Varus Gonarthrosis Predisposes to Varus Malalignment in TKA

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Abstract Postoperative alignment is a predictor for long-term survival of total knee arthroplasty (TKA). The purpose of this study was to evaluate whether or not preoperative deformities predispose to intraoperative malposition of TKA components. A retrospective radiographic analysis of 53 primary TKA cases was performed. Preoperative AP hip to ankle and lateral knee radiographs were compared with postoperative views to evaluate component positioning. The following angles were measured: the hip–knee–ankle (HKA) angle expressing the mechanical axis of the leg, the mechanical lateral distal femur angle (mLDFA), the medial proximal tibia angle (MPTA), the posterior distal femur angle (PDFA), and the posterior proximal tibia angle (PPTA). Postoperative measurement of the HKA revealed 34.0% of the cases had a deviation of $\geq \pm 3^\circ$ from neutral alignment. Sixteen knees (30.2%) were in varus and, with one exception, all presented with severe varus gonarthrosis prior to surgery with a mean tibiofemoral angle of 12.4° compared with 1.0° of valgus in the optimally aligned group. Patients (93.3%) with preoperative valgus malalignment showed optimal postoperative HKA. Odds ratios for malalignment of TKA for varus knees in comparison with

valgus knees were 7.1 for HKA, 2.4 for MPTA, 4.9 for PDFA, and 1.7 for PPTA. The overall number of outliers in the presented data corresponds well with reports from other authors using different implants and guide systems. The presented data indicate that patients with preoperative varus alignment have a higher risk of postoperative implant malposition than patients with valgus alignment. The data supports that preoperative varus deformity predisposes to varus malposition of TKA. The risk for intraoperative malposition is significantly lower in valgus knees.

Abbreviations

AP	Anteroposterior
HAI	Hip–ankle intersection
HKA	Hip–knee–ankle angle
mLDFA	Mechanical lateral distal femur angle
MPTA	Medial proximal tibia angle
PDFA	Posterior distal femur angle
PPTA	Posterior proximal tibia angle
OA	Osteoarthritis
TKA	Total knee arthroplasty

Level of Evidence: Level IV: Retrospective Case Series

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Introduction

The introduction of computer navigation in total knee arthroplasty (TKA) has focused research on implant positioning. The debate continues as to what extent component positioning affects the longevity of implants. Jeffery et al. reported on a series of 115 primary TKA. The incidence of subsequent component loosening was 3% when Maquet's line passed through the middle third of the prosthesis. When Maquet's line was aberrant more than $\pm 3^\circ$, the incidence of loosening was 24% after 8 years [1]. Rand and Coventry showed a 10-year survival of 90% for knees between 0° and 4° of valgus. However, they described only 71% of survival for knees with 5° to 9° of valgus and 73% for knees in varus alignment [2]. On the contrary, Pagnano et al. recently showed no association between component position and early failure in 399 primary cemented TKA at

14 years follow-up. They reported an 84.6% survival in the group aligned within 3° from the mechanical axis ($n=293$). One hundred and six knees were regarded as outliers deviating more than 3° at a survival of 87%. It was suggested that restoring a straight axis in TKA might aim at the wrong target [3].

Varus alignment of a total knee replacement has been associated with early tibial component loosening and the presence of radiolucent lines [4, 5]. In the normal knee, the articular surface of the proximal tibia angle is an average of 3° of varus to the mechanical axis. To improve load distribution and optimize implant survival, however, it is recommended to position the tibial component perpendicular to the anatomical axis of the tibia to provide a uniform distribution of load across the interface between implant and bone [6–8].

The restoration of the physiologic anatomical valgus of approximately $4\text{--}8^\circ$ has been shown to improve long-term implant survival after TKA [6, 8, 9]. Hvid and Nielsen defined the optimal anatomical tibiofemoral angle as $7\pm5^\circ$ and stated that radiolucencies were correlated with varus malposition [10]. Even in a normal leg with a physiologic axis at a tibiofemoral angle of 7° , loads in the medial compartment have been found to be greater than in the lateral compartment. Hsu reported 75% of the knee joint load pass through the medial tibial plateau during simulation of a one-legged weight-bearing stance [11]. Varus malalignment is thus much more likely to lead to excessive stress peaks for both natural cartilage surface and the components of a total knee replacement.

Moderate malalignment following TKA is a global finding described by different authors using all types of prostheses affecting many patients. Bathis et al. reported a neutral mechanical axis of the leg within a range of $\pm 3^\circ$ in 78% of patients after primary TKA. In their study, 86% had a femoral alignment within $\pm 3^\circ$ of the optimal position and 94% of the patients had a tibial alignment within $\pm 3^\circ$ [12]. These numbers are consistent with those reported by other authors after primary TKA [5, 13].

The purpose of this study was to investigate the following questions: (1) Does pre-op varus malalignment predispose to varus malalignment in the TKA? (2) How does preoperative deformity influence the position of the femoral and tibial components in the coronal and sagittal planes? (3) Does preoperative valgus malalignment carry the same risk as varus? (4) Are there correlating factors which predispose to postoperative malalignment?

Materials and methods

This retrospective study included 53 patients in a consecutive series undergoing primary TKA for primary or secondary osteoarthritis of the knee between September 2006 and May 2007. All surgeries were performed by the senior author. There were no defined exclusion criteria. All patients received cemented posterior stabilized TKAs with patellar resurfacing (Genesis II, Smith & Nephew, Memphis, TN, USA). Surgery was performed following the manufacturer's instructions using a conventional instrument tray through a parapatellar

approach. For both femoral and tibial referencing, intra-medullary alignment rods were used. The distal femoral cut was made at 6° to the intramedullary rod.

Radiographic analysis was performed on all patients including preoperative and 3 months postoperative weight-bearing anteroposterior (AP) and non-weight-bearing lateral radiographs. In addition, pre- and postoperative weight-bearing hip to ankle standing radiographs were analyzed. The amount of preoperative gonarthrosis was classified using Ahlback's criteria [14]. Radiographs for all 53 (32 female and 21 male patients; 27 left and 26 right knees) patients were available for analysis. All X-rays were evaluated by two independent investigators (T.H. and R.D.) who had not been involved with the surgical procedure.

The following angles were used for descriptive analysis of pre- and postoperative alignment: The hip–knee–ankle (HKA) angle was defined as the angle between the mechanical axis of the femur and the mechanical axis of the tibia (Fig. 1). The mechanical femorotibial angle was defined to be normal between $\pm 3^\circ$ of the neutral alignment. Postoperatively, the mechanical axis of the tibia was drawn from the middle of the tibial component to the center of the ankle. The hip–ankle intersection (HAI) was defined as the intersection of a line between the center of the femoral head and the center of the talus at the knee (Maquet's line, Fig. 1) [15]. The tibial plateau was divided in three zones with an equal width (M1, C, L1). Additional zones were defined medially (M2) and laterally (L2) of the joint line.

The mechanical lateral distal femur angle (mLDFA) is defined as the angle between the mechanical axis of the femur and the tangent of the condyles, measured on the medial side of the knee joint (Fig. 1). The distal femoral articulate surface is normally in a slight valgus relative to the mechanical axis of the femur [11]. The medial proximal tibia angle (MPTA) was defined as the angle between the mechanical axis of the tibia and the tangent to the tibial plateau, measured on the medial side of the knee (Fig. 1). The proximal tibial joint line is normally in a slight varus relative to the mechanical axis of the tibia [11]. The post-op mechanical axis of the tibia was drawn between the middle of the tibial implant plateau and the center of the ankle. The desired post-op angle is 90° .

The posterior distal femur angle (PDFA) is defined as the angle between the tangent to the femoral posterior diaphyseal cortical bone and the tangent to the distal femoral cut or the femoral box in the case of a PS implant (Fig. 2). The normal acceptable angle is defined as 90° . The posterior proximal tibia angle (PPTA) is defined as the angle between the tangent to the posterior diaphyseal cortical bone limitation and the tangent to the tibial plateau (Fig. 2). The normal angle is 90° .

Continuous variables were displayed as mean and SD. Categorical data were given in absolute numbers. Equally distributed values were analyzed by dependent or independent Student's *t* test. Odds ratios were determined to measure effect sizes. The two-sided Pearson's coefficient was applied for correlations. A *p* value of less than 0.05 was considered statistically significant. Statistical analysis was supported by using SPSS for Windows

Fig. 1. Weight-bearing bilateral long-leg standing radiograph of a 69-year-old female pre-TKA, right knee, and post-TKA, left knee. *I* Angle between the mechanical axis of both tibia and femur (HKA). *II* Maquet's line, intersecting the joint line in significant varus. *III* Angle between mechanical axis of femur and a tangent of the prosthesis condyles (mLDFA). *IV* Angle between mechanical axis of the tibia and the tibial plateau (MPTA)

(SPSS Inc., Chicago, USA) and Microsoft Excel (Microsoft Corporation, Seattle, USA).

Results

The average mechanical axis in the entire cohort was improved from the preoperative malalignment by the TKA

($p < 0.00001$). Preoperative long-leg standing films showed an average mechanical HKA angle of $4.3 \pm 9.5^\circ$ of varus. Postoperative long-leg standing films showed an average mechanical HKA of $2.4 \pm 4.5^\circ$ of varus. Four patients (7.5%) showed neutral alignment prior to surgery. Fifteen patients (28.3%) showed a preoperative valgus and 34 (64.1%) a varus malalignment of their knee.

Preoperative varus malalignment as opposed to pre-op valgus predisposed to varus postoperative malalignment in the TKA ($p < 0.00002$). After TKA 18 out of 53 patients (34.0%) showed a deviation of more than 3° from neutral alignment. Sixteen knees (30.2%) had more than 3° of postoperative varus malalignment. All but one were found in patients with preoperative varus gonarthrosis at a mean HKA of 12.4° compared with 1.0° of valgus in patients with $\leq 3^\circ$ of postoperative malposition. Only two patients had a postoperative valgus deviation of the HKA. Of these, one had a preoperative valgus (9.3°) and the other patient had neutral alignment (0.2°) prior to surgery.

The post-op Maquet's line crossed the central third of the joint in 38 cases ($C = 71.7\%$), L1 in two patients (3.8%), M1 in 11 (20.8%), and M2 in two cases (3.8%). Patients in M1 and M2 showed a mean pre-op tibiofemoral varus of 13.3° compared to a pre-op slightly valgus alignment (1.7°) in C ($p < 0.00001$).

Pre-op varus predisposed to malpositioning of both the tibial and femoral components in both the coronal and sagittal planes. On the postoperative hip to ankle standing radiographs, the orientation of the tibial component to the anatomical axis of the tibia was within 3° of 90° in 40 patients (75.5%). Twelve tibial components had more than 3° of varus malposition (22.6%) and one more than 3° of valgus malposition (1.9%). Moreover, 86.8% of the tibial components were within 4° of the optimal position. The 12 patients with tibial varus malposition had an average preoperative varus of 10.3° of HKA compared to 2.5° in patients with normal postoperative alignment ($p < 0.01$).

The one tibial component in valgus malposition was the right knee of a patient with a preoperative valgus HKA of 12.3° with a hip/ankle intersection (HAI) at L2 and a normal pre-op TMA with 88.2° .

On the lateral radiographs, the angle between the tibial component and the anatomical axis of the tibia was seen to be within 3° of the optimum 90° in 43 limbs (81.1%). Nine of the remaining components showed an excessive slope of more than 3° . The posterior proximal tibia angle (PPTA) was higher than 93° in one case. Patients with an excessive preoperative slope showed a varus malalignment of the leg axis in eight cases with an average of $10.5 \pm 3.2^\circ$ compared with $3.3 \pm 4.1^\circ$ pre-op varus among the well-sloped tibiae ($p < 0.02$).

In 47 limbs (88.7%), the angle between the femoral component and the anatomical axis of the femur (mLDFA) was within 3° of a neutral position in the AP view. In six limbs (11.3%), the femoral component was positioned in relative varus. All cases of femoral malposition were found in patients who had severe HKA varus malposition prior to surgery (average varus = 17.1° compared to 2.6° in the well-aligned group, $p < 0.0001$). No cases had femoral compo-

Fig. 2. Postoperative non-weight-bearing lateral radiograph. The tangent to the femoral posterior diaphyseal cortical bone and the tangent to the femoral box of the PS implant define the femoral flexion angle (PDFA). The tibial flexion angle (PPTA) is defined by the tangent to the posterior diaphyseal cortical bone and the tangent to the tibial plateau

nents placed in relative valgus. The angle between the femoral component and the anatomical axis of the femur was between the optimum 87° and 93° on the lateral radiographs in 39 patients (73.6%). All of the remaining components were in slight flexion. Preoperative varus was common in these cases ($\approx 7.2^\circ$ of varus compared to 3.2° in optimal alignment ($p=0.09$)).

Fifteen patients showed a valgus malalignment of their knee prior to TKA with a mean mechanical tibiofemoral angle of 8.3° . Fourteen showed optimal postoperative mechanical alignment of the whole leg (93.3%). In this group, the coronal alignment of all femoral components was optimal. One femoral component was in excessive flexion (6.7%). One tibial component was positioned in varus and one in valgus. One tibial component showed excessive

slope (6.7%). Odds ratios for malalignment of TKA for varus knees were calculated in comparison with valgus knees. In varus knees, the risk for malalignment was 7.1 for HKA, 2.4 for MPTA, 4.9 for PDFA, and 1.7 for PPTA.

The Pearson correlation analysis indicated that pre-op HKA correlated with the postoperative positioning of the femoral and tibial components (Table 1). The pre-op HKA correlates well with post-op HKA, post-FMA, post-TMA, and post-TFA. Eleven left and one right TKA showed malposition, and correlations were less pronounced in right knees (post-op HKA 0.529**, post-FMA 0.594**, post-TMA 0.490*, and post-TFA 0.217) than they were in left knees (post-op HKA 0.740**, post-FMA 0.719**, post-TMA 0.384*, and post-TFA 0.505**, other data not shown). Sex did not have any influence on malalignment.

Discussion

To date, there is no data that shows precise relationships between preoperative radiological findings and postoperative malpositioning. The presented data clearly indicates that preoperative tibiofemoral varus malalignment predisposes to varus malposition after TKA. Additionally, the higher pre-op malalignment increased the chance of component malposition. The tibial components that were malaligned in varus were seen in patients who showed significant mechanical femorotibial varus prior to TKA. These findings should help the surgeon decide the most appropriate instrumentation and guide strategy in varus knees especially with tibial component positioning. Although 28.3% of the patients presented substantial tibiofemoral valgus prior to surgery, postoperative tibiofemoral malalignment or malposition of the tibial component was rare in this subgroup. The odds ratio for tibiofemoral mechanical malalignment was 7.1 for knees with pre-op varus when compared to pre-op valgus. Obviously, the current strategies and the instrumentation of alignment are effective in correction of a valgus malalignment and do provide proper positioning of both tibial and femoral components. Finally, we found that the pre-op HKA correlates with post-op HKA, LDFA, MPTA, and PPTA with a high degree of significance (Table 1).

Table 1 Correlations between all pre- and post-op angles expressed by Pearson correlation analysis

	HKA pre-op	HKA post-op	Pre-mLDFA	Pre-MPTA	Post-mLDFA	Post-MPTA	Post-PDFA	Post-PPTA
HKA pre-op	1	0.664**	0.655**	0.677**	0.563**	0.495**	0.132	0.394**
HKA post-op	0.664**	1	0.560**	0.595**	0.707**	0.758**	-0.123	0.263
Pre-mLDFA	0.655**	0.560**	1	0.314*	0.493**	0.362**	-0.049	0.265
Pre-MPTA	0.677**	0.595**	0.314*	1	0.451**	0.421**	0.116	0.267
Post-mLDFA	0.563*	0.707**	0.493**	0.451**	1	0.335*	-0.108	0.206
Post-MPTA	0.495**	0.758**	0.362**	0.421**	0.335*	1	-0.106	0.198
Post-PDFA	0.132	-0.123	-0.049	0.116	-0.108	-0.106	0.1	0.024
Post-PPTA	0.394**	0.263	0.265	0.267	0.206	0.198	0.024	1

Pearson correlation analysis: *two-sided significance <0.05 , **two-sided significance <0.01

HKA mechanical axis of the whole leg, mLDFA mechanical lateral distal femur angle, MPTA medial proximal tibia angle, PDFA posterior distal femur angle, PPTA posterior proximal tibia angle

In this study, 53 patients (32 female and 21 male) were included. In many prior studies, the ratio between women and men has been reported to be 3:1. It is unlikely, however, that differences add to statistical bias when evaluating radiological findings. Preoperative tibiofemoral axes were normal in 7.5% of the patients. Also, 28.3% presented in valgus and 64.1% were in varus malalignment. This seems to be in accordance with the amount of axis deformations typically found in patients prior to TKA. The degree of flexion and rotation over the knee joint both affect the coronal alignment on whole-leg standing films [16, 17]. However, Wright et al. concluded that rotation of the lower limb $<10^\circ$ did not have a significant effect on measurement of tibiofemoral alignment [18]. There is consensus that short-leg films might be sufficient for screenings in busy outpatient departments but long-leg standing films should be used for the purpose of scientific studies.

In the presented data, the postoperative mechanical axis of the limb exceeded 3° of varus/valgus deviation in 34.0% of the patients using the intramedullary guide for both the femur and the tibia. This is in accordance with numbers reported by other authors not utilizing navigation [12]. Petersen and Engh reported varus/valgus deviation of the axis of $>3^\circ$ in 26% of their patients [19]. Mahaluxmivala et al. presented results of 673 total knee arthroplasties. Measured from standard short-leg radiographs, an ideal anatomical tibiofemoral angle of 4° to 10° of valgus was achieved in 75.3% ($<4^\circ$ in 18.6% and $>10^\circ$ in 6.1%) [20]. In a recent meta-analysis of 29 studies comparing computer navigation to conventional instrumented TKA, 31.8% of conventional TKA had more than 3° of varus and valgus alignment [21].

In the current series, 22.6% of the tibial components were in relative varus malposition ($>3^\circ$) and 1.9% in valgus malposition ($>3^\circ$). Moreover, 86.8% of the tibial components were within 4° of the optimal position. Mahaluxmivala et al. [20] reported 17.1% of the tibial components were inserted with an excessive varus $>3^\circ$ in their study. Ishii et al. described 88% of tibial components were within 4° of the perpendicular position of the tibial component using either an intra- or extramedullary guide [22]. Teter et al. compared the accuracy of tibial component alignment using an intramedullary and an extramedullary device. Using an extramedullary device, 92% of the tibial cuts were within 4° of 90° . The same was true for 94% of the cases when an intramedullary device was applied. Differences were not statistically significant [23]. Their study showed an obvious trend towards making cuts in relative varus using the extramedullary guided technique. Moreover, they described that a bowed tibia is less suitable for the application of an intramedullary alignment jig. Dennis et al. emphasized that extramedullary guides should be distally positioned over the center of the talus, 3 mm medial to the midpoint of the ankle rather than right at the midpoint to avoid varus tibial resection. With this technique, 88% of tibial components were aligned within 2° of the $\pm 90^\circ$ goal [24]. In this series, left-sided knees had a higher incidence of malposition. It might be more difficult to do a left total knee as a right-handed surgeon.

The overall numbers of position outliers in the presented data correspond with numbers presented by other authors using different implants and instrumentation systems. The comparability of cited studies is limited since some used short-leg films for evaluation of the postoperative axis rather than long-leg standing films. Short-leg radiographs are reported to overestimate tibiofemoral varus between 1.4° and 1.9° compared with long-leg films [19, 25].

The data presented here supports previously reported literature that shows a clear tendency towards varus malposition and malalignment using existing guide instrumentation in many patients. There is little data that provides clear explanation or identifies specific reasons or predisposing factors. Mahaluxmivala et al. described excessive varus of the tibial component as a common error. They saw possible explanations in a tendency to perform the bone resection parallel to the osteoarthritic articular surface, in which varus is a very common finding. They identified other contributors as well to include obstruction of the cutting block by patellar tendon or fat pad with inadequate exposure, improper identification of the center of the ankle joint, and asymmetry of cement mantle thickness [20].

In this series, coronal malalignment of the femoral component was found (11.3% positioned in relative varus $>3^\circ$, all in cases of severe femorotibial varus malalignment prior to surgery) when using the intramedullary femoral guiding rod. Also, 26.4% of the femoral components were in slight flexion. Teter et al. described femoral component positioning after intramedullary alignment. In 8.5% of the cases, component position deviated $\geq 4^\circ$ from what was described to be optimal. In their series, most of those femoral components were in excessive valgus. They described medial femoral bowing of the distal third of the femoral shaft and a capacious femoral canal in combination with a relatively undersized guide rod as possible sources for malposition. They suggested preoperative radiographs of the entire femur to identify patients at risk [26]. Mahaluxmivala et al. [20] reported femoral components were inserted in relative varus in 9.1% and in relative valgus in 39.0% of the cases in their study.

In conclusion, the presented data clearly indicates that preoperative tibiofemoral varus predisposes to varus malposition and malalignment after TKA. The risk for malalignment in valgus knees is significantly lower. It remains unclear as to how this might affect long-term survival of the implants.

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