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ORIGINAL ARTICLE • KNEE - ARTHROPLASTY

Lateral subvastus approach with tibial tubercle osteotomy for primary total knee arthroplasty: clinical outcome and complications compared to medial parapatellar approach

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Abstract
Purpose The lateral subvastus approach (LSVA) with tibial tubercle osteotomy (TTO) is an alternative approach for total knee arthroplasty (TKA) in selected patients. The aim of this study was to compare clinical outcomes between LSV and medial parapatellar approaches for primary TKA and to investigate incidence of complications related to TTO.
Methods A total of 580 patients with primary TKA, meeting the inclusion criteria, were treated at our hospital from February 2006 until February 2013. All patients' data were included in the local arthroplasty register and were followed up 12 months postoperatively. The data set contains: demographic data, the WOMAC score, the KSS as well as knee flexion and complications related to tibial tubercle osteotomy.
Results The clinical outcome after TKA using the LSVA combined with TTO was comparable with those using the medial standard approach 1 year postoperatively. Four patients (3.8 %) needed a revision due to complications related to tubercle osteotomy.
Conclusions The LSVA is thus a viable alternative in cases of primary TKA if technical difficulties with the medial approach are anticipated. Applying precise surgical technique, the LSVA seems to be a safe and reproducible procedure.

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Keywords Total knee arthroplasty · Tibial tubercle osteotomy · Lateral approach

Introduction

Total knee arthroplasty (TKA) is a regularly performed surgical procedure. There is convincing evidence in the literature that good clinical outcome and a high level of patient satisfaction can be expected after TKA [1, 2]. The key factors influencing long-term outcome after TKA are restoration of anatomical leg alignment, correct ligament balancing and precise positioning of prosthetic components [3, 4]. Furthermore, it could be demonstrated that the surgical approach also has a direct influence on the outcome [5–7]. Different surgical approaches are currently under discussion among surgeons.

The most common approach is the medial parapatellar arthrotomy. However, for particular indications, the lateral subvastus approach (LSVA) combined with tibial tubercle osteotomy (TTO) seems to have several advantages [7–9]. This surgical procedure is primarily used for revisions, but under certain circumstances, such as valgus deformities or patellar tracking abnormalities, it could also be an alternative in primary TKA. Improved exposure as well as better controllable positioning of the femoral component has been discussed as being advantageous [4, 6, 10]. Moreover, the medial vastus muscle, the patellar tracking and the blood supply to the patella are preserved when performing the LSV approach combined with TTO [11]. In our hospital, we use the LSVA for fixed valgus deformities, for maltracking of the patella and in revision arthroplasty.

The aim of this retrospective study was to compare functional outcomes of the LSVA with TTO to the standard

medial parapatellar approach (MPA) and analyze the TTO-related complications of the LSVA.

Materials and methods

Patients

From our local knee arthroplasty registry, we retrieved data retrospectively for a sample of patients who had undergone TKA at our hospital between February 2006 and February 2013. The following inclusion criteria were applied:

1. Primary TKA between February 2006 (start of registry) and February 2013.
2. LCS® complete™ prosthesis (DePuy Orthopaedics, Warsaw, USA).
3. TKA via computer-assisted surgery (CAS) or conventional surgical approach.
4. Age 18–85 years.
5. Sufficient command of German language.

Our inclusion criteria were met by 913 patients in our local knee arthroplasty registry. Patients from this data set were assessed for eligibility using the following exclusion criteria:

1. Bilateral TKA.
2. Missing clinical, radiological or patient-reported outcome data.
3. Other surgical approaches than MPA or LSVA.
4. Concomitant surgery (e.g., epicondylar slide, tibial tubercle advancement).
5. Aborted computer navigation.

After applying our exclusion criteria, 580 records with a full data set were available for further analysis (Fig. 1). One hundred six patients (the TTO group) underwent a LSVA, and the rest the MPA and have been used as the control group. All patients were categorized by clinical records, surgical notes and radiological measurements into three groups:

- *Control group (474 patients)* Standard MPA. Neutral leg alignment: Clinically and radiologically no valgus deviation than physiological.
- *Neutral TTO group (48 patients)* LSVA with TTO. Neutral leg alignment: Clinically and radiologically mild valgus (10°, grade I according to Ranawat [12]), no fixed valgus on clinical examination. Although alignment was normal, some patients ($n = 52$) had a LSVA with TTO because of previous lateral skin incisions (open reduction/internal fixation, open lateral meniscectomy), or because of surgeon preference.
- *Valgus TTO group (58 patients)* LSVA with TTO. Valgus leg alignment: Pronounced clinical and radiological valgus (>10°, grade II and III according to Ranawat), fixed valgus on clinical examination.

Operative technique

The interventions were performed by experienced surgeons specialized (5 consultants) or specializing in orthopedic surgery (10 attendings).

All patients received a cemented LCS® complete™ prosthesis with a rotating platform. In the control group, a standard MPA was performed, including temporary eversion of the patella and resection of the anterior and posterior cruciate ligament.

In the neutral and valgus TTO groups, a LSVA was performed including the lateral release, which is part of the lateral arthrotomy. In most cases, no further releases are needed. A step-cut osteotomy at the superior edge of the insertion of the patellar ligament was done to avoid proximal migration of the tibial tubercle (Fig. 2a). An osteotomy of approximately 70 mm × 30 mm × 10 mm was performed with an oscillating saw from the lateral cortex and completed with three osteotomes to break the medial cortex (Fig. 2b). The tibial tubercle was everted on the periosteal hinge and the patella subluxed medially, allowing flexion and full exposure of the knee (Fig. 2c) [10]. Resection of the cruciates and implantation of the prosthesis were then completed as in the standard MPA. After final reduction in the tibial tubercle, the osteotomy was fixed with two 3.5-mm-diameter bicortical screws without washer (Fig. 3).

Rehabilitation was the same in both groups. It consisted of the use of a continuous passive motion device in the hospital, ROM exercises as instructed by physiotherapists and the use of two crutches for 8 weeks with full weight bearing as tolerated.

Assessments

Patients were routinely assessed preoperatively and at 2 and 12 month follow-up visits. The registry data included clinical examination (range of motion, joint stability, etc.); radiographs (weight-bearing anteroposterior, lateral and skyline views); assessment of complications; and two outcome questionnaires: the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) [13] and the Knee Society Knee Scoring System© (KSS) [14]. This study was approved by, and conducted under the regulations of, the ethics committee of the canton St. Gallen (EKSG), Switzerland. The WOMAC contains 24 questions covering three

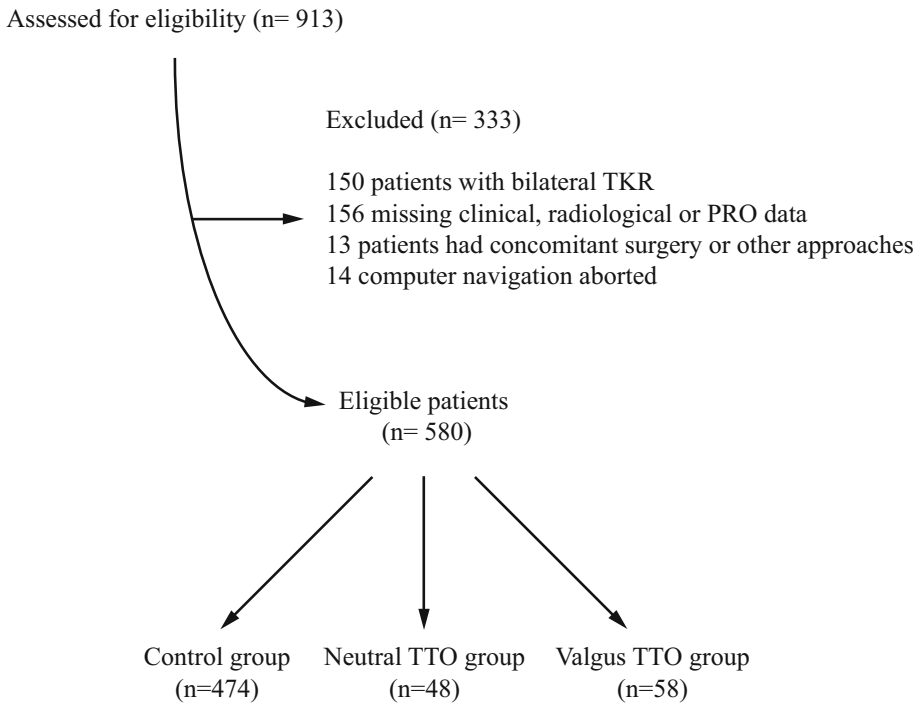

Fig. 1 Flowchart of patient enrollment and group assignment

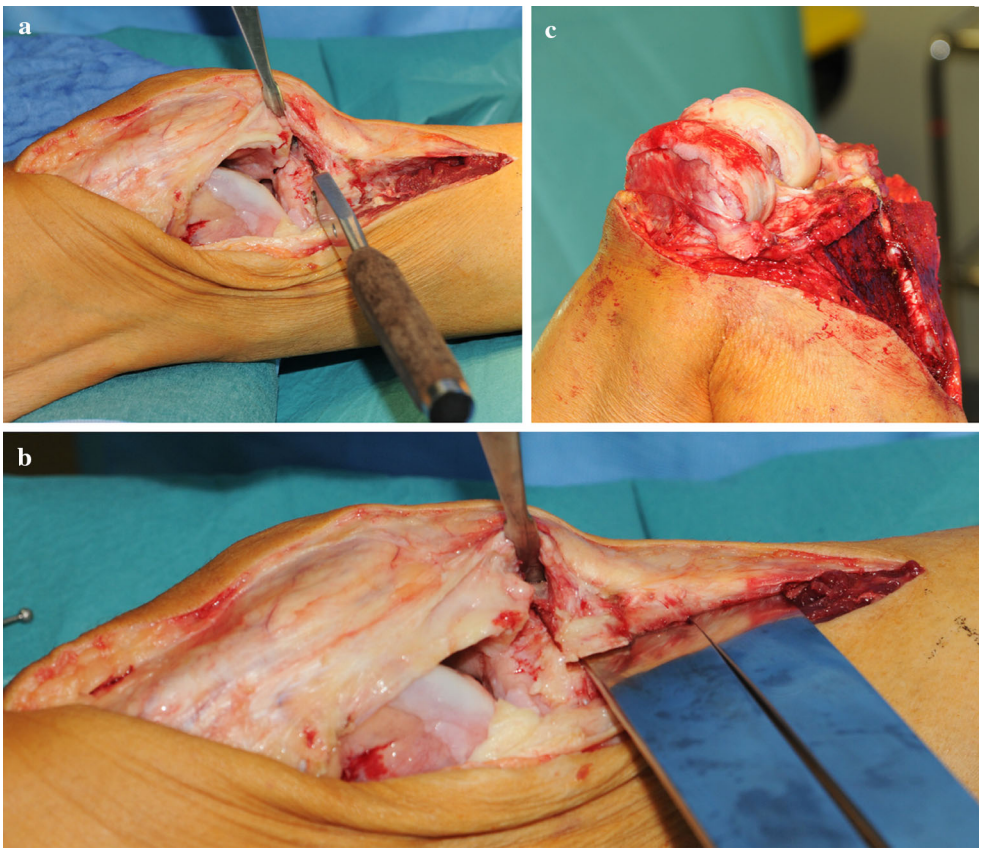

Fig. 2 Intraoperative images of the steps of the TTO procedure showing: step-cut osteotomy at the superior edge of the insertion of the patellar ligament. Osteotomy from the lateral to the medial cortex. Exposure of the knee with eversion of the tibial tubercle and medial subluxation of the patella

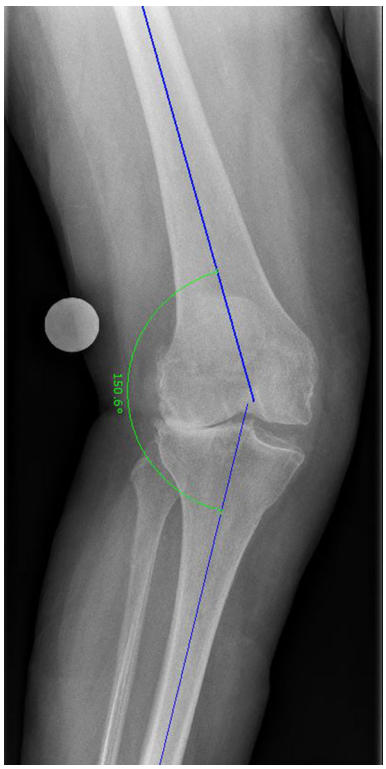

Fig. 3 Preoperative measurement of the tibio-femoral angle (LTFA)

dimensions: pain (five questions), stiffness (two questions) and function (17 questions). Each item is scored from 0 to 100 points, with higher scores indicating poorer outcomes. The WOMAC has been extensively tested for validity, reliability, feasibility and responsiveness over time [13, 15].

The KSS is a well-established and commonly used clinician-reported outcome score. The clinical portion of the KSS (pain and motion, KS) evaluates pain, joint stability, range of motion (ROM), flexion contracture and extension lag, and alignment. The functional portion (function score, FS) of the KSS evaluates walking aids, walking distance and ability to climb stairs. The score ranges from 0 to 100 for each part. Higher scores indicate better outcomes.

Two orthopedic surgeons independently reviewed digital full weight-bearing knee radiographs. The lateral tibiofemoral angle (LTFA) was measured from the anatomical femoral and tibial axes (Fig. 4).

Statistical and power analysis

Patient characteristics are presented as means, standard deviations, ranges and absolute and relative frequencies. Group comparisons of patient baseline characteristics were made with Chi-square tests or univariate analysis of variance depending on the type of variable.

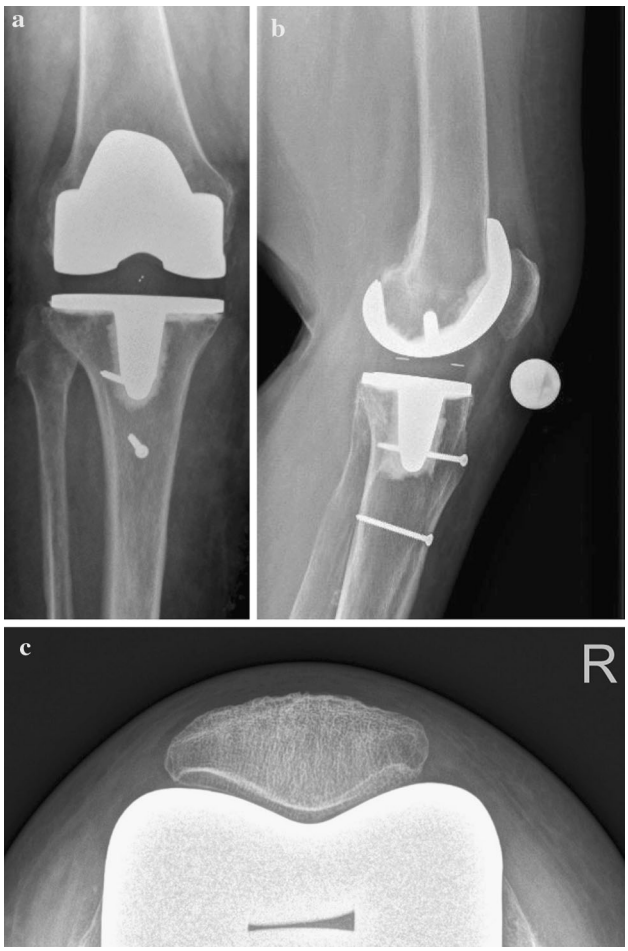

Fig. 4 Exemplary 1 year postoperative X-ray images showing: anteroposterior. Lateral fixation of the tibial tubercle with two cortical screws. Skyline view with centered alignment of the patella

To investigate the impact of type of surgery on surgical outcome (assessed with WOMAC, KSS, and knee flexion), we used mixed linear models with the following terms: a random intercept, a first-order autocorrelation covariance matrix, a fixed group effect (two TTO groups and one control group), a fixed time effect (preoperative and 2 and 12 month follow-up) and the group-by-time interaction term. The interaction term reflects the different impacts of type of surgery on change over time, i.e., a difference in surgical outcome.

Pairwise post hoc analysis was not necessary as there were no statistically significant interaction terms. For descriptions of change over time in the three groups, we provided estimated marginal means and their 95 % confidence intervals derived from the models. All statistical analyses were performed using SPSS (IBM, version 21.0, Armonk, USA). Power analysis was done for a repeated-measures analysis of variance. Because the available software (G*Power 3.1; Kiel University, Kiel, Germany) did not allow power analyses for different group sizes, we

chose a conservative approach, using the smallest group (48 patients) and calculating power for a comparison of two groups of 48 patients each (96 total) assessed at three time points. This sample size provided 90 % power to detect a group-by-time interaction with a Cohen's *f* of 0.16 (corresponding to a Cohen's *d* of about 0.30; i.e., a small to moderate effect).

Results

Demographic data are presented in Table 1. There were significantly more women in the valgus TTO group than in the other two groups. Age at surgery was significantly higher in the valgus TTO group. There was a trend toward lower body mass index (BMI) in the valgus TTO group that was not statistically significant ($p = 0.095$).

Leg alignment

The lateral tibio-femoral angle (LTFA) was similar between the control and neutral group preoperatively, but differed significantly to the valgus group (Table 2). Postoperatively no significant difference could be seen between the three groups (Fig. 5).

WOMAC and KSS scores and functional outcome

The three groups were comparable preoperatively at baseline and did not differ significantly with regard to improvement over time in WOMAC and KSS scores (Table 3). It is of note that FS was about 10 points lower at 2-month follow-up than preoperatively in all groups. This is because the FS deducts 20 points for the use of crutches. Knee flexion was comparable in all three groups preoperatively and 1 year postoperatively at approximately 115°. No significant differences were found among groups over time (Table 3).

Table 2 Radiological assessment of knee alignment measuring the lateral tibio-femoral angle (LTFA) in degrees

	Pre-op			12 months		
	Mean	SD	*N*	Mean	SD	*N*
Control group	176.4	5.1	378	174.7	2.7	417
Neutral TTO group	174.0	4.6	38	173.9	3.1	42
Valgus TTO group	165.7	5.1	40	174.3	2.8	49

SD standard deviation, *TTO* tibial tubercle osteotomy

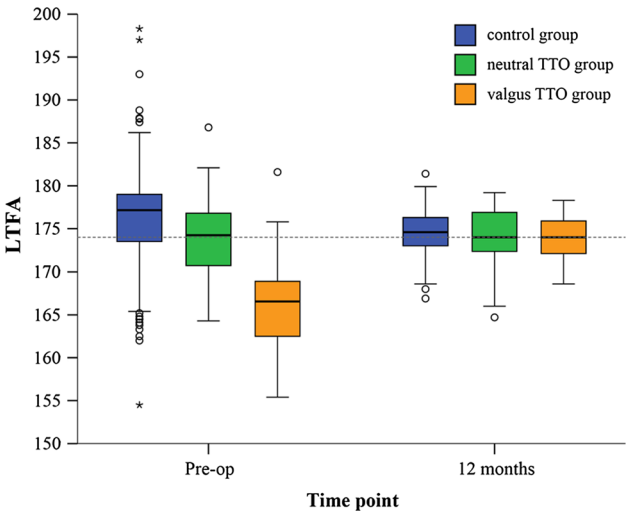

Fig. 5 Pre- and postoperative knee alignment assessed using LTFA for the control group (*blue*), neutral TTO group (*green*) and valgus TTO group (*orange*)

Table 1 Patient characteristics ($n = 580$)

	Control group ($n = 474$)	Neutral TTO group ($n = 48$)	Valgus TTO group ($n = 58$)	*p* value
Sex [*n* (%)]				
Men	205 (43.2)	25 (52.1)	13 (22.4)	0.003
Women	269 (56.8)	23 (47.9)	45 (77.6)	
CAS [*n* (%)]				
Yes	278 (58.6)	29 (60.4)	40 (69.0)	0.317
No	196 (41.4)	19 (39.6)	18 (31.0)	
Age at surgery (years)				
Mean (SD)	68.3 (9.5)	63.7 (9.6)	71.0 (7.5)	<0.001
BMI				
Mean (SD)	29.6 (5.4)	29.7 (4.9)	28.0 (5.0)	0.095

CAS computer-assisted surgery, *SD* standard deviation, *TTO* tibial tubercle osteotomy

Table 3 Preoperative, 2 and 12 months postoperative outcomes for the three groups

Outcome parameter	Pre-op Mean (95 % CI)	2 months Mean (95 % CI)	12 months Mean (95 % CI)	Group-by-time interaction
WOMAC				
Control group	50.6 (49.0–52.1)	23.8 (22.2–25.3)	15.0 (13.3–16.8)	$p = 0.337$
Neutral TTO group	49.6 (44.6–54.5)	28.0 (22.9–33.1)	16.1 (10.6–21.7)	
Valgus TTO group	50.5 (46.0–55.0)	22.4 (17.9–26.9)	11.5 (6.8–16.3)	
KSS knee score (KS)				
Control group	45.2 (43.5–46.9)	73.6 (72.0–75.2)	85.4 (83.6–87.1)	$p = 0.278$
Neutral TTO group	47.0 (41.5–52.5)	73.7 (68.6–78.8)	81.7 (75.9–87.5)	
Valgus TTO group	45.3 (40.5–50.2)	78.5 (74.0–83.0)	90.0 (85.3–94.8)	
KSS function score (FS)				
Control group	61.7 (59.9–63.5)	52.5 (50.8–54.2)	76.0 (74.1–77.8)	$p = 0.269$
Neutral TTO group	60.0 (54.2–65.8)	51.5 (46.1–56.9)	78.9 (72.9–84.9)	
Valgus TTO group	58.6 (53.5–63.7)	47.5 (42.8–52.2)	77.2 (72.2–82.2)	
Knee flexion				
Control group	113.1 (111.8–114.4)	103.6 (102.3–104.9)	113.7 (112.3–115.2)	$p = 0.318$
Neutral TTO group	116.4 (112.3–120.5)	103.5 (99.5–107.5)	114.5 (110.0–118.9)	
Valgus TTO group	111.9 (108.2–115.7)	105.3 (101.6–109.0)	115.9 (112.0–119.9)	

Control group, $n = 417$; neutral TTO group, $n = 42$; valgus TTO group, $n = 49$. Data expressed as mean score (range) or mean degree of flexion (range)

Complications

Of the 106 patients in the TTO groups, 4 developed TTO-related complications. Three patients required additional transverse screw fixation intraoperatively due to a fracture of the anterior tibial plateau. All three fractures were non-displaced and were noted when impacting the peg into the tibial plateau. However, weight bearing was not restricted and further postoperative outcome not affected. At 1-year follow-up, mean WOMAC scores for these three patients were 24.5 points and mean knee flexion was 117.5°. The fourth patient had a soft tissue revision for prolonged wound discharge and was given a short course of antibiotics. Antibiotics were stopped when tissue samples showed no bacterial growth, and further wound healing was uneventful. One-year outcome also remained unaffected in these patients (WOMAC score 24 points; knee flexion 120°). No other complications, such as nonunion or proximal displacement of the tibial tubercle, were observed in the 106 patients in the TTO groups.

Discussion

Patient specific anatomy, like strong valgus deformity of the knee, is one of the aspects to be taken into account when considering the best possible surgical approach for TKA. Additional surgical techniques can be necessary if the quality of surgical exposure is insufficient and the extensor mechanism in danger. In such cases, several authors advocate the lateral approach including tibial tubercle osteotomy [7, 10, 16, 17].

In this study, we compared the two most common approaches for TKA (lateral subvastus and medial parapatellar approach) currently performed at our hospital. In particular, we assessed clinical outcomes and osteotomy-related complications. We could not demonstrate any significant differences in clinical outcomes (WOMAC, KSS and knee flexion) of lateral and medial approach after 1 year, thus confirming previously published findings [4, 10, 18].

Hirschmann et al. [6] presented a significantly better functional outcome, less pain and more patient satisfaction 2 years after TKA with the LSVA including TTO compared to patients with a MPA.

In approximately 10 % of cases, valgus deformity occurs instead of varus malalignment. Most of the valgus knees need a lateral release for ligament balancing and to optimize patellofemoral tracking [19]. The combination of lateral release and a medial approach can significantly disrupt patellar blood supply and cause necrosis of the patella [20]. When using the LSVA, the lateral release is incorporated and patella tracking can be restored properly without disrupting medial patellar blood supply.

The clinical outcome in valgus knees has been poorer compared to those of varus knees with major deformities [19, 21]. Mechanical axis restoration was not achieved in

more than 20 % of valgus knees, even though it is one of the most important goals in TKA for valgus deformities [19, 21].

Considering postoperative alignment, Nikolopoulos reported that residual valgus deformity occurred in one-third (32 %) of the group with the standard medial approach compared to 9 % in the group with TTO [18]. Apostolopoulus [22] and Nikolopoulos preferred the lateral approach with TTO to restore anatomical axis accurately in moderate to severe cases of valgus deformities. As recently published, range of motion, the KSS and the WOMAC improved significantly in knees with non-correctable valgus knee osteoarthritis using a lateral approach with TTO [23]. According to our data, the 1-year post-op clinical outcome of the valgus TTO group effectuated equally good results despite inferior initial position.

It is known that women have worse preoperative physical function and do not reach the same final level of physical function as men, but they may have similar or even greater improvement in pain after TKA [24]. In our study, more women were affected with valgus deformities, but achieved the same clinical results as men.

Several studies highlighted other positive aspects of the lateral approach including TTO: (1) the facile patella eversion which will subsequently reduce adjacent forces onto patellar tendon [11]. (2) A direct lateral release to correct limited knee flexion [5]. (3) An optimization of patellofemoral tracking can be achieved by a medial transfer of the tibial tubercle [25]. (4) A decreased risk of fractures based on the preferential medial blood supply of the patella [11, 26].

Nonetheless, possible TTO-related complications present a certain disadvantage. The rate of complication in our study was only 3.8 % which is comparable to the recent literature [5]. Four out of 106 patients developed TTO-related complications after the LSVA. Three of these four patients required an additional screw fixation caused by intraoperative tibial fracture. Wound healing impairment is a dangerous complication, thereby increasing potential risk of infection [27]. Only one patient in the TTO group underwent revision surgery due to wound healing impairment. Importantly, these complications did not negatively affect the functional outcome of the four patients.

In the literature, TTO-related complications range from 0 to 9 % and the majority are attributed to proximal dislocation, avulsion fracture of the tubercle tibiae, TTO associated pain and fractures and fissures in the area of the TTO and tibial plateau [4, 5]. Partial weight bearing is recommended for 6 weeks in case of tibial plateau fracture [6]. In this study, we did not detect any other complications like nonunion or proximal dislocation of the tibial tubercle. Concordant to recent studies, we used two bicortical screws to ensure best stability for re-fixating the tibial tubercle [28, 29] as osteoregeneration can be delayed after wire fixation [22]. Proximal dislocation is preventable through sufficient step-cut osteotomy to support the TTO against proximal adjacent forces [6, 29]. With respect to these findings and knowing there was an intact quadriceps mechanism, we were able to allow early rehabilitation with full weight bearing and free range of motion as recommended already in 1990 [7]. In 1996, Ries et al. [27] reported a significantly higher risk of developing complications with a TTO length less than 5.5 cm. Moreover, bone quality and thickness of the TTO with the musculo-periosteal flap are important factors concerning complications like nonunion, skin necrosis or infection. It has been shown that TTO width of <14 mm and distal screws distance of <51.7 mm from the tibial component are advantageous in diminishing risk of complications [5, 29].

One limitation of our study is the retrospective study design. Furthermore, the decision about the approach to be used was not randomized. The surgeon decided which approach to use, based on clinical findings and history and according to his preference. This factor could probably influence the homogeneity of our groups. For clinical outcome studies, the follow-up period appears to be short. However, this should not be a serious limitation for our study as any differences potentially related to surgical approach should appear relatively early, most probably within 1 year. This applies especially to complications related to TTO.

Conclusions

The functional outcome after TKA using the LSVA with TTO was comparable with the medial standard approach 1 year postoperatively. Therefore, the results of the current study support the LSVA as a viable alternative in cases of primary TKA if technical difficulties with the MPA are anticipated. Considering the risk for complications related to TTO, the LSVA should be reserved for patients with increased valgus deformities and patella alignment problems. With application of precise surgical technique, the LSVA seems to be a safe and reproducible procedure.

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Compliance with ethical standards

Conflict of interest The authors Langen, Gaber, Zdravkovic, Giesinger and Behrend declare that they do not have any conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

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