Moderate varus/valgus malalignment after total knee arthroplasty has little effect on knee function or muscle strength

91 patients assessed after 1 year

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Background and purpose — Postoperative muscle strength and component alignment are important factors affecting functional results after total knee arthroplasty (TKA). We are not aware of any studies that have investigated the relationship between them. We therefore investigated whether coronal malalignment of the mechanical axis and/or of individual implant components would affect knee muscle strength and function 1 year after TKA surgery.

Patients and methods — We included 120 consecutive osteoarthritis (OA) patients admitted for TKA. Preoperative active range of motion (ROM) of the knee, patient age, sex, and BMI were recorded and the Knee Society score (KSS) and knee joint extensor/flexor muscle strength were assessed. At 1-year follow-up, the mechanical and coronal component alignment was measured from a postoperative long standing radiograph, and ROM, KSS, and muscle strength measurements were taken in 91 patients. Functional outcome and muscle strength measurements were compared between normally aligned and malaligned TKA groups.

Results — 29 of 91 TKAs were malaligned, i.e. they deviated more than 3° from the neutral mechanical axis. 18 femoral components and 15 tibial components were malaligned. Before surgery, the malaligned and normally aligned groups were similar regarding sex distribution, BMI, ROM, KSS, and muscle strength. At the 1-year follow-up, the differences between the groups regarding knee joint function and muscle strength were small, not statistically significant, and barely clinically relevant.

Interpretation — Moderate varus/valgus malalignment of the mechanical axis or of individual components has no relevant clinical effect on function or muscle strength 1 year after TKA surgery. ■

Failure to restore limb alignment in total knee arthroplasty (TKA) increases the risk of revision (Jeffery et al. 1991, Ritter et al. 1994 and 2011, Berend et al. 2004), but the effect of accurate postoperative alignment on TKA function is controversial (Lotke and Ecker 1977, Choong et al. 2009, Fang et al. 2009, Longstaff et al. 2009, Huang et al. 2012).

Huang et al. (2012) reported that TKAs with a coronal alignment within 3° from the neutral axis had better function and quality of life at 5-year follow-up than TKAs that deviated more than 3° from neutral alignment. Other studies comparing computer-assisted TKA with conventional TKA surgery have not been able to correlate malalignment with inferior functional outcomes (Spencer et al. 2007, Kamat et al. 2009, Kim et al. 2009, Burnett and Barrack 2013).

Patients with greater preoperative muscle strength have been reported to have faster recovery and better functional outcome after TKA (Mizner et al. 2005, Yoshida et al. 2008). However, full recovery of muscle strength after TKA is uncommon (Berth et al. 2002, Valtonen et al. 2009, Maffiuletti et al. 2010, Vahtrik et al. 2012).

It is plausible that failure to restore the mechanical axis restoration results in inferior muscle function. Sogabe et al. (2009) found different cross-sectional areas in the quadriceps muscles with different knee alignments. They suggested that knees with varus or valgus deformation should have poorer muscle function compared to normally aligned knees. However, we have not been able find any studies investigating muscle strength after TKA in relation to component alignment and mechanical axis restoration.

We investigated whether coronal malalignment of the mechanical axis and/or of individual implant components would affect knee muscle strength and function 1 year after TKA surgery.

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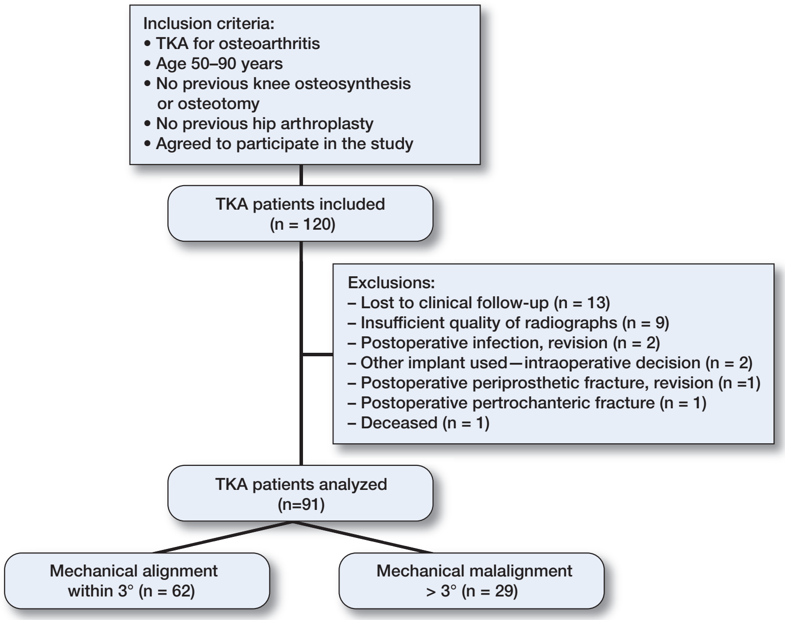

Figure 1. Flow chart of study.

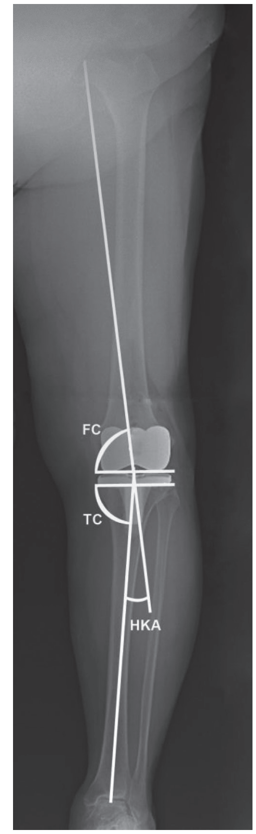

Figure 2. Standing anterior-posterior radiograph with a varus malalignment. Mechanical axis as hip-knee-ankle (HKA) and component alignment angles are represented. The HKA angle is the angle formed between the mechanical femoral and tibial axes. The femoral component (FC) angle is the angle medially between the distal surfaces of the femoral component and the femoral mechanical axis. The tibial component (TC) angle is the medial angle between the tibial component plateau and the tibial mechanical axis.

Patients and methods

We prospectively investigated 120 consecutive osteoarthritis (OA) patients who were admitted for elective TKA with one type of prosthesis (NexGen LPS; Zimmer, Warsaw, IN) (Figure 1).

1 day before surgery, the active range of motion (ROM) in the affected knee was measured with a goniometer. The patient's age, sex, height, weight, and body mass index (BMI) were recorded and their Knee Society score (KSS) was assessed using both objective subscales (pain, leg alignment, stability, and joint motion) and functional subscales (walking distance, stair climbing, and walking aids) (Insall et al. 1989). Pain was evaluated according to KSS and graded (severe, moderate continual or occasional, mild while walking or in stairs or occasional, and none). The OA was graded preoperatively according Burnett's radiographic atlas (Burnett et al. 1994) in stages from 0 to 21. The preoperative knee extensor/flexor (quadriceps/hamstring) isometric muscle strengths were measured at 90° and 60° knee joint flexion angles using a Biodex System 4 Pro dynamometer (Biodex Medical Systems, Shirley, NY) according to the manufacturer's instructions. Each test was repeated twice and the average of the isometric peak torques was taken and adjusted to the patient's body weight. In addition, hamstring-quadriceps ratios were calculated from the isometric peak torques. Isometric muscle strength evaluation has been reported as a valid and reliable assessment in TKA patients (Lienhard et al. 2013).

All arthroplasties were performed using the same cemented implants through a medial parapatellar approach. The patella was everted but not resurfaced. All operations were performed by 4 experienced consultants using spinal-epidural anesthesia.

At 1-year follow-up, ROM and KSS were assessed and muscle strength measurements were performed with the same methodology as preoperatively. Additionally, long standing lower extremity anterior-posterior radiographs were obtained at a focal distance of 2.5 m with a consistent stance: the patients were standing on both legs with patella facing forward and the medial aspects of both feet parallel (Jonsson and Boegard 2002). The overall mechanical alignment of the lower extremity was defined as the hip-knee-ankle (HKA) angle formed by the mechanical femoral and tibial axes (Sheehy et al. 2011). HKAs with a positive value were in varus and those with a negative value were in valgus. The coronal alignment of the femoral and tibial components in the frontal plane was also measured (Figure 2), with the femoral component angle being defined as the angle medially between the distal surfaces of the femoral component and the femoral mechanical axis, and the tibial component angle being defined as the medial angle between the tibial component plateau and the tibial mechanical axis (Ng et al. 2012). The measurements were performed using a radiology viewer (Cedara I-Reach 4.4; Cedara Software Corp., Mississauga, ON, Canada). Radiological outliers were defined as TKAs in which the position of components and/or the mechanical axis measured deviated by more than 3° from the neutral mechanical axis.

Table 1. Postoperative radiological data (mean (SD); °) for patients with hip-knee-ankle (HKA) angle and component alignment within ± 3° or > 3° (varus or valgus) from a straight mechanical axis

Postop. data	Mechanical axis ± 3° (n = 62)	Mechanical axis > 3° (n = 29) Varus (n = 24)	Valgus (n = 5)	Femoral component ± 3° (n = 73)	Femoral component > 3° (n = 18) Varus (n = 15)	Valgus (n = 3)	Tibial component ± 3° (n = 76)	Tibial component > 3° (n = 15) Varus (n = 12)	Valgus (n = 3)
HKA angle	0.5 (2)	5 (2)	–5 (2)	1 (3)	5 (3)	–5 (2)	1 (3)	4 (3)	–1 (1)
Femoral component angle	89 (2)	88 (2)	93 (1)	90 (2)	86 (1)	94 (0.3)	89 (2)	90 (2)	88 (2)
Tibial component angle	90 (2)	87 (1)	91 (2)	90 (2)	89 (2)	91 (1)	90 (2)	86 (1)	93 (0.4)

Statistics

Data are presented as mean (SD) or mean difference with 95% confidence interval (CI). To determine whether the data were normally distributed, we performed a Shapiro-Wilk test for normality. As part of the data was not normally distributed, we used both parametric and non-parametric tests. As the calculated p-values were similar in terms of significance irrespective of the method used, the non-parametric tests were chosen for reporting of the data. We used the non-parametric Mann-Whitney test for independent samples and Wilcoxon test for paired samples. Fisher's exact test was used when comparing proportions between the groups. Any p-value of < 0.05 was considered significant. We used SPSS software for the calculations.

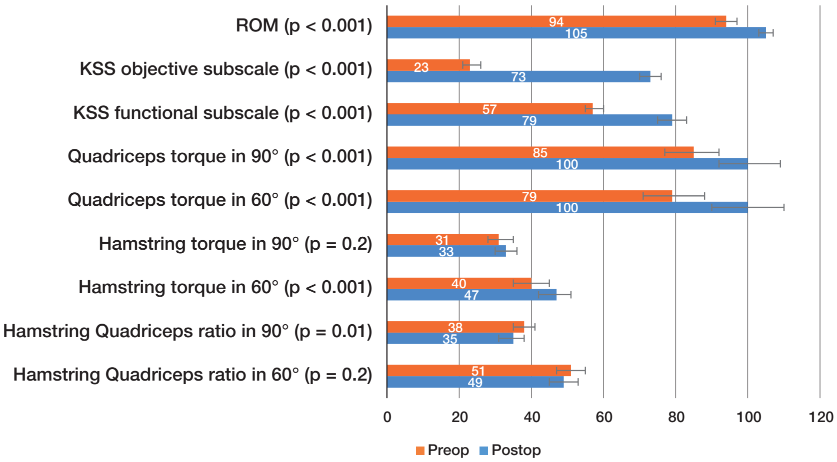

Figure 3. Comparisons of mean (with 95% CI; whiskers) ROM (°), KSS (points), muscle torques (Nm), and hamstring-quadriceps ratios (%) (n = 91) preoperatively and postoperatively.

Ethics

The study was approved by the regional biomedical research ethics committee (reference no. BE-2-5).

Results

91 of the 120 TKA patients remained for analysis at the 1-year follow-up (Figure 1). Radiological data are presented in Table 1.

Regarding mechanical axis, 29 of 91 TKAs were malaligned, 24 in varus (3° to 11°) and 5 in valgus (–3° to –8°). In 12 of these 29 mechanically malaligned TKAs, both the femoral and the tibial components were normally aligned (< 3° deviation), although the combination led to an overall malalignment. The other 17 TKAs had malaligned components (9 femoral, 6 tibial, and 2 both). Of the 62 TKAs with a normal mechanical axis, 13 had malaligned components (6 femoral, 6 tibial, and 1 both).

Overall, 18 femoral components and 15 tibial components were malaligned. Of the 18 femoral components, 3 were in valgus and 15 were in varus (–5° to 5°). Of the 15 malaligned tibial components, 3 were in valgus and 12 were in varus (–4° to 5°).

Preoperatively, the malaligned and normally aligned groups were similar regarding sex distribution, BMI, OA grade, ROM, and KSS, but the mean age was statistically significantly lower in the malaligned femoral component group (71 (8) years as opposed to 67 (7) years) (Table 2, see supplementary data). Preoperative muscle strength or hamstring-quadriceps ratios were similar in normally aligned and malaligned knees (Table 3, see supplementary data).

Comparing muscle strength before and 1 year after the TKA, a significant improvement was found in 3 of 4 measurements (Figure 3), as well as in ROM and KSS. As only quadriceps, but not hamstring torque, improved there was a postoperative worsening in hamstring-quadriceps ratio in the 90° position. This was not the case for the 60° position, where both quadriceps and hamstring torque improved, so the hamstring-quadriceps ratio in 60° position did not change significantly (Figure 3). A further comparison of muscle strength, hamstring-quadriceps ratio, KSS, and ROM between normally aligned and malaligned groups did not reveal any statistically significant differences at the 1-year follow-up (Table 3, see supplementary data, and Table 4).

Table 4. Postoperative ROM, KSS objective, functional and pain assessment subscale (ss) results (mean (SD), mean difference with 95% confidence intervals (CI), or rates) between patients with mechanical and component alignment within ± 3° and > 3°

	Mechanical axis ± 3° n = 62	Mechanical axis > 3° n = 29	Mean difference (95% CI)	p-value	Femoral component ± 3° n = 73	Femoral component > 3° n = 18	Mean difference (95% CI)	p-value	Tibial component ± 3° n = 76	Tibial component > 3° n = 15	Mean difference (95% CI)	p-value
ROM, °	105 (10)	105 (9)	–0.4 (–5 to 4)	0.9	106 (9)	103 (11)	2 (–3 to 7)	0.7	105 (10)	105 (8)	0.3 (–5 to 6)	0.9
KSS objective ss	74 (14)	70 (14)	4 (–2 to 11)	0.2	75 (13)	67 (15)	8 (–0.4 to 14)	0.05	74 (15)	70 (6)	4 (–1 to 9)	0.2
KSS functional ss	80 (17)	77 (22)	3 (–6 to 11)	0.7	78 (18)	81 (21)	–2 (–12 to 8)	0.4	78 (20)	83 (10)	–5 (–12 to 2)	0.6
KSS pain ss	43 (7)	44 (8)	–1 (–4 to 2)	0.3	44 (7)	42 (10)	2 (–2 to 6)	0.7	43 (8)	43 (7)	0.4 (–4 to 5)	0.6
KSS pain [a]	2/7/13/21/19	1/3/5/7/13		0.8	1/9/13/25/25	2/1/5/3/7		0.1	3/8/14/23/28	0/2/4/5/4		0.8

[a] Pain grades: (moderate occasional/mild walking/or stairs/or occasional/none)

Discussion

The radiological definition of “normally” aligned TKA knees is debated (Abdel et al. 2014, Gromov et al. 2014), but most papers on implant survival and radiological alignment have used some deviation from the mechanical or anatomical coronal axis for definement of malalignment. Several studies have used a deviation of 3° from a neutral alignment as a threshold for what is acceptable for good long-term results (Jeffery et al. 1991, Ritter et al. 1994 and 2011, Berend et al. 2004). Such a 3° threshold has also been chosen in numerous other studies investigating results after TKA (Choong et al. 2009, Longstaff et al. 2009, Parratte et al. 2010, Huang et al. 2012), and an alignment within 3° of the mechanical axis has been considered to be the gold standard (Lombardi et al. 2011). Based on this, we decided to use a deviation from the neutral mechanical axis of 3° as the threshold between normally aligned and malaligned TKA knees.

We found that one third of the patients had a mechanical axis that deviated from 3° to 11° from the neutral mechanical axis, with 20% of the femoral components and 16% of the tibial components being outliers (> 3° varus or valgus). Similar proportions of components and axis malalignment after conventional TKA was observed by Huang et al. (2012), who reported malalignment of > 3° in up to one third of conventional TKAs, but up to two-thirds has been reported (Haaker et al. 2005).

The accurate restoration of axis and correct implantation of components is of importance, as it may affect the survival of the TKA. Jeffery et al. (1991) reported 24% loosening if the deviation from neutral axis after TKA exceeded 3° (as compared to 3% loosening in normally aligned knees). Concerning the positioning of components, it has been reported that more than 3° of varus malalignment of the tibial component has a higher incidence of failure (Hsu et al. 1989, Berend et al. 2004), and on the femoral side it has also been reported that an isolated malalignment increases the risk of failure (Ritter et al. 2011). Such increased failure risk may be explained by uneven distribution of load on the bone (medial bone collapse) or on the polyethylene insert, causing greater wear and subsequent osteolysis. However, the effect of malalignment on the muscles around the knee in the short term has not been thoroughly investigated after TKA.

When comparing normally aligned and moderately malaligned TKAs both pre- and postoperatively, we found that muscle strength was similar between the groups. The same applied for KSS and ROM, where the differences were small and hardly clinically relevant (Table 2, see supplementary data, and Table 4). This is in agreement with the results of Matziolis et al. (2010), who reported that postoperative varus malalignment as compared to neutral knee alignment after TKA had no influence on clinical outcome (KSS, the WOMAC, and the SF36). Furthermore, Magnussen et al. (2011) even found KSS to be better in patients with residual varus than in those with neutral alignment. However, there have been reports showing the opposite; Choong et al. (2009) and Huang et al. (2012) reported better KSS in TKA patients with a mechanical axis within 3° than in those with malaligned knees, which remained consistent from 6 weeks to 5 years of follow-up. We have no clear explanation for these contradictory findings, but Choong et al. (2009) and Huang et al. (2012) included patients with a variety of preoperative diagnoses, different implant types, and use of patellar resurfacing—which may have influenced the results. In contrast, our study only included OA patients with the same type of implant and no patellar resurfacing.

A weakness of the present study was that the rotation of femoral and tibial components was not measured. Malrotation of femoral or tibial components has been correlated with pain and inferior function (Barrack et al. 2001, Pietsch and Hofmann 2012), which could have an effect on KSS and muscle strength. However, none of the patients included in this study were revised due to a painful knee (according to the KSS objective subscale) before the end of the 1-year follow-up. In addition, another possible weakness of our study was that we did not measure pain during muscle strength assessment. One might suspect that during the examination, a painful knee would have had some influence on the muscle strength. However, in our material the mean KSS pain assessments or grades, which were recorded just before the muscle strength measurements, showed no statistically or clinically significant differences between normally aligned and malaligned TKA knees. Another weakness of the study was that we did not investigate the alignment in the sagittal plane for posterior offset and tilting of femoral component, or tibial slope. These parameters could possibly affect ROM and muscle strength.

In the present study, postoperative muscle strength 1 year after surgery exceeded the preoperative strength in 3 out of every 4 measurements. Similar findings were reported by Berth et al. (2002) and Yoshida et al. (2008), who investigated muscle strength from 1 to 3 years after TKA and observed an increase relative to preoperative values. However, Vahtrik et al. (2012), who investigated muscle strength at 3 and 6 months after TKA, found that postoperative muscle strength was lower than the preoperative value. Thus, it may be that after TKA surgery, the recovery and improvement of muscle strength can take more than 6 months.

We did not find that TKA malalignment had a statistically significant effect on muscle strength and function at the 1-year follow-up, so any subsequently higher failure rates caused later by malaligned TKAs are unlikely to be directly related to the function of the surrounding muscles. It appears that muscles can adapt to a malaligned axis or components without loss of strength, and can also produce function similar to that in normally aligned TKAs.

We conclude that moderate varus/valgus malalignment of the mechanical axis, or of individual components, has no relevant clinical effect on function or muscle strength 1 year after TKA surgery.

Supplementary data

Tables 2 and 3 are available at Acta's website (www.actaorthop.org), identification number 7800.

JS: data collection, measurements, data analysis, and writing of manuscript. AS and AL: data collection and analysis, and editing of manuscript. OR, HW, and ST: organization of study, data analysis, and editing of manuscript. All the authors read and approved the final manuscript.

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No competing interests declared.

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