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ORIGINAL PAPER

Influence of the post-operative axis on the clinical results of total knee replacement for severe varus deformities: does a slight residual varus improve the results?

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Abstract

Purpose Some recent articles have suggested that in the case of large varus deformity, it may be advantageous to leave some residual post-operative varus as a means of improving functional outcome.

The objective of this study is to compare the results of total knee replacement (TKR) performed for significant varus deformity (HKA < 170°) where there is a residual post-operative varus (HKA < 180°) to the results of TKR for significant varus deformity with either neutral post-operative (HKA = 180°) or mild valgus post-operative alignment (HKA > 180°).

Methods This series was made up of 208 knees. The mean pre-operative HKA angle was 166 ± 3° (154–169°), of which 150 were followed up for a mean 8.5 years (58 lost to follow-up). Based on post-operative radiographs, two groups were formed: group 1 (88 knees) in which post-operative alignment was 177.8 ± 1° (175–179°) and group 2 (62 knees) in which post-operative alignment was 181 ± 1° (180–184°).

Results The mean international knee society (IKS) score for group 1 was 178.8 ± 22 points (113–200) and 181.7 ± 22 points (95–200) for group 2. Oxford knee score was 20.4 ± 9 points (12–45) in group 1 and 19.2 ± 9 (12–50) in group 2. The results were slightly better in group 2 (in slight valgus) but this difference was not statistically significant ($p = 0.44$ and 0.4).

Conclusion The results of knee replacement performed for severe varus deformity are not adversely affected by post-operative valgus alignment. There is in fact a trend towards superior results for neutral or valgus alignment than slight residual varus, but this difference was not statistically significant.

Keywords Genu varum · Osteoarthritis · Alignment · Axis · Total knee arthroplasty (replacement)

Introduction

Obtaining a neutral mechanical axis for the lower limb when performing total knee replacement (TKR) represents the gold standard [1, 2]. It has been demonstrated in the literature that the restoration of a neutral mechanical axis in combination with well-balanced soft tissues leads to increased implant survival [2] and improved patient satisfaction [3]. Conversely, poorly balanced implants can lead to early failure [4]. Ritter et al. [5] have shown that a hip-knee-ankle (HKA) angle of 180° or in slight valgus improves implant survival. This recommendation is however not universally accepted by all authors [6]. Bellemans et al. [7] suggest a large proportion of the population finish their growth with mild varus alignment of their lower limbs of around 3° and that restoring a mechanical axis of 180° should be avoided as in these patients, it will feel abnormal. Furthermore, Vanlommel et al. [8] have reported that patients with preoperative varus deformity had better clinical and functional results when this was under corrected compared with patients with neutral postoperative alignment of 180°. Finally, Howell et al. [9] suggested that kinematic alignment, that is, a true resurfacing of the tibio-femoral joint line, aiming to restore the highly variable individual native pre-arthritic (or constitutional) anatomy, could lead to better results than mechanical axis alignment.

The aim of this study was to compare the clinical results of two groups of navigated mobile bearing cruciate retaining

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knee replacements: group 1 in which patients have residual post-operative varus (HKA < 180°) and group 2 in which knees are either neutral (HKA = 180°) or in slight valgus (HKA > 180°) postoperatively. Both groups had significant pre-operative varus deformities (> 10°).

Our hypothesis was that TKR in neutral or slight valgus had at least equivalent results to TKR with residual varus.

Materials and methods

This is a longitudinal cohort study of a single surgeon series performed in accordance with the declaration of Helsinki and having received ethical approval from our local ethics committee.

It is a consecutive retrospective series based on 208 knees with pre-operative genu varum greater than 10° operated on between January 2006 and December 2011. Exclusion criteria included follow up less than five years and a pre-operative HKA angle greater than or equal to 170°. All the patients had pre-operatively and within three months post-operatively plain radiographs and long-leg standing xRays according to Ramadier's protocol [10] in order to measure the HKA angle. The same protocol was used for all the patients to avoid any errors in the measurements related to the rotation of the lower leg [11]. The measurements were done with a ruler and a manual goniometer, by two independent observers, one radiologist and one orthopaedic practitioner.

Postoperative radiographs allowed for the formation of two groups: one in which post-operative alignment was less than 180° (group 1) and one in which the post-operative alignment was 180° or more (group 2). Fifty-eight knees were lost to follow-up whilst the remaining 150 have been followed up for an average of 8.5 years.

The implant used was the e-Motion FP® (B-Braun-Aesculap, Tuttlingen, Germany). This is a mobile bearing cruciate retaining prosthesis. All implants were implanted using the Orthopilot™ navigation system (B-Braun-Aesculap, Tuttlingen, Germany). The aim was to have a post-operative HKA angle between 177° and 183° in a well-balanced knee. In order to achieve ligament balancing, a medial release was performed in 106 out of 208 knees (51%) and in 75 out of the 150 remaining knees. In group 1, the release was performed in 44 knees (50%) and in 31 knees (50%) for group 2. In 15 of these, the medial collateral ligament was released from its femoral attachment and in 60 knees, the release was performed using a pie crusting technique.

All patients were reviewed by an independent observer at a minimum follow-up of five years. Knee range of movement and sagittal and coronal stability were recorded as well as IKS [12] and Oxford knee scores [13]. Standard radiographs were subsequently obtained at follow-up in order to look for signs of wear and or lucency using the EWALD classification [14].

All results were analysed using Microsoft Office Excel™ (Redmond, USA) and SPSS® (SPSS Inc., Chicago) software. The series' characteristics were described using mean and standard deviation for continuous variables and using percentages for categorical variables. Student's t test was used to compare quantitative data. The test was considered statistically significant when $p < 0.05$. Kaplan-Meier survival curves were then produced, with a confidence interval of 95%. The exit criterion used was surgical revision, for any cause. Patients lost to follow-up were excluded from the analysis.

Results

The series

The overall population was made up of 192 patients, 104 women (54.1%) and 88 men (45.8%) including 101 right knees (48.5%) and 107 left knees (51.5%). The mean age at the time of surgery was 71.3± eight years (44–88) with a mean BMI of 29.5 ± 4.8 (20–47). The aetiology was degenerative in 196 cases (94%), post-traumatic in five cases (2.5%) and secondary to avascular necrosis of the medial condyle in four cases (2%). Two patients were rheumatoid (1%) and one patient had an osteoarthritis secondary to osteomyelitis (0.5%). The mean pre-operative HKA angle was 166 ± 3° (154–169°). Based on the modified Ahlbäck classification [15], one knee was stage 2, 28 were stage 3, 125 were stage 4 and 48 knees were stage 5.

Group 1 was made up of 84 patients (88 knees) aged on average 71.6± 8 years (44–88) and group 2, 59 patients (62 knees) aged on average 71.3 ± seven years (57–82). Table 1 summarises the characteristics of both groups. Both groups were comparable in terms of pre and post-operative variables with no statistically significant difference noted, especially for HKA angle (166 ± 3° versus 166 ± 3°) and IKS score (70 ± 26 versus 72 ± 27 points). The lateral instability as well as the tightness of the medial side were checked intra-operatively with navigation, and there was no significant difference between the two groups.

Clinical results

The population studied in these results consisted of 134 patients, for 150 prostheses (16 bilateral surgeries). The population lost to follow-up was no different from the population studied in terms of age, sex, BMI, severity of osteoarthritis according to the modified Ahlbäck scale [14], pre-operative HKA angle, and IKS score ($p > 0.05$). The revision rate in the study was 69.7%, with an average of 104.5 months follow-up (60–117). This follow up was not different between the two groups (group 1: 90 ± 25 months and group 2: 91 ± 29 months; $p = 0.65$).

Table 1 Characteristics of the two groups

Population	Group 1	Group 2	*p*=
Sex			
Men	46 (55%)	30 (51%)	
Women	38 (45%)	29 (49%)	
Operated knees	88	62	
Right	48 (54.5%)	24 (38.5%)	
Left	40 (45.5%)	38 (61.5%)	
Mean age	71.6 ± 8 (44–88)	71.3 ± 7 (57–82)	0.6
BMI	29.5 ± 4.5 (20–40)	30 ± 5.4 (22–47)	0.97
Global pre-operative IKS Score	70 ± 26 (0–136)	72 ± 27 (28–131)	0.8
Function Score	38.5 ± 21 (0–90)	37.5 ± 18 (0–80)	0.65
Knee Score	31.5 ± 12 (0–56)	34 ± 13 (8–55)	0.2
Flexion angle (°)	116.7 ± 12 (80–140)	117.7 ± 13 (80–135)	0.7
HKA (°)	166 ± 3 (154–169)	166 ± 3 (156–169)	0.3
FMA (°)	88 ± 3.3 (79–99)	88.7 ± 3.2 (83–94)	0.14
TMA (°)	82 ± 3 (74–91)	83 ± 3.5 (76–90)	0.85
Stage of the osteoarthritis (modified Ahlbäck criteria)			
Stage 2	4	0	
Stage 3	14	13	
Stage 4	47	34	
Stage 5	23	15	

HKA: hip-knee-ankle, *FMA* femoral mechanical angle, *TMA* tibial mechanical angle

Group 1 (Fig. 1a, b)

The average IKS score was 178.8 ± 22 points (113–200) with a functional score of 86.6 ± 16 points (25–180) and a knee score of 93 ± 8 points (67–100). The Oxford score was 20.4 ± 9 points (12–45) and the average knee flexion 115 ± 10° (80–130°).

Group 2 (Fig. 2a, b)

The average IKS score was 181.7 ± 22 points (95–200) with a functional score of 87.6 ± 15 points (40–100) and a knee score of 94 ± 8.7 points (55–100). The Oxford score was 19.2 ± 9 points (12–50) with average knee flexion of 117 ± 11° (90–135°).

Complications

Among the immediate complications of the overall series, we noted four thromboembolic complications (2%), including two pulmonary embolisms requiring suitable anticoagulant treatment, one (0.5%) subcutaneous haematoma which was drained without needing additional surgery and three cases (1.5%) of superficial cutaneous necrosis requiring prolonged local treatment. Among the secondary and late complications, we noted one case of complex regional pain syndrome (0.5%), two infections (1%) at three and six months respectively, one patellar luxation (0.5%) re-operated on at one year post-TKR and one case of prosthesis instability (0.5%), re-operated on at five months post-TKR to remove the original prosthesis and fit a more constrained one. It should also be noted that five cases (2.5%) required closed manipulation under general anaesthetic for post-operative stiffness, and three periprosthetic distal femur fractures occurred, at an average of 10.3 ± one years post-operatively. These complications were divided in the two groups without any significant difference.

Comparison of the two groups

In terms of clinical outcomes, group 2 showed higher scores than group 1. However, this difference was not statistically significant. The principle results are summarised in Table 2.

The rate of survival in the two groups using as end points loosening, sepsis or premature wear was 98.8% for group 1 and 98.4% for group 2. At two year follow-up, the results were similar for both groups except for the flexion which was 2° less than at the latest follow up and the number of cases (20 knees lost to follow up in spite of 58).

Discussion

Obtaining a neutral mechanical axis for the lower limb when performing TKR represents the gold standard [1, 2]. It has

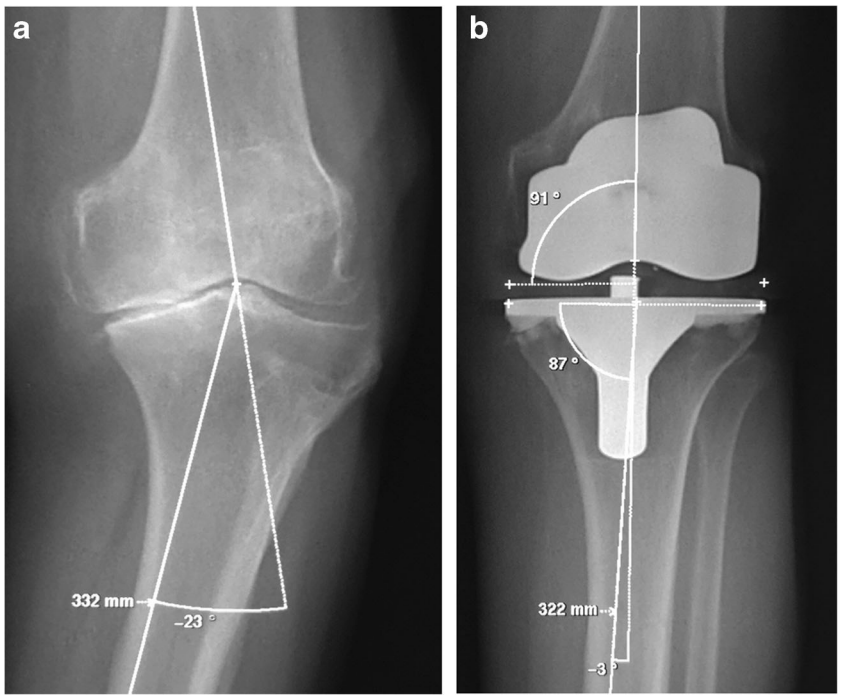

Fig. 1 **a** Eighty-two-year-old patient with severe genu varum deformity (23° of varus). **b** Post-operative residual varus of 3°. At 8 years follow up: IKS score = 171 points; Oxford score = 22 points

been demonstrated in the literature that the restoration of a neutral mechanical axis in combination with well-balanced soft tissues leads to increased implant survival [2] and improved patient satisfaction [3]. Conversely, poorly balanced implants can lead to early failure [4]. Ritter et al. [5] have shown that a HKA angle of 180° or in slight valgus improves implant survival.

The results of this study confirm Ritter's assertion and our initial hypothesis, i.e. neutrally aligned TKR or TKR with mild post-operative valgus alignment, have clinical outcomes which are at least equivalent to TKR with mild residual post-operative varus in the context of the treatment of significant pre-operative varus deformity. In terms of survival, we found no difference between the two groups. This is probably accounted for by the fact that the residual varus and valgus deformities were relatively mild and therefore did not negatively affect the longevity of the implants. For some time, several studies have shown that malalignment of TKR implants in the coronal plane leads to poor results [16–18].

Matziolis et al. [19] and Magnussen et al. [20] have reported good medium-term results in TKR with residual varus. Other authors have also shown that, in fact, residual varus was favourable leading to improved functional results and satisfaction [9, 21]. The concept of constitutional varus was proposed by Bellemans et al. [7]. They analysed the proportion of patients with constitutional varus greater than or equal to 3°. They reported on incidence of 32% in men and 17% in women. They proposed the hypothesis that restoration of a mechanical axis of 180° may be abnormal and therefore poorly tolerated in this population. This assertion is not confirmed by our experience with high tibial osteotomy (HTO) for genu varum deformity. Indeed, gait analysis and return to sport are not affected by the valgus overcorrection needed to get a good result [22, 23]. In a cadaveric study, Delport et al. [24] analysed the different levels of ligamentous tension between the neutral and constitutional axis. They suggest that the restoration of the constitutional alignment provides more physiological soft tissue tension compared with the restoration of a neutral mechanical axis and that this could therefore be of benefit. Elsewhere, other authors advocate the restoration of a more individualised mechanical axis as opposed to an axis of 180° [25]. Vanlommel et al. [8] found that moderate post-operative varus with a HKA between 175 and 177° offered improved subjective and functional results compared with patients in neutral alignment or with an under correction (HKA < 174°).

Contrary to this, Fang et al. [26], in a series of 6070 TKR, found higher failure rates in knees left in varus than knees left with residual valgus. Their recommendation was a post-operative valgus of between 2.4° and 7.2°. In addition, Huang et al. [27], in a series of TKR with large pre-operative varus deformities, found in the medium term, no difference in functional outcome between knees with residual varus and neutrally aligned knees. However, they did observe progression of varus on radiographs, suggestive of excess medial polyethylene wear and increased lateral laxity. This finding is understandable, given that, in order to leave the prosthesis in varus, virtually no medial release is performed, and there will therefore be some residual lateral laxity. These radiological observations place a question over the likely long-

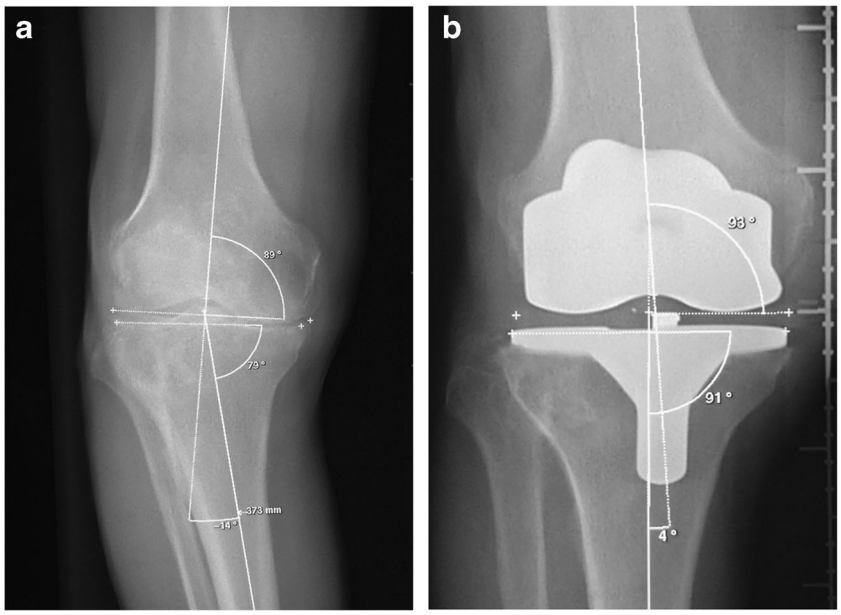

Fig. 2 **a** Seventy-six-year-old patient with severe genu varum deformity (14° of varus). **b** Post-operative valgus of 4°. At 7 years follow up: IKS score = 173 points; Oxford score = 22 points

term survival of such implants. Excessive polyethylene wear has also previously been reported by Collier et al. [28] in the case of excessive varus or valgus alignment of greater than 5°. In a paper from 2017, Saragaglia et al. [29] found that in 90% of cases at 8.5 years average follow up, there were no measurable radiological signs of wear in prostheses with a post-operative axis of 180 ± 3°.

Elsewhere, in a recent review of the literature, Vandekerchove et al. [30] found that frontal plane alignment in neutral may not be as strongly correlated to survivorship as previously thought, but they suggested that further studies were required before they could recommend a change in practice in line with new concepts and thought processes around post-operative alignment. Several authors do however advocate a kinematic approach to alignment [9, 31–34]. Although it might be that this concept is applicable to mild deformities, it seems unlikely if not unsafe to apply this in large deformities where ligamentous laxity is frequently found on the convexity of the deformity.

The limitations of this study are the numbers of patients which is probably not enough to give a strong conclusion, the minimum follow up and the fact that it is not a prospective randomised study. The strengths are the characteristics of the series based on severe genu varum deformities and the pre, intra, and post-operative protocol which was the same for all the patients (same surgeon, same prosthesis, same navigation system, same approach, etc.).

Table 2 Comparison of post-operative clinical scores

	Group 1	Group 2	*p*=
Global IKS Score	178.8 ± 22 (113–200)	181.7 ± 22 (95–200)	0.44
Function IKS Score	86 ± 16 (25–100)	87.6 ± 15 (40–100)	0.52
Knee IKS Score	93 ± 8 (67–100)	94 ± 8.7 (55–100)	0.4
Oxford Score	20.4 ± 9 (12–45)	19.2 ± 9 (12–50)	0.4
Flexion angle	115 ± 10° (80°–130°)	117 ± 11° (90°–135°)	0.24

IKS International Knee Score

Conclusion

The clinical results of TKR performed in the context of significant genu varum are not inferior in the case of residual post-operative valgus alignment. In fact, we found these to be slightly superior; however, this difference was not statistically significant. Whilst the clinical results in the medium term of patients with residual varus alignment appear satisfactory, long-term well-evidenced results are necessary to confirm this theory. Based on this study and our knowledge of the literature, we suggest a post-operative mechanical axis around 180° or in slight valgus should remain the reference standard in order to avoid an increased failure rate in case of excessive residual varus.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest related to this article. D. Saragaglia receives royalties from B-Braun related to the e-Motion Knee Prosthesis. The other authors had, sometimes, financial support for attending orthopaedics meetings.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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

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