary malalignment persists (Fig. 2). This is, in our hands, the indication for the distalizing osteotomy of the lateral condyle.

Technique of the navigated distalizing osteotomy of the lateral condyle

Before the osteotomy is performed, the standard anterior and posterior cuts, as well as the champfer cuts, are made, and the trial components and insert are placed. The gap measurement in extension and flexion is again performed, and the differences between medial and lateral gaps are recorded. If the knee is unbalanced in extension only, as shown in Fig. 2, a decision to perform the osteotomy of the lateral epicondyle is made, and in a second step, the gap difference again is recorded during manually performed maximal varus and maximal valgus stress.

The osteotomy is performed as described by Briard [3] and Brilhault et al. [4]. With an oscillating saw, the osteotomy is done parallel to the femur. The width of the bone block is approximately 1 cm. In this new navigated technique, the sliding distance was calculated by the difference of the maximum medial and lateral gap in extension stress test. This difference is then multiplied by 2.5, and the condyle is fixed in this new position with 2 wires for 4.5-mm cannulated screws. After this, two screws are placed, and the bone surface of the distalized epiconyle is remodelled according to the bone surface of the lateral condyle (Fig. 3). It is important that the condyle is transferred only in a distal direction and not in an anterior or posterior direction to avoid flexion-gap alteration. The result of the condyle distalization is recorded with the trial components implanted (Fig. 4).

After optimizing the femoral-tibial kinematics, the patello-femoral kinematics were assessed. With the trial

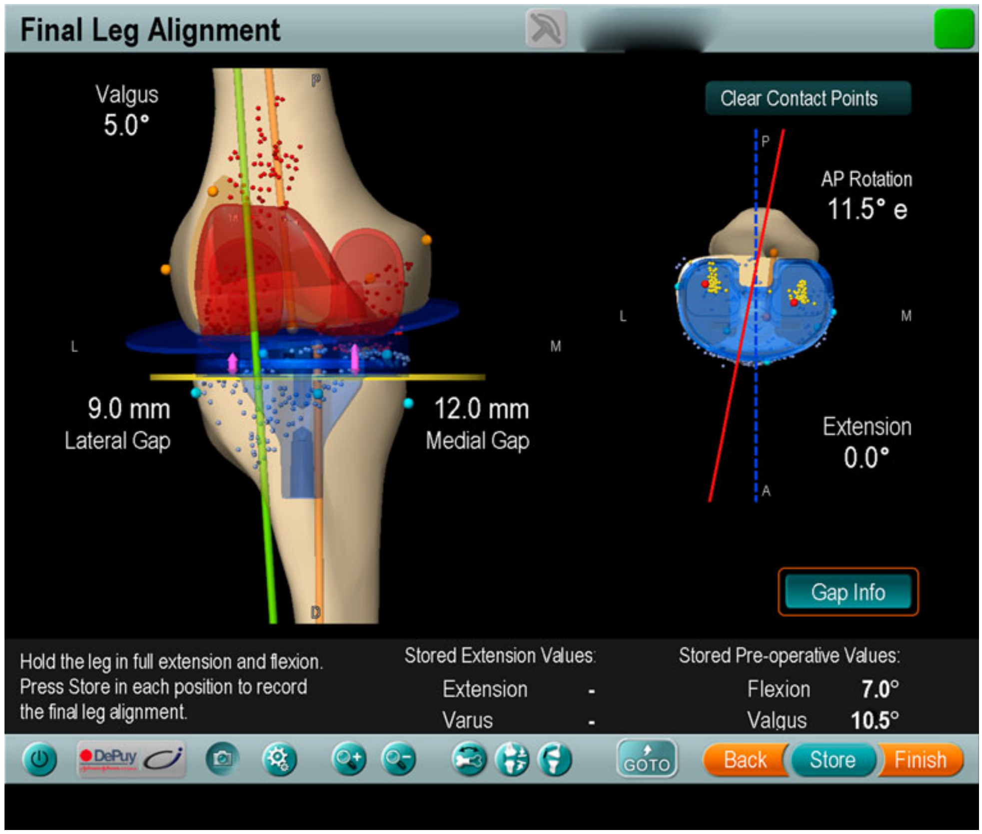

Fig. 2 This figure shows a screenshot of leg alignment after the trial components have been implanted. The mediolateral gap difference of 3 mm and the 5° valgus alignment is stored

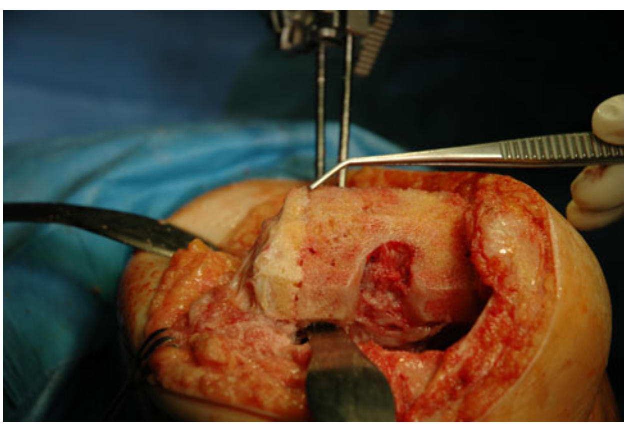

Fig. 3 This figure shows the direction and thickness of the osteotomy performed

components in place, the height of the patella as well as the tracking of the patella was assessed. No further treatment for patella recentering was necessary in any knee. Finally, after tibia preparation and patella resurfacing, the original implant (P.F.C. Sigma MBT; DePuy) was cemented.

A lateral condyle osteotomy did not alter our postoperative management. Full load bearing was allowed, CPM therapy and physiotherapy also started on the first postoperative day.

Statistical analysis

Preoperative range of motion as well as WOMAC score, American Knee Society score and Patella score values were compared with those obtained postoperatively. Statistics were obtained using *t* test and Mann–Whitney U-test [24] using the sigma plot 11.0 software (Systat Software, Inc.). Further, the leg axis was measured radiologically (hole leg radiographs) and by navigation as well as the mediolateral gap in extension and flexion. In order to analyse the correlation between the preoperative valgus deformity (HKA) and the distance of the sliding osteotomy, a Pearson correlation test was performed.

Results

The sliding distance in our 27 knees varied between 5 and 16 mm (10.8 mm ± 3.4 mm). No significant correlation between the preoperative HKA and the sliding distance of the lateral condyle existed. No further readjustment of the initial osteotomy was necessary to achieve knee balance. No complications including infection, instability, nonunion of the osteotomy or spin-out were found in this group.

All three clinical scores showed considerable and significant improvement (Table 1).

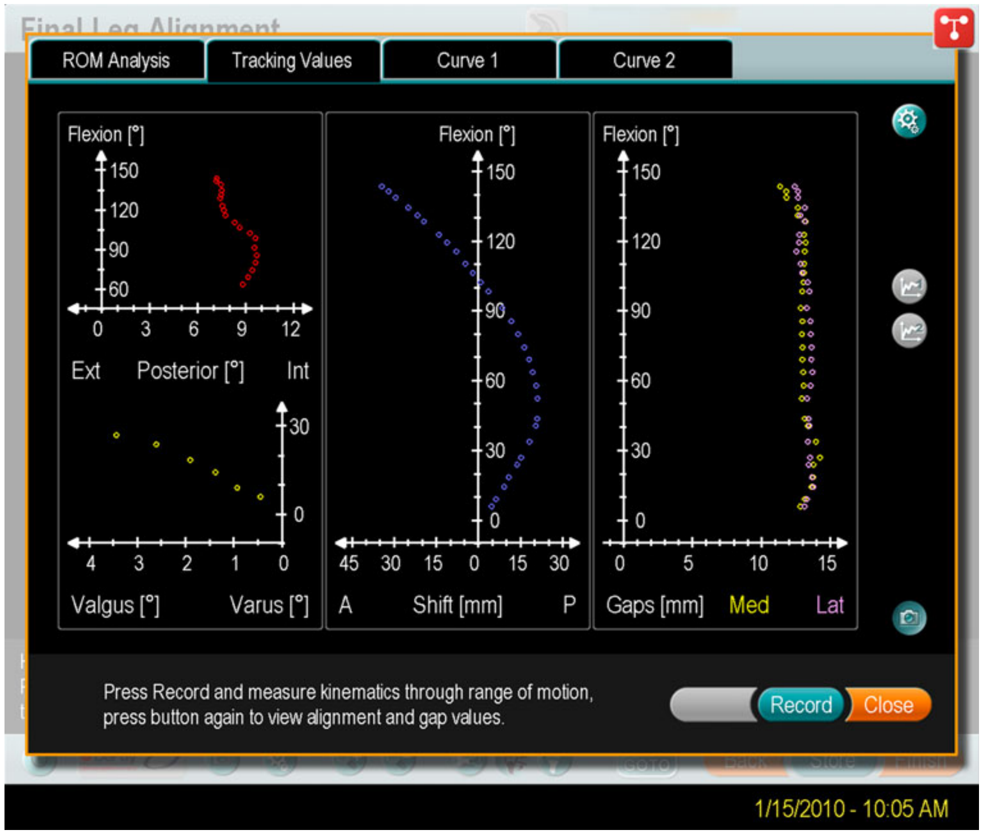

Fig. 4 The correct final leg alignment and ligament balance are demonstrated throughout the whole range of motion

ROM preoperatively was only slightly reduced showing 118.8° ± 16°. After surgery, this parameter was not significantly altered (119.4° ± 14°).

The HKA was corrected from preoperative 191° ± 4.7° to 180.3° ± 1.1° postoperatively.

The femoro-tibial angle was corrected from 17.7° ± 5.0° of valgus preoperatively to 7.2° ± 3.8° postoperatively. According to the hypothesis, the alignment was corrected from 8.2° ± 2.7° valgus to 0.2° ± 0.9° of varus. No outlier with a deviation of more than 1.5° was found in the postoperative group (Table 1). The femoral valgus deformity (ADLF) was corrected from 76.1° ± 2.7° to 83° ± 2.8°. On the tibia, no significant correction was necessary, and alignment (MPTA) was changed from 91° ± 3.2 to 89.8° ± 1.9° postoperatively. Again, the small range postoperatively shows the technical precision possible with a navigated technique.

All other parameters in the sagittal plane or of the patello-femoral compartment were anatomically restored (Table 1).

The extension as well as the flexion gaps was well balanced. As postulated in the initial hypothesis, all patients at postoperatively were found to have gaps that were within 1-mm difference between medial and lateral gap in extension and in flexion (Table 1).

Discussion

The most important finding of the present study was that the amount of distalization of the lateral epicondyle could be exactly calculated before performing the osteotomy itself. In this study, the initial hypothesis that the sliding osteotomy of the lateral condyle in a navigated technique is not only able to restore the mechanical axis but also to achieve a balanced medial and lateral gap throughout the entire range of motion could be underlined. By restoring the femoral-tibial kinematics, it was also possible to restore femoral-patellar kinematics with a well-centred patella.

The treatment of fixed valgus knees is one of the most challenging problems in primary TKA. Over the last decades, different techniques have been described [12, 15, 23, 25, 29]. Retensioning of the medial structures has shown to be less predictable than releasing the lateral structures. Anatomical and biomechanical analysis of these structures have shown that except for the iliotibial band, they all have a simultaneous stabilizing effect in both extension and flexion [8, 18]. This effect is even more pronounced in flexion. Therefore, a release to balance a knee in extension can sometimes lead to an over-released knee in flexion. This effect must sometimes be compensated by implanting a more constrained type of insert. However, this may lead

Table 1 Showing the mean and standard deviation of clinical scores, radiological analysis and navigation data pre- and postoperatively and the level of significance

	Preoperative mean (±SD)	Postoperative mean (±SD)	Significance
Clinical scores			
WOMAC	41.9 (±6.0)	20.0 (±9.0)	$p < 0.001$
AKSS	87.9 (±18.0)	157.5 (±23.0)	$p < 0.001$
Patella score	12.5 (±3.5)	24.5 (±3.6)	$p < 0.001$
ROM	118.8 (±16.0)	119.4 (±14.0)	n.s.
Radiographic analysis			
Femoro-tibial ° ap	17.7 (±5.0)	7.2 (±3.8)	$p < 0.001$
Lateral patella tilt °	3.9 (±6.3)	0.0 (±5.4)	n.s.
Lateral patella shift %	27.6 (±22.1)	4.2 (±6.8)	$p < 0.001$
ADLF °	76.1 (±2.7)	83.0 (±2.8)	$p < 0.001$
MPTA °	91.0 (±3.2)	89.8 (±1.9)	n.s.
Femoral post. Offset mm	26.0 (±3.9)	28.0 (±4.2)	n.s.
Tibial slope °	7.9 (±3.8)	4.0 (±1.4)	$p < 0.05$
HKA °	191.0 (±4.7)	180.3 (±1.1)	$p < 0.05$
Navigation data			
Alignment °	Valgus 8.2 (±2.7)	Varus 0.2 (±0.9)	$p < 0.001$
Gap difference mm in extension	1.2 (±2.8)	0.6 (±1.1)	n.s.
Gap difference mm at 90°	2.3 (±3.4)	0.4 (±1.1)	n.s.
mm distance of Osteotomy	10.8 (±2.7)		n.s.

WOMAC Western Ontario and McMaster Universities Arthritis Index, *AKSS* American knee society score, *ROM* range of motion, *ADLF* anatomic distal lateral femur angle, *MPTA* medial proximal tibia angle, Alignment = the deviation from the perfect leg axis, HKA = describes the angle that is formed by a line from the femoral head to the centre of the knee to the centre of the angle

to an increase in polyethylene wear over time. Therefore, the releasing technique should be able to balance the knee in extension without having a destabilizing effect in flexion. The distalizing osteotomy of the lateral condyle has been advocated to be helpful in doing that [3, 12]. Until now, however, it was time-consuming to identify the precise amount of sliding distance needed to rebalance the knee. With the technique presented, we were able to obtain this distance prior to the osteotomy and balance all of our knees on the first attempt.

The technique entails measuring the difference between the medial and lateral extension gap with varus and valgus stress test, respectively, and the difference was multiplied by 2.5. This calculated value determines the sliding distance of the osteotomy of the lateral condyle. In small knees, this procedure can lead to an anatomical limitation, as the option to distalize the lateral condyle is limited and can thus be insufficient if an extreme imbalance exists. Therefore, it is very important to know the sliding distance before performing the osteotomy. However, until today, this has yet to occur in our daily practice.

The indication for this new technique has to be carefully respected. Extraarticular deformities are a contraindication for this technique. In a non-fixed valgus deformity, this procedure is also not necessary. This can be treated with an isolated release of the iliotibial band in most cases. Fixed valgus deformities are almost always caused by a hypoplasia of the distal lateral condyle, and in a few cases, this hypoplasia includes also the posterior part of the lateral condyle. In these cases, the indication for the distalizing osteotomy of the lateral condyle should be checked very carefully, because the imbalance might also be obvious in the flexion gap. When using navigation, this hypoplasia of the posterior-lateral condyle is obvious, because the individual model generated by palpation of the anatomical landmarks will show the defect and, due to that, a persisting mediolateral gap difference throughout the entire range of motion.

The results of this short-term, follow-up study showed a high percentage of good and excellent results in the different scores. These results are comparable to previous studies using other balancing techniques [5]. It was also possible to reconstruct femoro-tibial angle to the desired 3° range in all the knees. Other studies without navigation have shown outliers beyond this 3° range of around 20–40 % of cases [1]. Navigation was not only helpful in performing correct bone cuts, but also in measuring the imbalance of each knee and correcting it throughout the range of motion. This measurement can also be performed with stress tests yielding important information about the necessity of balancing steps and the amount of the sliding distance of the distalizing osteotomy of the lateral condyle.

This new technique is not only able to help restore femoral-tibial kinematics but also femoral-patellar kinematics. In the radiological postoperative analysis, we could show that all patella components were well centred in the trochlear groove of the implant. Recent studies have described the necessity of up to 76 % of lateral releases in such valgus knees [27]. In this study, this was not necessary in a single case. By restoring the joint line, patella height was correct in all cases. However, in cases with severe preoperative patella baja or alta, additional procedures to realign the patella might be necessary.

Once the osteotomy is performed and the surface is reshaped, the femoral component is cemented, and the osteotomy is then covered by the implant. The resulting forces on the osteotomy have almost only one direction in extension, this direction being distally orientated. This direction is limited by the femoral implant; so, no further distalization of the osteotomy is possible. During flexion, the forces are orientated posteriorly. This force is also covered by the cemented implant. The only forces needed to be addressed are the ones pulling the osteotomy laterally. These minimal forces can easily be neutralized by the cannulated screws. This force analysis might be the reason why we have not found non-union or dislocation of the osteotomy in our follow-up.

In many valgus knees, there is a pathologic increase in femoral-tibial rotation, and therefore, we implanted a mobile bearing tray in all knees in order to allow for free femoral-tibial rotation. We had no cases of spin-out and a documented mediolateral balance throughout the entire range of motion.

This study has some shortcomings that should be kept in mind. Our series is small, and therefore, this should be considered as a description of a technique and final conclusions regarding long-term results of this new technique cannot be made without longer follow-up. However, the short-term results are encouraging, and we will continue to utilize this technique in all cases with a fixed valgus deformity. Although we had no procedure related complications, one has to keep in mind that an osteotomy per se can result in malunion or fracture, and therefore, meticulous surgical technique is needed.

Conclusion

A new navigation-based technique for the distalizing osteotomy of the lateral condyle in fixed valgus knees undergoing TKA has been presented. With this technique, it was possible to restore femoral-tibial balance throughout the entire range of motion as well as exact coronal and sagittal alignment. The navigation technique helps to exactly calculate the amount of sliding distance needed before the osteotomy is performed and therefore reduces the number of attempts to reach a completely balanced knee. By using a mobile bearing inlay, we could address the additional problem of increased femoral-tibial rotation in valgus knees. Due to our balancing technique, no spin-out problems were observed. Also, the patello-femoral kinematics were successfully addressed by this new technique. However, long-term results are needed to be awaited. Based on these promising findings, the presented technique has become the standard in the treatment of fixed valgus deformities in our daily practice.

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