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Preoperative TKA Planning on Long-Leg Hip-Knee-Ankle Radiographs and It's Impact on Postoperative Coronal Knee Alignment

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Abstract

Background. The importance of measuring of the angle between the mechanical and anatomical femoral axis (FVA) during the preoperative total knee arthroplasty (TKA) planning is not recognized by all. Some surgeons believe that it is acceptable to set distal femoral resection guide at 6° or 7° in all cases or adjust femoral resection guide FVA accordingly with patient height. ***Materials and Methods.*** We conducted two studies. One — retrospective analysis of radiographs of patients with TKA performed since 1.09.2014 till 31.01.2015 (n = 261, 273 TKA). In this cohort, we were looking for correlation between the parameters obtained on long hip-knee-ankle radiographs (FVA, coronal knee alignment) and gender, age, body mass index (BMI) and height, as well as the implant model and the level of constraint. After that we conducted a prospective, randomized trial with TKA performed since 1.02.2015 till 31.05.2015 (n = 225, 225 TKA). The patients were randomly divided into two groups. In the "individual FVA" group (n = 121), the distal femoral resection guide FVA was set accordingly with measured FVA, in the control group (n = 104) — at 7° (average FVA for the Sverdlovsk area patients' population). We compared TKA x-ray results of both groups. ***Results.*** First stage. We found no correlation between FVA and age, BMI, height and sex of patients (p>0.05). After TKA residual varus deformity of more than 3° (malalignment) (3.9±1.06) was observed in 7% of cases (19 joints). We found correlation between coronal knee malalignment after TKA and two factors: BMI and initial severity of varus deformity (p = 0.003 and p<0.001). Second stage. In the control group we've seen femoral component deviation of more than 3° from the perpendicular to neutral mechanical axis (malposition) 3 times more often then in the "individual FVA" group (9 vs. 3, p = 0.021). ***Conclusion.*** We did not identify the dependence of FVA on sex, age, BMI and height. With initial varus of more than 20° and BMI of more than 30 kg/m^2, the risk of coronal components malalignment is increased. The average FVA in patients of Sverdlovsk area is 6,7±1,5° (3–11°). Implementation of preoperative FVA measurement and following femoral distal cut adjustments improves femoral component positioning and overall leg alignment postoperatively.

Keywords: total knee arthroplasty, valgus deformity, components malalignment, knee alignment.

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Introduction

Currently, there are two main philosophies of alignment in totaedknee arthroplasty (TKA) that have been competing with each other: mechanical and kinematic concepts. Regardless of the alignment type we use, our aim is to have the best clinical outcome in TKA [1].

Digital preoperative planning is created to help us achieve these results. It allows us not only to choose the optimal implant size, but also to draw bony resections levels and the alignment method [2].

In our experience and recent publications call into question the need for neutral knee alignment after TKA in patients with varus knee osteoarthritis [1, 3–7]. Majority of orthopedic surgeons still consider that it is an error to place the components with a deviation above 3° from perpendicular to the mechanical axis of the lower extremity [8–11].

Computer navigation and robotics allow us to make accurate bony resections and increase the rate of achieving neutral knee alignment [12,13]. However, these methods significantly increase the cost of TKR, have long learning curve and prolong operative time [14]. Therefore, in Russia , it have not been widely used, and the main method of axial alignment for TKR in the daily practice remains the conventional use of an intramedullary guides for distal femoral resection and intra — or extramedullary guides for proximal tibial resection. Careful preoperative planning and accurate surgical techniques will allow us to make bone cuts with the same accuracy as achieved with computer navigation system [15].

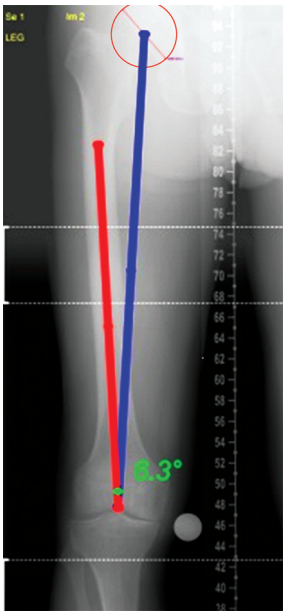

Fig. 1. X-ray of the right femur, measuring the angle of femur valgus deviation: red line — anatomical axis, blue line — mechanical axis, green — FVA angle

One of the key elements of traditional preoperative TKR planning is the measurement of femoral valgus angle (FVA – angle between the anatomical and mechanical axes of the femur) (Fig. 1) [16].

Some authors propose to abandon the orientation of the distal femoral resection guide according to the individually calculated FVA and always choose the average value for the area population, considering this approach to be absolutely safe [17, 18]. Others, on the contrary, insist on the need of individual measurement of FVA for each patient, demonstrating a large error if fixed FVA is used [19–21]. Taking advantage of the opportunities available to us for accurate preoperative planning and the evaluation of postoperative results, as well as a high degree of uniformity in TKR surgical technique in our center, we decided to contribute to this discussion.

The goal of our research was to find whether it is favorable to align distal femoral resection guide according to individual FVA or is it acceptable to use the average FVA of an area population for distal femoral resection during TKA.

In order to achieve this goal, we divided our study into two stages: the first stage was retrospective, the second — prospective and randomized.

We analyzed the results of 951 TKA performed in our center since September 2014 till May 2015 (933 patients) for varus knee arthritis. We analyzed the following data from the electronic database of our center: gender, age, BMI, height, type and the level of implant constrain, the hip-knee-ankle (HKA) angle, the femoral valgus angle (FVA), lateral distal femoral angle (LDFA) and medial prox-

imal tibial angle (MPTA), the original angle of the FVA before and 3 months after TKA.

Coronal alignment was evaluated on the long weight bearing hip-knee-ankle radiographs, (Philips Diagnosis (Netherlands) by the method described by A. Durandet et al. [22], on a personal computer using the program "VEPRO ver.8.2" (Germany) (Fig. 2).

Inclusion criteria:

– Varus knee arthritis stage 3 (by N.S. Kosinskaya);

– TKA with the use of standard surgical technique with no computer navigation;

– Preoperative and control (3 post op.) long X-rays with calculated FVA available in our electronic database;

– No extra-articular deformity (above 10°);

– No correcting osteotomy, periarticular osteosynthesis in the area of the knee or hip replacement in the past;

– residents of Sverdlovsk area.

The first stage

We were looking for correlation between: 1) sex, age, height, BMI and FVA; 2) sex, age, height, BMI, implant type and level of constrain and residual varus after TKA.

Of all patients operated from 01.09.2014 till 31.01.2015 (512 TKA in 502 patients), 261 patients (273 TKA) met the inclusion criteria. Data on these patients were subjected to statistical analysis. Some characteristics of patients in the first stage of the study are presented in table 1.

In all cases, during TKA, the distal femoral resection angle was set according to the calculated FVA angle.

The second stage

We tried to determine the significance of individual calculation of FVA before TKA for varus knee arthritis. From all the TKA performed in our center since 01.02.2015 till 31.05.2015 (439 TKA/431 patients) 225 patients (225 TKAs) passed inclusion criteria.

Patients were divided into two groups by computer randomization. In one group (121 patients, 121 joints) distal femoral resection guide was set at individual FVA (the individual FVA group,). In the control group (104 patients, 104 joints) – at 7° to the intramedullary rod (the average angle of FVA in the area population). In both groups, TKA was performed by the standard technique without computer navigation. Intramedullary guide was used for the femur and extramedullary guide for the tibia. All surgeries were reformed by three experienced teams of orthopedic surgeons (whose surgical experience exceeded 2000 TKA/300 cases a year per surgeon). The study groups were comparable in sex, age, BMI, and angle of initial varus deformity (Tab. 2).

All post-op calculations were done using long X-rays taken 3 months after TKA, during the patient's control examination.

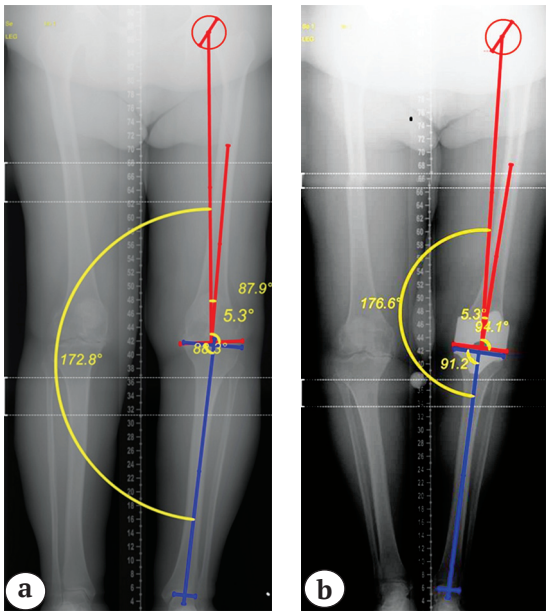

Fig. 2. Hip-knee-ankle X-ray of the patient with varus knee osteoarthritis: FVA = 5,3°, LDFA = 87,9°; MPTA = 88,3°, HKA = 172,8° (a); 3 months after TKA: FVA = 5,3°, LDFA = 94,1°, MPTA = 91,2°, HKA = 176,6°, residual varus — 3,4° (b)

Table 1

The first stage patients' characteristics (*n* = 261/273 TKA)

Feature	
Age (years)	64,6±8,9
Sex m/f	65/196
BMI (kg/m²)	29,4±4,8
Average varus deformity	11,9±5,5
Level of constraint — CR/UC/PS	99/52/122
Implant brand and model:	
Aesculap Columbus UC	52
Biomet AGC CR	21
Implantcast CR/PS	24
Stryker Scorpio NRG CR/PS	94
Zimmer NexGen CR/PS	82

Table 2

Second stage patients' characteristics

Features	Individual FVA group (*n* = 121)	Control group (FVA = 7°)
Age (years)	32/89	26/78
Sex m/f	64,21±5,4	63,66±7,2
BMI (kg/m²)	28,1±6,1	30,4±8,1
Average varus deformity	10,8±5.4	9,1±5,1

p>0,05.

Statistical analysis

Statistical processing was performed using StatSoft Statistica 6.0 result processing package using SD standard deviation. The differences of the compared groups were evaluated using the Mann-Whitney U–test, the linear relationship between the changes in the values of the data variables were calculated using the Pearson correlation coefficient. P<0.05 was considered to be the criterion of statistical significance of the results.

Results

Phase one

The average FVA in men was 6.7±1.5 (3° to 11°) and 6.6±1.49 (3° to 11°) in women (*p*>0.05) (Fig. 3). We found no correlation between FVA and patient's age and BMI (*p*>0.05) (Fig. 4–6).

Thus, none of the estimated factors had an impact on the value of FVA. Analysis of 273 postoperative long coronal X-rays showed that the deviation of the mechanical axis of the limb from the neutral position of more than 3° (malorientation) (average 3.9°±1.06) was revealed in 19 (7%) cases. In 18 cases, residual varus deformity remained and in one case 4° of valgus hypercorrection was detected. Malorientation in most cases (90%) ranged from 3.1° to 5.0° — 17 (90%). The remaining two cases, the figures were 5.1° and 6.0°. In one case, the source of the residual deformation was the position (deviation of the component from the perpendicular to the mechanical axis >3°) of the femoral component (5%), in 3 cases of the tibial component and in 15 cases of both components.

The analysis showed that patients with initial varus deformity of the lower limb more than 20 and BMI more than 30 kg/m^2 have an increased risk of malposition of components. The relative risk with 95% confidence interval was 6,667 and 4,506 respectively (p<0.05). However, we did not reveal any influence of such factors as gender, age, FVA, implant brand and the level of constraint on coronal alignment after TKA (Table 3).

Table 3

FVA/sex distridution, %

Sex	FVA°								
	3°	4°	5°	6°	7°	8°	9°	10°	11°
Men	0	5	15	29	18	23	6	2	2
Women	2	6	16	24	21	19	8	2	2

Table 4

FVA/age distribution, %

Age, years	FVA°								
	3°	4°	5°	6°	7°	8°	9°	10°	11°
<60	2	5	17	17	28	22	5	2	2
60–70	2	6	19	31	15	16	8	1	2
>70	0	6	9	20	27	25	9	3	1

Table 5

FVA/BMI distribution, %

BMI, kg/m^2	FVA°								
	3°	4°	5°	6°	7°	8°	9°	10°	11°
<30	1	6	17	24	26	17	6	2	1
≥30	1	6	14	28	17	23	8	1	2

Table 6

FVA/height distribution, %

Height, sm	FVA°								
	3°	4°	5°	6°	7°	8°	9°	10°	11°
150	0	4	17	14	17	26	9	4	9
150–160	3	6	16	34	9	16	16	0	0
160–170	1	6	9	22	23	27	9	3	0
170–180	1	5	24	28	23	13	5	0	1
>180	0	7	11	26	27	20	2	2	5

Table 7

Association between patient/implant related factors and knee alignment after TKA

Factor		Total	Deviation from neutral axis				*p*
			<3°		≥3°		
			n	%	*n*	%	
Sex	Male	68 (25%)	64	94.1	4	5.9	0.688
	Female	205 (75%)	190	92.7	15	7.3	
Age (years)	<60	66 (24%)	61	92.4	5	7.6	0.877
	60–70	136 (50%)	126	92.6	10	7.4	
	>70	71 (26%)	67	94.4	4	5.6	
BMI (kg/m^2)	<30	149 (55%)	145	97.3	4	2.7	0.003
	≥30	124 (45%)	109	87.9	15	12.1	
Initial varus deformity	<10°	96 (35%)	94	97.9	2	2.1	<0.001
	10-20°	138 (51%)	131	94.9	7	5.1	
	>20°	39 (14%)	29	74.4	10	25.6	
FVA	≤5°	62 (23%)	60	96.8	2	3.2	0.219
	6°–8°	180 (66%)	167	92.8	13	7.2	
	≥9°	31 (11%)	27	87.1	4	12.9	
Level of implant constrain	CR	99 (36%)	94	94.9	5	5.1	0.642
	UC	52 (19%)	48	92.3	4	7.7	
	PS	122 (45%)	112	91.8	10	8.2	
Brand	Aesculap Columbus UC	52 (19%)	49	94.2	3	5.8	0.367
	Biomet AGC CR	21 (8%)	19	90.5	2	9.5	
	Implantcast CR/PS	24 (9%)	20	83.3	4	16.7	
	Stryker Scorpio NRG CR/PS	94 (34%)	89	94.7	5	5.3	
	Zimmer NexGen CR/PS	82 (30%)	77	93.9	5	6.1	

Table 8

Frequency of components malposition after TKA

Component	Malposition >3°		*p*
	Individual FVA group (*n* = 121)	Control group (*n* = 104)	
Femoral	3 (3%)	9 (9%)	0.021
Tibial	13 (11%)	12 (11%)	0.954
All cases with residual deformity	9 (7%)	14 (14%)	0.034

Second stage

Both groups were comparable in FVA, which was 6.6±1.5° in the group of individual FVA and 6.7±1.4° in the control group (p = 0.621). The results of the analysis of control radiographs are presented in Table 4. Femoral component malposition was observed 3 times more often in the control group (9 vs. 3, p = 0.021), the frequency of the tibial component malposition did not differ between groups (11%). Malorientation in the control group was observed twice as often as in the group of individual FVA, 14 (14%) versus 9 (7%) (p = 0.034).

Discussion

In recent decades, a large number of papers have been published on the need for frontal alignment of components in a neutral position relative to the mechanical axis of the lower limb [9,10, 23]. Despite the fact that many authors note that residual varus deformity does not entail negative clinical consequences, none of them calls for deliberate alignment of the lower limb in the varus position [5, 24, 25]. Neutral alignment of the lower limb axis is still the standard for TKR [26].

If one uses standard TKR surgical technique to align femoral component it is recommended to set intramedullar guide at an angle equal to FVA. In patients of our region with varus knee arthritis the mean FVA was 6,7±1,5 (from 3 to 11) and did not depend on sex, age and constitutional features. Our data are consistent with the data of J. Stucinskas et al.: FVA = 6,7±1,3° (from 4 to 10°) [21]. However, in the British population Kharwadkar et al. determined the average FVA of 5.4±0.9° (3.1 to 8°) [17]. According to Tang data et al. in persons with knee arthritis in China FVA = 5,1±0,9° (from 2,6 to 7,4°) [27].

Recently, K. Zhou et al. conducted a meta-analysis of six studies (a total of 1167 patients with TKR) and came to the conclusion that the use of the individual FVA in the case of distal resection of the femur can increase the accuracy of postoperative alignment of the entire lower limb and the femoral component in the coronal plane [28]. Our study also highlighted the importance of the preoperative measuring of FVA. Thus, according to our results, positioning of the distal femoral resection guide at the preoperatively measured FVA made it possible to reduce the frequency of errors in coronal femoral component alignment plane by 3 times, and the frequency of the deviation of the lower limb axis from the neutral position by 2 times.

Despite the fact that we did not find a statistically significant correlation between patient's BMI and FVA, in patients with initial varus of more than 20° and BMI of more than 30 kg/m^2 , we often observed residual varus (p<0.05), which is consistent with the work of Mullaji A. B. et al., in the part of the initial varus deformity of more than 20° [29]. J Järvenpää et al. emphasized that patients with obesity (BMI ≥30 kg/m^2) have worse clinical and radiological results of TKR compared to people with lower BMI [24]. Like them, we believe that obese patients should be informed of the increased risk of TKR complications.

In conclusion, it should be noted that our study did not aim to evaluate the effect of coronal knee alignment on the clinical or functional outcomes of TKR. Considering the given data, we were able to include in the study quite large groups of patients: 273 in the first and 225 in the second stage, respectively. It is obvious that the clinical results of TKR are influenced not only by the coronal components positioning, but many other factors: the initial range of motion, the surgeon's approach to soft tissue balance, concomitant pathology, the type of implant and the position of its components in the sagittal and horizontal planes, the postoperative rehabilitation program and etc. In order to study the coronal position of the compo-

nents input in clinical result, it is necessary to take into account all these factors in the compared groups, which we tried to do in the previously published studies [3, 4]. All data of TKR performed in our center is systematically entered into electronic database, including data of annual control examinations. This will allow us to conduct a more comprehensive analysis of the importance of component positioning in the coming years.

We have found no correlation between FVA and other related factors. Patients with varus knee osteoarthritis of more than 20° and BMI above 30 kg/m^2 have an increased risk of deviation of the TKR components of more than 3° from the perpendicular to the mechanical lower limb axis in 6,667 and 4,506 times, respectively, with a 95% confidence interval (p<0.05). The average FVA of Sverdlovsk region residents is 6,7±1,5° (3–11°). Implementation of individual FVA in distal femoral resection guide positioning 3 times reduces the probability femoral component mispositioning, compared with a fixed FVA 7.

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