



Computer navigation helps achieving appropriate gap balancing and restoration of alignment in total knee arthroplasty for fixed valgus knee osteoarthritis irrespective of the surgical approach

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The aim of this study was to describe the deformity of both bone and soft tissues in valgus knees and attempt, with the help of computer-assisted total knee arthroplasty (CAS-TKA), to answer the question whether a medial or lateral approach should be used in a fixed deformity.

This was a prospective study of 52 consecutive patients with valgus knee osteoarthritis (OA) on who CAS-TKA was performed between 2008 and 2012. Only patients (N = 42) with valgus deformity Krackow type II and III were included for detailed analysis : 17 were operated utilizing a medial and 25 using a lateral approach. Computer navigation was used to perform quantitative control of alignment and gap changes in the medial and lateral knee compartment after each step of the release. Radiological alignment as well as functional results with Knee Society and WOMAC scores were evaluated after a mean (SD) of 23 (5) months in all patients.

Twenty-eight different combinations of pathological changes of bone and soft-tissues were described in the 52 patients making the identification of a typical pathological pattern for valgus deformity impossible. In 60% of patients, irrespective from the approach, the valgus deformity was reduced after release of the ilio-tibial tract.

No significant difference between both groups was observed in the extent of releases, gap balancing, surgical time, implants constraint, leg alignment and mid-term functional outcomes. None of the included patients were revised for any reason.

In conclusion, regardless of the approach, CAS TKA facilitates the achievement of precise soft tissue balancing and alignment in patients with valgus type II and III deformity leading to good mid-term functional and radiological outcomes.

Level of evidence : Level IV study.

Keywords : knee arthroplasty ; valgus deformity ; approaches ; navigation ; computer-assisted surgery.

INTRODUCTION

Among patients in need for total knee arthroplasty (TKA) the frequency of valgus deformity is about

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10% (21). Valgus knees can be challenging, even for the experienced surgeon (22). Postoperative residual valgus deformity does not necessarily provoke early implant loosening but could compromise the clinical outcome. The lack of performing the appropriate bone cuts with respect of the joint line and/or extensive soft-tissue releases that destabilize the knee may lead to the necessity of using a constrained implant (18).

In the valgus knee, both the medial and lateral approach is commonly used and they have each their specific advantages and difficulties (4,6,7,12). Proponents of the medial approach argue that it's a more common approach for surgeons, the patella subluxates to the lateral side more easily and all necessary steps in the release process can be performed sequentially (8). Whereas advocates of the lateral approach emphasize that it allows direct visualization and precise step by step release of pathologically contracted lateral structures, a lateral capsular release occurs automatically, the weak medial stabilizers (Medial Collateral Ligament ; MCL) do not suffer from additional slackening and finally preservation of the blood supply from superior and inferior medial arteries reduces the risk of avascular necrosis of the patella (3,23). In the literature today there is no consensus about the type of approach that should be preferentially used or the sequence of soft-tissue releases in patients with fixed valgus deformity. Computer-assisted surgery (CAS), despite its unique ability to provide quantitative real-time feedback, is still seldom used during TKA (20). Potential reasons are the capital cost of the hardware and the time spent during surgery. Especially when CAS is utilized to measure several parameters, additional time is lost during the procedure.

The aim of this study was to describe the deformity of bone and soft tissues in fixed valgus knees and with the help of computer navigation to answer the question whether a medial or lateral approach should be used in a fixed deformity. The hypothesis of this study was that in Krackow type II and III fixed valgus deformity a lateral approach would lead to better clinical outcomes, neutral mechanical alignment with less outliers and a reduced sequence of soft-tissue releases to obtain adequate soft tissue balancing.

MATERIALS AND METHODS

This study was conducted at the Russian Research Institute of Traumatology and Orthopedics n.a. R.R.Vreden (Vreden's Institute) in St. Petersburg, Russia. The study was approved by the Local Ethics Committee at Vreden's Institute. Informed written consent was obtained from all patients. From 2008 to 2012, 52 consecutive patients with fixed valgus knees were prospectively evaluated for this study. Among these patients 42% (22/52) suffered from posttraumatic OA, 39% (20/52) from idiopathic OA ; 17% (9/52) from rheumatoid arthritis (RA) and finally 2% (1/52) of avascular necrosis (AVN) of lateral femur and/or tibia condyles. The mean age (SD) of the patients was 64 (7) years. The mean (SD) degree of mechanical valgus deformity was 20° (4°) as measured with the Hip Knee Ankle (HKA) angle. More than half of the patients (27/52) had a flexion contracture : 9/52 (17%) up to 10° ; 11/52 (21%) from 10° to 20° and 7/52 (13%) more than 20°. Eleven/52 (21%) patients had an hyperextension ranging from 5° to 38°.

In all included TKA the pre-operative and post-operative alignment as well as a range of motion was measured. Before and after each step of the surgery, an optical navigation system was used to perform intra-operative quantitative control of surgical parameters like leg alignment, gap changes in the medial and/or lateral knee compartments in extension and flexion, the amount of passive extension and flexion and the patellar tracking.

The amount of pre-operative and post-operative mechanical deformity in the coronal plane was measured on full leg standing radiographs. Clinical outcome was evaluated using two clinical scoring systems, the Knee Society Score (KSS) and WOMAC-score.

All patients were divided into 3 categories using the valgus deformity classification described by Krackow (13). Pre-operative clinical examination was performed by the surgeons performing the procedure (NK and TK). Stratification was the following : 10 type I patients ; 29 type II patients and 13 type III patients. Patients were followed up by younger surgeons (AP and VI) at 3, 6, 12 months and than yearly. Clinical exam included evaluation of passive and active ROM, frontal stability in full extension and at 30 degree of flexion, sagittal stability at 30 and 90 degree of flexion as well as the Patient Reported Outcome Measurement systems.

Among all 42 patients with type II and type III valgus deformity only for one case (2%) there was the need to use a semi-constrained implant (NexGen-LCCK, Zimmer Biomet, Warsaw, US). In the other 41 patients unconstrained Posterior Cruciate Ligament (PCL)

-retaining (28/41 or 66%) and Posterior-Stabilized (PS) (13/41 or 32%) implants were utilized. The implanted CR types were 20 Sigma (DePuy Johnson & Johnson, Warsaw, US), 7 NexGen CR (Zimmer Biomet, Warsaw, US) and 1 AGC (Zimmer Biomet, Warsaw, US). PS implants included 7 NexGen PS (Zimmer Biomet, Warsaw, US), 4 LCS (DePuy Johnson & Johnson, Warsaw, US) and 2 Sigma (De Puy Johnson & Johnson, Warsaw, US). In the group with the lateral approach there were 16 CR and 9 PS implants, in the medial approach group there were 12 CR, 4 PS and 1 semi-constrained implant.

The decision on the choice of the surgical approach was randomized in all cases by the order of surgery. The first case of the day undergoing a medial and the second case a lateral approach.

Surgical Procedure

Spinal anesthesia was used for all patients. In the group with a standard medial approach, a midline incision of skin, subcutaneous fat and fascia was made in one layer, than a medial parapatellar arthrotomy was performed. In the other group a lateral parapatellar approach was used as described by Keblish *et al* (12) with the creation of a capsular-fat pad flap everted on the lateral inferior geniculate artery. The patella was left unresurfaced in all patients, but treated with peripheral osteophytes resection as well as surrounding synovium excision and circumferential denervation by electrocautery.

In all cases computer navigation system VectorVision (Brainlab, Munich, Germany) was used. Rigid femoral and tibial trackers were fixed to the bones by two 4 mm Schanz screws either through the main approach or via additional stab wounds. After collection of all required anatomical landmarks the amount of valgus deformity and full flexion and extension positions were recorded.

Both menisci and the ACL were excised. In CR TKA the distal insertion of the PCL was slightly mobilized at the level of the tibial cut to avoid damaging during tibial resection.

First an extension gap was created, based on the principles of measured resection and secondly the flexion gap, utilizing a balancing technique with equal tension between resected surfaces, was created with patella in situ. Both gaps were planned and controlled by navigation.

Conventional distal femur and proximal tibial cuts perpendicularly to the mechanical axis were performed first with resection corresponding to the type of implant used. If residual bone defects were less than 5 mm depth

and less than 50% of condyle they were ignored and filled by bone cement during implantation. In 5 cases with more important bone deficiency, bone autograft (3 patients) or substitution by metal block (2 patients) was performed.

Further posterior horns of menisci, posterior osteophytes and loose bodies were removed to clear the posterior aspect of the knee. At this stage of the surgery the decision to retain or resect the PCL was made depending on its status. The extension gap was measured with a spacer block and with the help of navigation 3 parameters were quantitatively controlled: leg alignment, degree of extension and medial-lateral symmetry under manual varus/valgus stress. If at this point full leg extension, neutral leg alignment and medial-lateral symmetry within 2 mm was not achieved, soft-tissue releases on the concave side of the deformity were performed.

The sequence of soft tissue releases was the following: ilio-tibial band (ITB), postero-lateral corner (PLC), posterior capsule (PC), lateral head of gastrocnemius (LHG), mobilization of proximal tibio-fibular syndesmosis for relative lengthening of lateral collateral ligament (LCL) and biceps tendon (BT) and, finally, partial resection of fibular head near syndesmosis for its further mobilization and relative lengthening of lateral collateral ligament and biceps tendon. Release of the lateral collateral ligament and/or popliteal tendon as described by several authors (2,24) was avoided because of the higher risk to compromise the preservation of the appropriate knee stability suitable for standard unconstrained CR or PS implant as was previously noted by McAuley *et al* (15).

For the planning of the rotational position of the femoral component, before definite cuts were performed, a balancing device called "sensor-tensor" (BrainLab, Germany) was used with the extensor mechanism in place and the knee flexed at 90°. The epicondylar, anterior-posterior (Whiteside) and posterior condylar lines were used as second rotational reference control with preference to the first balanced one.

The size of the tibial and femoral components was determined to match the patient's anatomy as close as possible. But usually after reducing the deformity in extension by releases on the concave side and resection of the PCL, the flexion gap increased and became bigger than the extension gap both with medial and lateral approaches. To equal both gaps the femoral component was upsized one size or when it was not possible from an anatomical point of view to avoid medio-lateral overhang, the component was slightly flexed and moved more posteriorly to increase the posterior offset and decrease

the flexion gap. Navigation showed that flexion of the femoral component by 1° decreased the flexion gap by 1 mm and the extension gap by 0.5 mm. Posterior displacement of the femoral component by 1 mm reduced only the flexion gap by 1 mm. Usually both flexion and posterior displacement of the femoral component was combined under control of the navigation system. For none of the cases 5 degrees of flexion and a 2 mm increase of the posterior femoral offset were combined. Besides reducing the flexion space one can also equal the gaps by increasing the distal femur resection. It was intended however to keep the distal joint line in an anatomic position and never to change it more than 2 mm.

After manual fine-tuning of femoral component orientation in all three planes; distal, anterior-posterior and chamfer femoral cuts were performed and checked with navigation. During trial implantation leg alignment and joint stability were evaluated under quantitative control of navigation system throughout the whole arc of motion. The knee was considered balanced when up to 2 mm of laxity was seen under varus/valgus stress in full extension and up to 3 mm at 90 degree of flexion with same size insert and patella in place.

The patellar tracking was evaluated according to the criteria described by Akagi *et al* (1). It was noted whether no thumb, one thumb or a lateral release were necessary when mal-tracking happened.

Tibial and femoral components were fixed using low-viscosity gentamicin loaded bone cement (CMW1, DePuy Johnson&Johnson, UK). After cement polymerization tourniquet was released for bleeding control. One suction drain was used for 24 hours. Closure in flexion was conventional.

Active exercises as well as mobilization with two crutches started the day after surgery and was prolonged for three weeks. Cefazolin was used for infection prophylaxis (first 1 g 30 minutes prior to incision, followed post-operatively by 1 g every 8 hours for 24 hours) and Enoxaparine Sodium injections for venous thromboembolism prophylaxis during 14 days.

Statistical analysis

For comparison of proportions between groups univariate analysis was performed with chi-square and Fisher's exact test. Statistical analysis was performed with Mann-Whitney U test to compare nonparametric data between two independent and the Student's test for dependent samples. All differences were considered significant at a probability level of 95% ($p < 0.05$).

Statistical analysis was performed with STATISTICA software (version 10.0; StatSoftInc; Tulsa; Oklahoma; USA).

RESULTS

During the surgery the following pathological changes were observed:

At the level of the bone:

- 1) lateral femoral and tibial osteophytes – 52 (100%) patients;
- 2) bone defects or hypoplasia of the distal part of the lateral femur condyle – 47 (90.5%);
- 3) lateral patellar subluxation compared to the trochlea – 41 (79%);
- 4) bone defects of lateral tibial condyle – 27 (52%) patients: contained defect in 12 (23%) and uncontained defect in 15 (29%);
- 5) patellar trochlea wear or hypoplasia – 13 (25%);
- 6) bone defects or hypoplasia of posterior part of lateral femur condyle – 6 (11.5%);
- 7) lateral patella dislocation (patella completely lateral of trochlea) – 3 (6%).

Observed abnormalities of soft-tissue stabilizers:

- 1) ilio-tibial band tightness and shortening – 43 (83%);
- 2) lateral patella retinaculum tightness – 39 (75%);
- 3) medial collateral ligament lengthening/insufficiency – 13 (25%);
- 4) sclerotic changes to posterior capsule and stabilizers in postero-lateral corner of the knee – 12 (23%).

Twenty-eight different combinations of pathological changes of both bone and soft-tissues were observed making a typical pathological pattern for valgus deformity impossible. The most common features of valgus pathology were femoral and tibial osteophytes (100%), lateral condyle bone loss in both femur (90.5%) and tibia (52%); malrotation of the distal femur (90%); and finally ilio-tibial band (83%) and lateral patella retinaculum (75%) tightness.

Patients with a type I valgus deformity didn't need any soft-tissue releases during TKA because

Table I. — Baseline characteristics of patients with types II and III valgus deformity

Variable	Approach	Min	Max	Mean	SD	m	t	p	Conclusion
Age	Medial	33	76	63.5	12	2.93	0.5	0.53	insignificant
	Lateral	46	78	62	10	1.91			
BMI	Medial	22	33	29	2.74	0.66	1	0.53	insignificant
	Lateral	19	39	28	4.14	0.83			
Flexion	Medial	100	50	76	14.5	3.51	0.2	0.68	insignificant
	Lateral	100	45	75	16.5	3.27			
Extension	Medial	153	197	173	11	2.69	0.6	0.88	insignificant
	Lateral	140	218	176	16	3.23			
Amount of deformity	Medial	12	46	21	10	2.38	1.7	0.05	insignificant
	Lateral	10.5	50	26	9	1.75			
KS knee score	Medial	6	55	23	13	3.08	1.4	0.33	insignificant
	Lateral	0	41	18	11	2.16			
KS function score	Medial	20	92	44.5	21	5.12	0.3	0.81	insignificant
	Lateral	10	86	46.5	20.5	4.09			
WOMAC	Medial	43	80	68	13	3.13	0.2	0.75	insignificant
	Lateral	44	82	67	12	2.34			

leg alignment was corrected automatically after restoring the anatomy by osteophytes removal and proper bone cuts. Therefore only the patients with valgus type II and III were included for detailed analysis.

Table I shows the equal distribution of patients among two groups. Frequency of releases depending of the approach are shown in table II. In one third of patients (5/17) operated with a medial approach an extensive lateral retinaculum release was necessary to normalize patella tilt and tracking.

The findings of this study showed that in 60% of patients irrespective from the approach, the valgus deformity was reduced after release of the ilio-tibial tract. The relative lengthening of the lateral collateral ligament and biceps tendon (steps V and VI) was necessary more often in case a medial approach was utilized (29,5% vs 24%), but the difference was not significant.

The differences in sagittal position of the femoral component during flexion gap balancing are presented in Table III but were non-significant between two groups. In the group with a medial approach the mean (SD) distal resection was 11.5 (2) mm and with the lateral approach it was a mean (SD) 11

(1.5) mm ($p = n.s.$). The choice of surgical approach did not have an influence on the relative values of extension and flexion gaps, but in valgus deformity patients significant gap mismatches occur very often. Computer navigation allowed to control precisely the size of the extension and flexion space, both medially and laterally. In patients undergoing a medial approach the mean difference between the lateral and medial compartment in extension was 1 mm (range from -1 to 7 mm) and in flexion 0.1 mm (range from -3.5 to 5.5 mm) (negative value corresponds to a larger gap in the lateral compartment). The maximum imbalance of the extension and flexion gap (7 and 5.5 mm respectively) was observed in one patient where a semi-constrained implant was therefore necessary to use. The mean difference between extension and flexion gaps was 2.7 mm (0 to 6 mm). In patients with a lateral approach the mean difference between the lateral and medial compartment in extension was 0.1 mm (range from -2.5 to 1.5 mm) and in flexion -0.2 mm (range from -3.5 to 3 mm) (the negative value correspond to larger gap in lateral compartment). The mean difference between extension and flexion gaps was 3.1 mm (0 to 7,5 mm). The differences between

Table II. — Frequency of releases in groups with lateral and medial approach

Release step	Anatomical structure	Medial approach		Lateral approach	
		abs.	%	abs.	%
I	ITB mobilization from Gerdy tubercle	2	12%	12	48%
II	I + transverse cut of ITB at the level of joint line	8	47%	3	12%
III	II + PLC incision and resection of sclerotic posterior capsule in lateral compartment	2	12%	2	8%
IV	III + mobilization of lateral gastrocnemius head from the femur	0	0.0%	2	8.0%
V	IV + mobilization of proximal tibio-fibular syndesmosis (relative lengthening of lateral collateral ligament and biceps tendon)	3	17.5%	4	16.0%
VI	V + partial resection of fibular head near syndesmosis for it further mobilization (advanced relative lengthening of lateral collateral ligament and biceps tendon)	2	11.5%	2	8.0%

two groups were not significant. The choice of approach did not show any influence on achieving good knee balancing in patients with valgus deformity.

There was no influence for leg alignment either. Leg alignment was precisely restored in both groups of patients : with the medial approach a mean (SD) 180.5° (0.5°) valgus and with the lateral approach a mean (SD) 181° (1°) valgus was obtained.

When comparing both approaches the lateral is usually considered to be technically more difficult. The time of surgery might indirectly confirm this idea. In this study the mean (SD) surgery time in patients with a medial approach was 158 (37) minutes, while with a lateral approach it was a mean (SD) 149 (18) minutes (n.s.). During surgery more

time was spent performing the lateral approach on itself, but less time was necessary to obtain correct balancing.

The results of TKA were evaluated after a mean (SD) 23 (5) months in all patients : there was no statistically difference between two groups (Table IV). None of the patient were revised for any reason.

DISCUSSION

The most important finding of this study was that the hypothesis that the lateral approach would be more appropriate to correct a fixed valgus deformity of the knee could not be confirmed. With the help of CAS both medial and lateral approaches may be

Table III. — Flexion gap planning variables after achieving balance and neutral alignment in extension

Variables	Approach	Min	Max	Mean	SD	m	t	p	Conclusion
Flexion of femoral component	Medial	-0.5°	8°	4°	2.2	0.53	0.2	0.44	non-significant
	Lateral	0.5°	8°	4°	2.0	0.4			
Posterior displacement of femoral component	Medial	2 mm	10.5 mm	1.8	3.1	0.76	0.5	0.72	non-significant
	Lateral	1.5 mm	14.5 mm	2.2	3.2	0.6			
Thickness of distal femoral resection	Medial	8 mm	16.5 mm	11.5	1.9	0.47	0.5	0.77	non-significant
	Lateral	7.5 mm	14 mm	11	1.6	0.3			
Difference between medial and lateral side in flexion gap	Medial	3.5 mm	5.5 mm	0.1	1.9	0.47	0.6	0.97	non-significant
	Lateral	-3.5 mm	3 mm	-0.2	1.5	0.3			
Difference between medial and lateral side in extension gap	Medial	-1 mm	7 mm	1.0	1.7	0.42	2.6	0.11	non-significant
	Lateral	-2.5 mm	1.5 mm	-0.1	1.0	0.2			
Difference between extension and flexion gaps	Medial	0	6 mm	3.1	2.1	0.5	0.7	0.95	non-significant
	Lateral	0	7.5 mm	2.7	1.9	0.4			

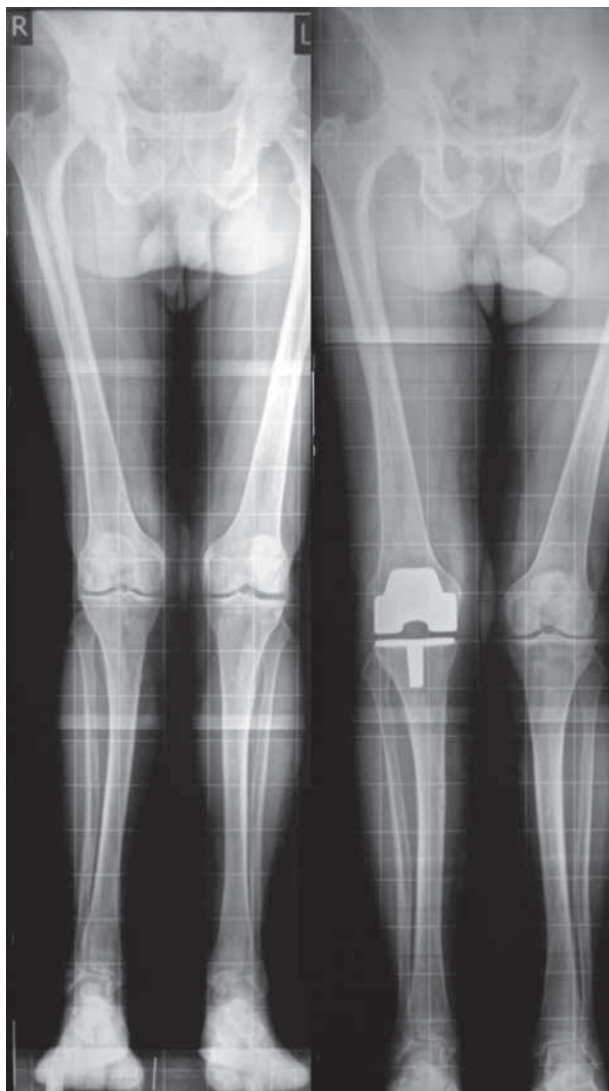


Fig. 1. — Frontal leg alignment in valgus OA patient before and after CAS TKA.

equally effective in achieving proper balance and good alignment in patients with valgus type II and type III deformity obtaining good clinical outcomes in both groups.

Nikolopoulos *et al* have compared both approaches in 44 valgus TKA and found that clinical results were similar, however residual valgus deviation occurred in 9% of TKA patients after lateral and in 32% after medial approach concluding that the lateral approach was more adapted for cases

with significant deformity (17). In this study no difference in alignment could be observed because of the use of CAS.

In the study of Hirschmann *et al* lateral approach was combined with a tibial tuberosity osteotomy (TTO) which lead to slightly better functional results and less pain two years after TKA but was associated with a higher risk of complications due to secondary displacement of the tibial tuberosity (10). Interestingly, patients treated with a lateral approach were also significantly more stable in terms of valgus laxity (10). In this series quantitative control of ligament balancing with CAS during surgery helped avoiding frontal deviations irrespective from approach.

The diversity of pathological changes to the soft tissues and bone among valgus knee patients proved to be very variable : 28 different combinations in 52 patients were observed. Therefore every valgus knee might be considered somewhat unique asking for specific bone cuts and soft tissues releases. The valgus knee is one of the clinical situations where the unique abilities of computer-assisted surgery to give real-time quantitative feedback can be of value (20).

In the past decade numerous studies dedicated to navigated TKA were mostly focusing on the precision of bone cuts for achieving neutral leg alignment. However as demonstrated by Parratte *et al* this might be less important for long-term survival of the implant than other relevant factors like instability or tightness (19).

Chou *et al* reported that the aid of computer navigation for soft tissue balancing and component implantation, in conjunction with novel pre-op templating techniques, improved both clinical and radiographic results in 21 valgus patients with a mean follow-up of 37.8 months (5).

Hadjicostas *et al* successfully used computer-assisted surgery to find the correct isometric position for the osteotomized lateral epicondyle in order to balance severe valgus knees without ligament release on the lateral side in 15 patients with excellent mid-term outcomes (9). A similar technique was later used by Mullaji *et al* (16).

In our series no lateral epicondylar sliding osteotomy was performed although it might have been

Table IV. — Postoperative functional results of TKA in both groups of patients

Variable	Approach		p	Conclusion
	Medial Mean (SD)	Lateral Mean (SD)		
KS knee score	83.5 (8.5)	84 (8.5)	< 0.05	insignificant
KS function score	84.5 (8)	86.5 (7.5)	< 0.05	insignificant
WOMAC	11.5 (3)	11.5 (3)	< 0.05	insignificant

an alternative in 5 cases where step V and VI releases were used.

Recently Huang *et al* found that CAS TKA helps to control the joint line significantly better than conventional surgery and it helps reduce the need for a lateral retinaculum release in patient with type II valgus deformity (11). However, there were no differences in clinical function, limb and component alignment, as well as survival of implants between 34 CAS and 36 conventional TKA patients after a mean follow-up of 6.2 years.

Another value add of CAS to the flexion gap balancing approach, as observed in the current study, was the possibility to plan and predict the rectangular gap in flexion before anterior and posterior cuts were done, while leg alignment and stability in extension were already corrected by utilizing a measured resection technique. Despite this meticulous and time-consuming approach (all surgeries lasted more than 1.5 hours) in one case unbalanced gaps led to necessity of a semi-constrained TKA. A more constrained implant should be available on the shelf when treating fixed valgus knees.

An important limitation of this study is that 6 alternative CR or PS knee systems were implanted in this series of type II and III valgus patients. This reflects the busy practice of a high volume orthopedic center with over 2500 primary TKA performed each year. To compensate for differences in implant designs all surgeries were performed in a similar manner by two senior authors (NK and TK) with each step quantitatively estimated with the help of computer navigation system.

CONCLUSION

Regardless of the surgical approach CAS TKA facilitates the achievement of precise soft tissue bal-

ancing and accurate alignment in patients with valgus type II and III deformity that finally leads to good mid-term functional and radiological outcomes. Quantitative feedback from CAS might be the reliable tool for relevant surgical decision-making in difficult primary TKA.

REFERENCES

1. Akagi M, Matsusue Y, Mata T, Asada Y, Horiguchi M, Iida H, Nakamura T. Effect of rotational alignment on patellar tracking in total knee arthroplasty. *Clin Orthop Relat Res*. 1999 ; 366 : 155-63.
2. Apostolopoulos AP, Nikolopoulos DD, Polyzois I, Nakos A, Liarokapis S, Stefanakis G, Michos IV. Total knee arthroplasty in severe valgus deformity : interest of combining a lateral approach with a tibial tubercle osteotomy. *Orthop Traumatol Surg Res* 2010 ; 96 : 777-784.
3. Boyer P, Boublil D, Magrino B, Massin P, Hutten D. Total knee replacement in the fixed valgus deformity using a lateral approach : role of the automatic iliotibial band release for a successful balancing. *Int Orthop* 2009 ; 33 : 1577-1583.
4. Brillhault J, Lautman S, Favard L, Burdin P. Lateral femoral sliding osteotomy lateral release in total knee arthroplasty for a fixed valgus deformity. *J Bone Joint Surg Br* 2002 ; 84 : 1131-1137.
5. Chou WY, Siu KK, Ko JY, Chen JM, Wang CJ, Wang FS, Wong T. Preoperative templating and computer-assisted total knee arthroplasty for arthritic valgus knee. *J Arthroplasty* 2013 ; 28 : 1781-1787.
6. Easley ME, Insall JN, Scuderi GR, Bullek DD. Primary constrained condylar knee arthroplasty for the arthritic valgus knee. *Clin Orthop Relat Res* 2000 ; 380 : 58-64.
7. Engh GA. The difficult knee : severe varus and valgus. *Clin Orthop Relat Res* 2003 ; 416 : 58-63.
8. Favorito PJ, Mihalko WM, Krackow KA. Total knee arthroplasty in the valgus knee. *J Am Acad Orthop Surg* 2002 ; 10 : 16-24.
9. Hadjicostas PT, Soucacos PN, Thielemann FW. Computer-assisted osteotomy of the lateral femoral condyle

- with non-constrained total knee replacement in severe valgus knees. *J Bone Joint Surg Br* 2008 ; 90 : 1441-1445.
10. **Hirschmann MT, Hoffmann M, Krause R, Jenabzadeh RA, Arnold MP, Friederich NF.** Anterolateral approach with tibial tubercle osteotomy versus standard medial approach for primary total knee arthroplasty : does it matter ? *BMC Musculoskelet Disord* 2010 ; 11 : 167.
 11. **Huang TW, Lee CY, Lin SJ, Peng KT, Huang KC, Lee MS, Hsu RW, Shen WJ.** Comparison of computer-navigated and conventional total knee arthroplasty in patients with Ranawat type-II valgus deformity : medium-term clinical and radiological results. *BMC Musculoskelet Disord* 2014 ; 22 : 390.
 12. **Keblish PA.** The lateral approach to the valgus knee. Surgical technique and analysis of 53 cases with over two-year follow-up evaluation. *Clin Orthop Relat Res* 1991 ; 271 : 52-62.
 13. **Krackow KA, Jones MM, Teeny SM, Hungerford DS.** Primary total knee arthroplasty in patients with fixed valgus deformity. *Clin Orthop Relat Res* 1991 ; 273 : 9-18.
 14. **Krackow KA, Mihalko WM.** Flexion-extension joint gap changes after lateral structure release for valgus deformity correction in total knee arthroplasty : a cadaveric study. *J Arthroplasty* 1999 ; 14 : 994-1004.
 15. **McAuley JP, Collier MB, Hamilton WG, Tabaraee E, Engh GA.** Posterior cruciate-retaining total knee arthroplasty for valgus osteoarthritis. *Clin Orthop Relat Res* 2008 ; 466 : 2644-2649.
 16. **Mullaji AB, Shetty GM.** Lateral epicondylar osteotomy using computer navigation in total knee arthroplasty for rigid valgus deformities. *J Arthroplasty* 2010 ; 25 : 166-169.
 17. **Nikolopoulos DD, Polyzois I, Apostolopoulos AP, Rossas C, Moutsios-Rentzos A, Michos IV.** Total knee arthroplasty in severe valgus knee deformity : comparison of a standard medial parapatellar approach combined with tibial tubercle osteotomy. *Knee Surg Sports Traumatol Arthrosc* 2011 ; 19 : 1834-1842.
 18. **Pang HN, Yeo SJ, Chong HC, Chin PL, Chia SL, Lo NN.** Joint line changes and outcomes in constrained versus unconstrained total knee arthroplasty for the type II valgus knee. *Knee Surg Sports Traumatol Arthrosc* 2013 ; 21 : 2363-2369.
 19. **Parratte S, Pagnano MW, Trousdale RT, Berry DJ.** Effect of postoperative mechanical axis alignment on the fifteen-year survival of modern, cemented total knee replacements. *J Bone Joint Surg Am* 2010 ; 92 : 2143-2149.
 20. **Pearle AD, Kendoff D, Musahl V.** Perspectives on computer-assisted orthopaedic surgery : movement toward quantitative orthopaedic surgery. *J Bone Joint Surg Am* 2009 ; 91 : 7-12.
 21. **Ranawat AS, Ranawat CS, Elkus M, Rasquinha VJ, Rossi R, Babhulkar S.** Total knee arthroplasty for severe valgus deformity. *J Bone Joint Surg* 2005 ; 87A : 271-284.
 22. **Rossi R, Rosso F, Cottino U, Dettoni F, Bonasia DE, Bruzzone M.** Total knee arthroplasty in the valgus knee. *Int Orthop* 2014 ; 38 (2) : 273-283.
 23. **Sekiya H, Takatoku K, Takada H, Sugimoto N, Hoshino Y.** Lateral approach is advantageous in total knee arthroplasty for valgus deformed knee. *Eur J Orthop Surg Traumatol* 2012.
 24. **Whiteside LA.** Selective ligament release in total knee arthroplasty of the knee in valgus. *Clin Orthop Relat Res* 1999 ; 367 : 130-140.