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ORIGINAL PAPER

Total knee arthroplasty in patients with varus deformities greater than ten degrees: survival analysis at a mean ten year follow-up

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Abstract

Introduction Total knee arthoplasty (TKA) is a secure procedure with more than 90% survival at ten years. The purpose of this study was to report both clinical and radiological outcomes of TKA with a varus > 10°. The second objective was to identify risk factors for failure or bad clinical results. Our hypothesis was that results and survey are comparable to TKA with lesser deformities.

Methods Eighty-two TKA (69 patients) between January 2004 and December 2008 with a varus > 10° were reviewed retrospectively. The endpoints were clinical (range of motion, IKS knee score, Oxford, and SF-12) and radiological (HKA post-operative and the existence of radiolucent lines or loosening at last follow-up).

Results Sixty-three TKA (55 patients) were assessed with a mean follow-up of 10.9 years. The global IKS score significantly increased ($p = 0.04$). Seven TKA needed a revision: two for sepsis, four for aseptic loosening, and one for polyethylene wear, with an overall survival of 91.6% at ten years. For aseptic loosening, the survival rate was 94.7% at ten years. Risk factors for failure were age ($p = 0.001$), weight ($p = 0.04$), and a post-operative HKA lesser than 175° ($p = 0.05$) for aseptic loosening.

Discussion The hypothesis was confirmed: the results showed a significant improvement of function and quality of life with a survival rate comparable to those found in the literature for greater varus but also inferior to 10°. Three risk factors have been identified suggesting increased surveillance in these cases.

Conclusion The results of this survey confirm the work hypothesis. Total knee arthroplasty in patients with important axial deformities is a confirmed, reliable, patient-friendly and predictable good outcome procedure.

Keywords Total knee arthroplasty · Varus · Complication · Risk factors · Coronal deformity

Introduction

Total knee arthroplasty (TKA) is a reliable surgical procedure with good outcomes. The results showed survival rates over 90% at ten years [1–9]. Sometimes the initial deformities are major.

It is widely accepted that TKA on great varus can be difficult; however, the results seem sufficient and close to TKA for minor deformities [10, 11]. Only a few studies are treating with varus greater than 10° [10–14], some of them mixing deformities combining varus and valgus [11, 12], making the results difficult to interpret. Finally, these great deformities were sometimes characterized by a lower limb mechanical alignment (HKA angle) greater than 20° [10, 11], which is a very rarely encountered particular population.

The purpose of this study was to report the results with seven year minimal follow-up of a continuous and retrospective TKA series with an initial varus deformity greater or equal to 10°. The secondary objective was to identify risk factors for functional or mechanical failure. The primary endpoints were clinical and radiological. The secondary endpoints were the existence of revision surgery for aseptic loosening and research of evolutive radiolucent lines. The hypothesis of the present work was that results and survey were comparable to TKA with lesser deformities.

Level of evidence: IV, retrospective study.

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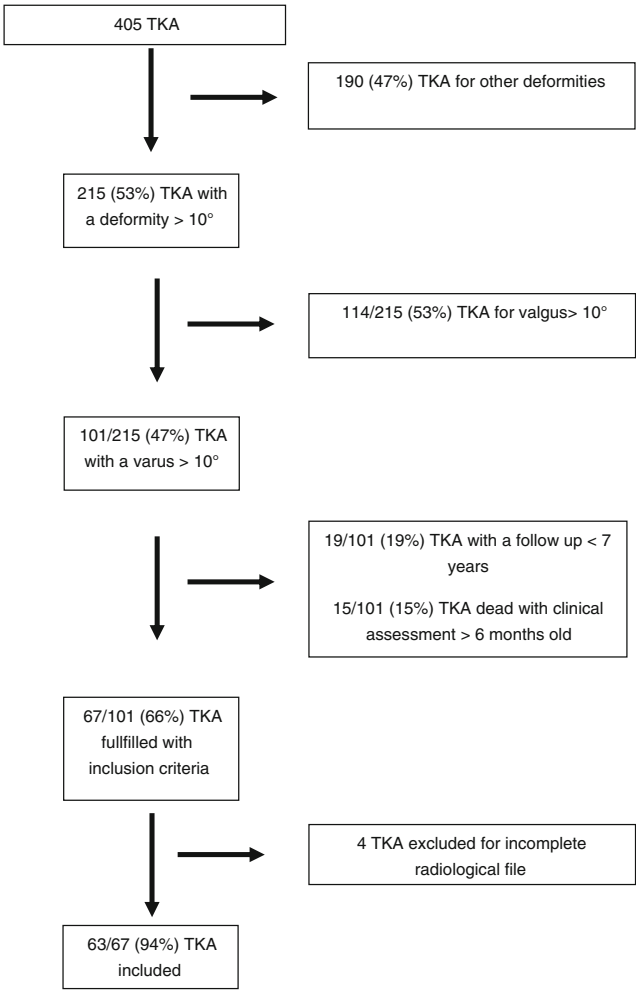

Fig. 1 Flow chart

Material and methods

Inclusion criteria

Every patient operated for TKA with an initial varus deformity greater or equal to 10° and with a minimal follow-up of seven years (from January 2004 to December 2008) was included.

Methods

Pre-operatively, age, sex, weight, initial diagnosis, range of motion, Charnley classification [15], Devane [16], and IKS knee and function [17] were noted. The radiological study used standard anteroposterior and lateral views and long-leg radiographs pre-operative, post-operative, and at last follow-up. Pre-operatively, the observer (BP) measured the HKA angle and patellar dislocation. Post-operatively, mMDFA and mMPTA were added.

When patients accepted to come back for last follow-up, clinical assessment included pre-operative scores plus Oxford 2 [18] and KOOS-PS [19]. The same X-rays than in pre-operative were taken. The presence of radiolucent lines was sought.

Patients refusing to come back were assessed by telephone and a prescription for X-rays was sent and transmitted to the observer. In these cases, Oxford and IKS function had been calculated. The IKS knee score was evaluated using the phone data and clinical data from the last consultation only if it was less than six months old. When the radiological assessment was not performed, patients were considered lost to follow-up.

In case of death, data were included only if radio-clinical assessment was complete and less than six months old with a minimal follow-up greater than seven years, provided that there was no revision after calling the family.

Post-operative complications were assessed and defined as early if succeeded within the first three months or late after three months.

Endpoints

At last follow-up, the primary endpoints were clinical (range of motion, IKS score, Oxford 2, KOOS-PS) and radiological (HKA angle, existence of radiolucent lines).

The secondary endpoints were (1) the existence of aseptic loosening requiring a surgical revision (considered as a failure and defining the survival rate) and (2) the existence of evolutive radiolucent lines.

Table 1 Pre-operative data (63 TKA)

Clinical data	Age (years)	Sex	BMI (kg/m^2)	Pathology	Range of motion (°)
	69.5 (44–81)	W 42 M 21	31.1 (20–45 + − 4.7)	55 (87%) primitive arthrosis 6 (10%) post-traumatic arthrosis 2 (3%) RA	102 (75–140, med 100)
	IKS [17]	IKS knee [17]	IKS function [17]	IKS pain [17]	
	72 (25–134, med 70)	22 (0–44, med 50)	49 (15–90, med 70)	10.9 (0–30, med 10)	
Radiological data	HKA (°)	Patellar tilt (°)	Patellar translation (mm)	mMPTA (°)	
	168 (155–170, med 169)	23 prostheses 9 (3–30, med 6)	19 genoux 6.3 (2–16, med 5)	85.89° + − 3.73 (83–95, med = 86)	

BMI body mass index, *W* women, *M* men, *RA* rheumatoid arthritis

Table 2 Technical data and characteristics of the implanted prosthesis

Approach	Tourniquet	Gap balancing	Implant type	Bearing	Patellar resurfacing	Cement
41 (65%) subvastus 22 (35%) médial para-patellar	No 46 (73%) yes 17 (27%)	61 (97%) Conventionnal 2 (3%) Navigated	62 (98%) Posterior-stabilized: 56 (90%) with cam and 6 (10%) ultra-congruent 1 (2%) constrained (varus >20°)	10/62 (16%) fixed 46/62 (74%) mobile	63 (100%)	63 (100%)

Series

During the study period, 67 TKA fulfilled the inclusion criteria and four (6%) were excluded for incomplete radiological file.

The population included 63/67 (94%) TKA in 55 patients (8 bilateral TKA) (Fig. 1).

Table 1 summarizes pre-operative data. Pre-operative Charnley score was A for 36 knees (57%), B1 for 21 knees (33%), B2 for one knee (2%), and C for five knees (9%). Devane score was, at time of surgery two in nine cases (15%), three in 45 cases (71%) and four in nine cases (14%).

Table 2 summarizes technical data and characteristics of the implanted prosthesis.

The mean post-operative HKA angle was 179° (168–184 ± 2.8) with a significant difference with pre-operative angle ($p = 0.0055$), mean mMDFA was 90° (80–92 ± 2), and mean mMPTA was 89.5° (85–96 ± 1.9). A patellar tilt was present in five knees (8%) with a mean of 9° (5–17 ± 5.1) with no significant difference with pre-operative status ($p = 0.46$). A patellar subluxation was present in three TKA with a mean of 8.3 mm (4–14 mm ± 5.1) with no significant difference with pre-operative status ($p = 0.36$).

Statistical analysis

Quantitative variables were described using standard statistics (mean, median, variance, minimum, maximum, maximum, quantiles). Qualitative variables were described along with the size and proportions of each modality. Cumulative proportions were calculated for variables with more than two modalities. The Gaussian character of the quantitative variables was evaluated using the Shapiro-Wilk test. If the conditions of application were met, the relationship between two quantitative variables was evaluated using the Pearson linear correlation test. Otherwise, a Spearman correlation test was performed. For the comparison of a quantitative variable within several subgroups, an analysis of variance or the Kruskal and Wallis test was used, depending on the use hypotheses of each of these tests. Finally, for the crossing of several qualitative variables, the χ^2 parametric test was used if the conditions of application allowed it. If not, Fisher's exact test was done. *P* value was set at 5% for all analyses. All the analyses were carried out on the R software, version 3.1 (R. Development Core Team (2008), Vienna, Austria).

Results

Series

The mean follow-up for the 63 TKA was 131 months (88–156 ± 14 months). Thirty-four patients (41/63 TKA, 7 bilateral) accepted a consultation with a clinical examination and X-ray. Twenty-one patients (22/63 TKA, 1 bilateral) were not willing to come back. The scores were obtained by telephone and X-rays taken in a private radiology centre and then sent to the observer.

Table 3 Clinical and radiological results at last follow-up

Clinical		Flexion (°)	IKS score [17]	IKS knee	IKS function	IKS pain
		115 (90–140, med 110)	154.5 (59–199, med 162)	91 (19–100, med 97)	65 (5–100, med 70)	47.6 (10–50, med 50)
	Gain	13	82.5	69	16	36.7
	Comparison to preop data	$p = 0.01$	$p = 0.04$	$p = 0.05$	$p = 0.001$	NS
Radiological		HKA	mMDFA	mMPTA	Patellar tilt (°)	Patellar translation (mm)
		177.6 (156–184, med 179)	88.7 (72–92, med 90)	89.5 + − 2.12 (82–96, med 90)	6 knees 7 (2–13, med 4.7)	3 knees 6.7 (5–10, med 5)
	Comparison to preop data	NS	NS	NS	NS	NS

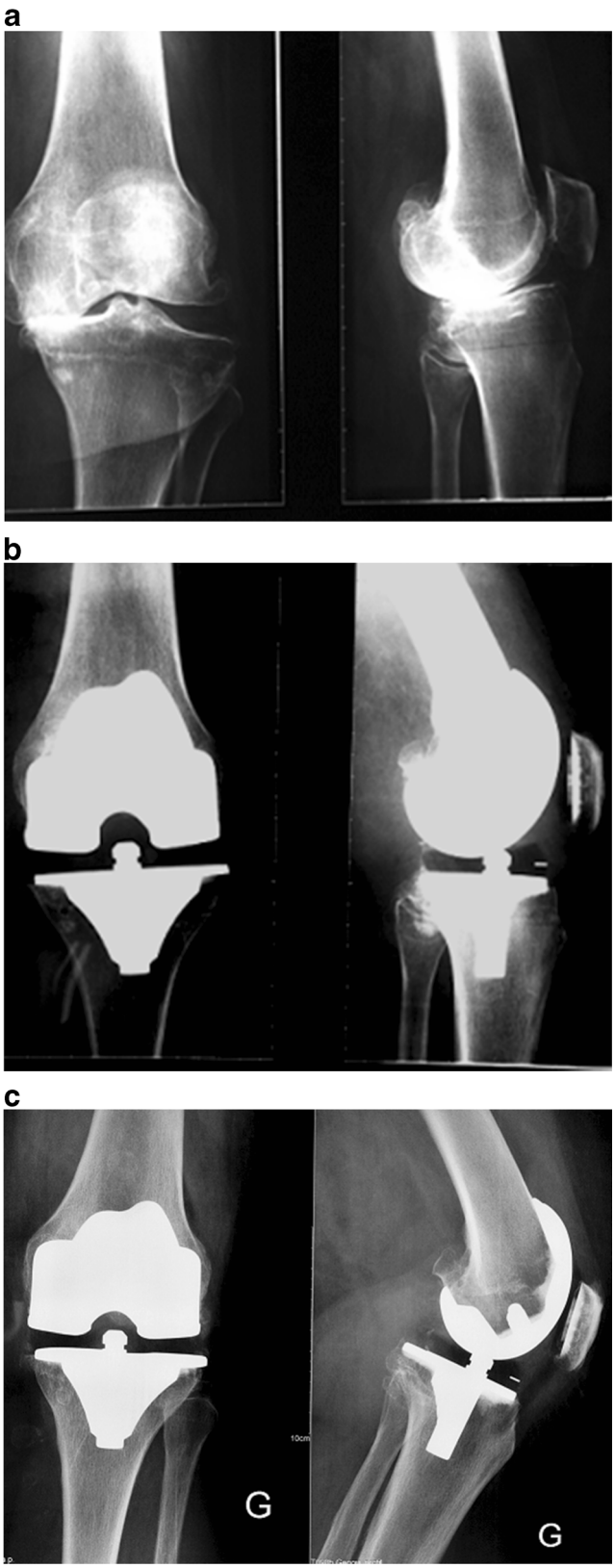

Fig. 2 XRays: AP and lateral view with a good result. **a** Before surgery, 12° varus; **b** immediate post-operative; and **c** and at last follow-up, 10 years, Oxford 2 = 42, KOOS-PS = 28

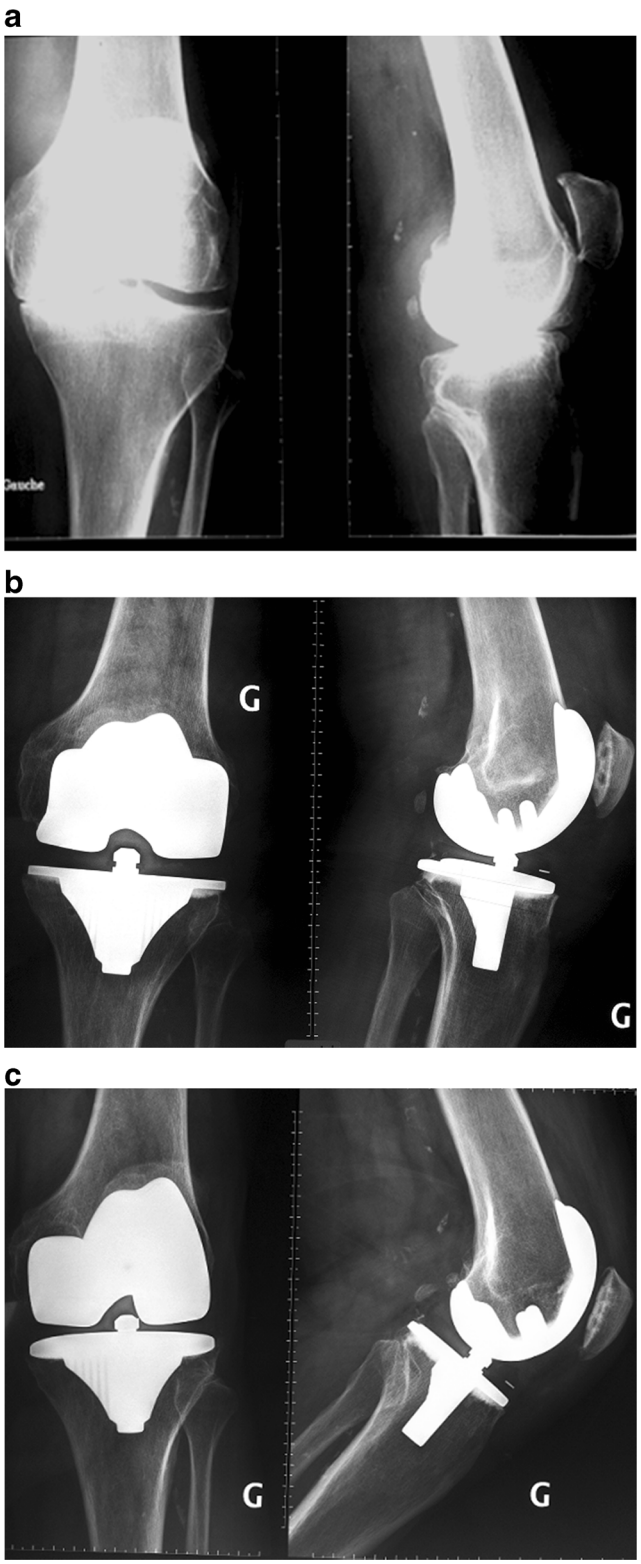

Fig. 3 XRays: AP and lateral view with a medium result. **a** Before surgery, 13° varus; **b** immediate post-operative; and **c** at last follow-up, 8 years, IKS global = 120, Oxford 2 = 36, KOOS-PS = 57

Table 4 Late complications

Cause of revision	Number of patients	Delay (years)
Aseptic loosening	4	9 (5–12, med 10)
Polyethylene wear	1	11.7
Infection	2	2.3 (1.7–2.8)

Clinical and radiological results

Table 3 summarizes the clinical and radiological results at last follow-up (Figs. 2 and 3).

The mean Oxford 2 score was 39.7 points (12–46 ± 6.5, med = 42) on a maximum of 48 points. The mean KOOS-PS score at last follow-up was 35.4 points (14.3–100 ± 18.8), the best score being 0 points.

A 2-mm non-evolutive radiolucent line (on femur and tibia) was seen in 1 TKA. The patient was free of symptoms and a simple annual surveillance was advocated.

Four evolutive radiolucent lines (one femoral and three tibial) leading to revision for aseptic loosening were found.

Complications

Twelve complications were observed (12 TKA (19%), 12 patients).

Five were early (5 TKA, 5 patients): 5 cases of deep venous thrombosis.

Seven were late complications (7 TKA (11%), 7 patients) (Table 4) and led to surgical revision: four aseptic loosening (4/7, 57%) (Fig. 4), one polyethylene wear (1/7, 14%), and two infections (2/7, 29%) cured by one-stage revision and adapted antibiotherapy. The mean delay for revision was seven years (1.7–12.5 ± 4.3, med = 5.6).

Survival rate

The survival rate for all causes at ten years was 91.6% [0.848; 0.990] [IC 95%] (Fig. 5). If we used aseptic loosening for survival criterion, the survival rate was 94.7% [0.889; 1] [IC 95%] (Fig. 6).

Risk factors

Three risk factors were found: age, weight, and a post-operative HKA angle < 175° in the cases of aseptic loosening (Table 5).

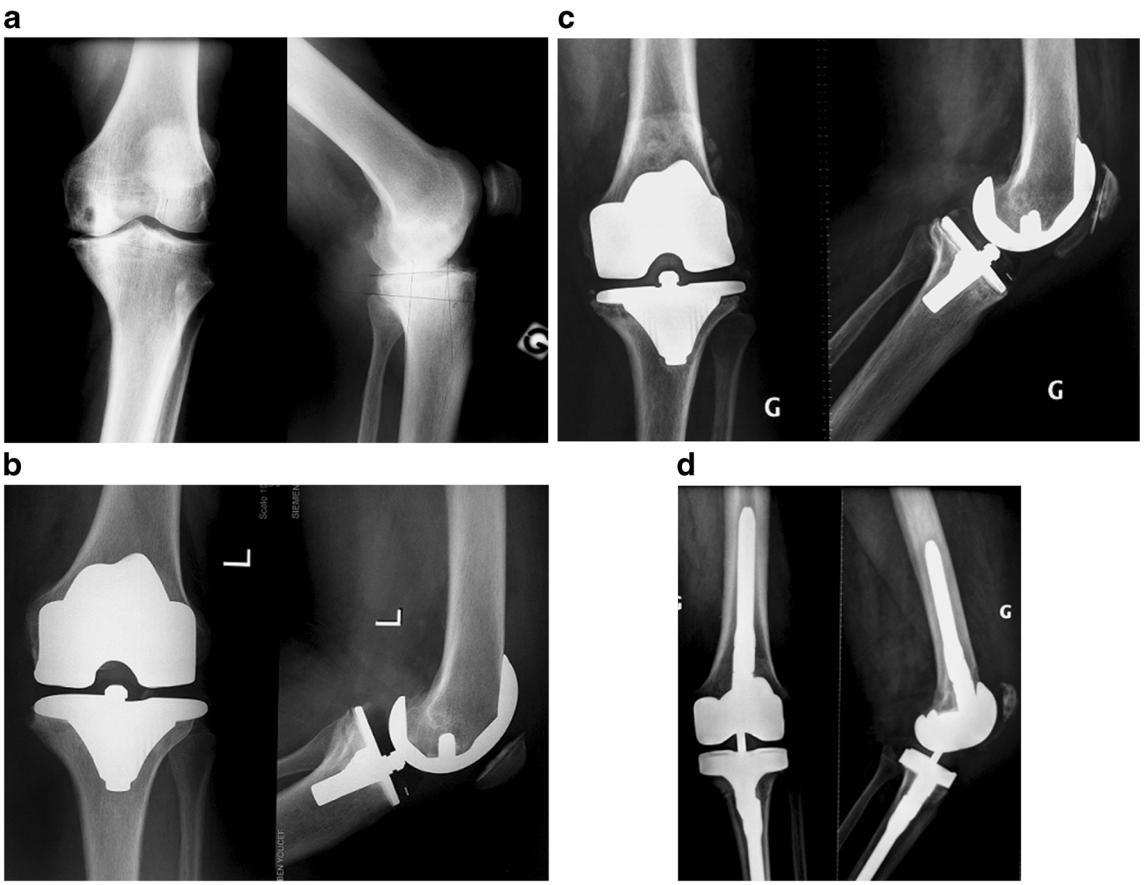

Fig. 4 One case of aseptic loosening. XRays: AP and lateral view. **a** Before surgery, 15° varus; **b** immediate post-operative; **c** before TKA revision, at 12 years, Oxford 2 = 18, KOOS-PS = 71; and **d** XRays immediate after TKA revision

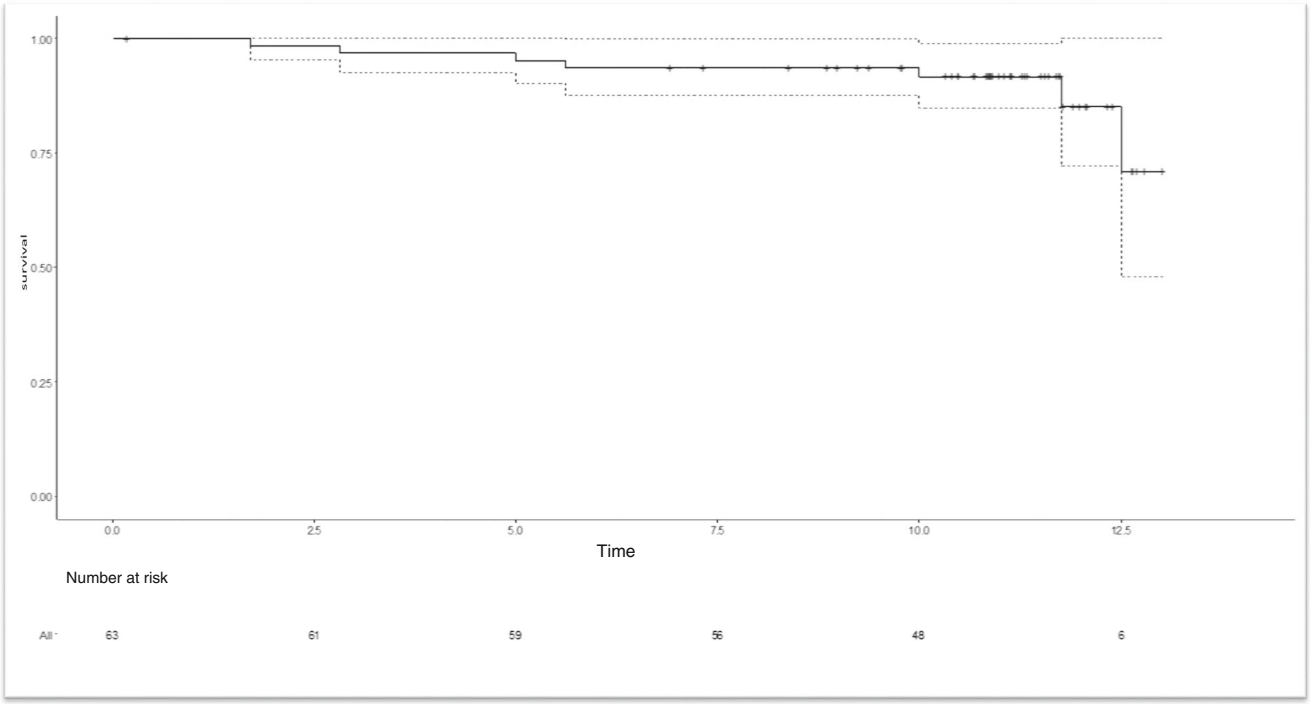

Fig. 5 The survival rate for all causes at 10 years

The pre-operative HKA angle was not found as a risk factor for all-causes surgical revision ($p = 0.3$), neither the post-operative HKA angle ($p = 0.18$), the post-operative mMDFA ($p = 0.21$), nor the mMPTA ($p = 0.32$).

Discussion

The main objective of this study was to report the results of TKAs for varus deformities greater or equal to 10° with a

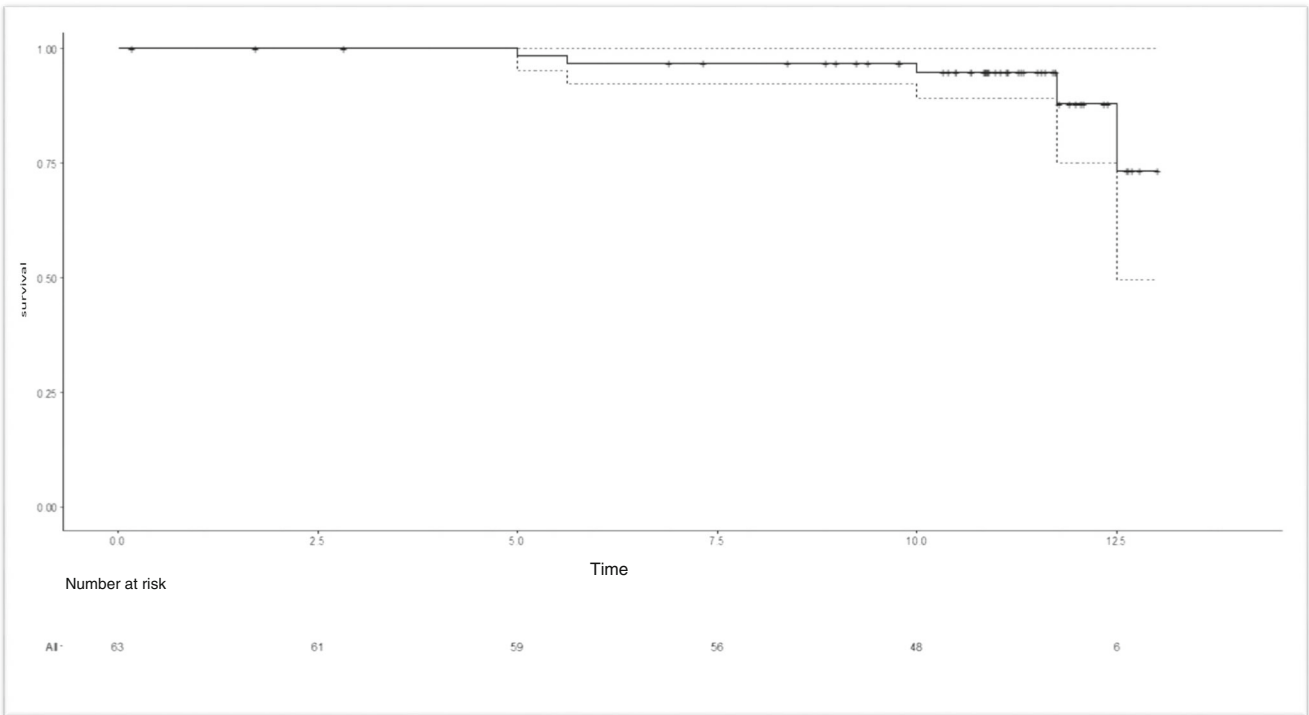

Fig. 6 The survival rate for aseptic loosening at 10 years

Table 5 Risk factors for failure

Risk factor	Cut-off	*p*	Relative risk
Age (years)	< 69	0.001	30
Weight (kg)	> 89	0.04	4.7
HKA post op (°)	< 175	0.05	7.7

minimal follow-up of seven years. The main results are an increase of range of motion of 13° at last follow-up ($p = 0.01$), a mean IKS knee score at 91 points, and mean IKS function at 65 points with a significant improvement of IKS score at 154.5 points ($p = 0.04$); the scores evaluating quality of life were good at last follow-up with a mean Oxford 2 at 39.7 points and a mean KOOS-PS score at 35.4 points; correction of the HKA angle was stable; there was only one case of non-evolutive radiolucent lines; the survival rate at ten years was 91.6% for all-causes revision and 94.7% for aseptic loosening. The secondary objective was to search for risk factors for failure. Three have been found: age at time of surgery ($p = 0.001$) with an age under 69 (RR 30), weight ($p = 0.04$) when exceeding 89.5 kg (RR 4.7), and a post-operative under-correction of HKA angle (under 175°) ($p = 0.05$). The hypothesis of this work was confirmed.

This study has some limits including (1) retrospective nature, (2) small sample size, and (3) the fact that more than a third of the patients were not willing to participate in an actual encounter and were therefore only interviewed by phone. The important number of lost to follow-up and deceased patients can be explained by the long follow-up of the series. The small sample size induces a lack of power but it remains one of the most important series found in the literature for great deformities with a long-term follow-up. The monocentric aspect also explains the small sample size but can be considered as a strength since indications and prosthesis implantation were from the same surgical team.

Eight studies report results of TKA in great deformities with a total of 775 TKA and a mean follow-up of 4.9 years (Table 6). However, some of these studies used deformities over 20°, which makes the comparison with the present, work problematic, and especially some mixed varus and valgus. To our knowledge, only one article [23] reports a series of TKA

Table 6 Literature data

Series	*n*	Type of deformity	Comparative study	Survival	Follow-up (years)	Results
Teeny et al. [10]	27	Varus > 20°	Yes ("nondeformity group")	–	4,9	Knee Evaluation Score = 89 points Poorer results in severe deformity group
Karachalios et al. [11]	51	Varus and valgus > 20°	Yes (deformity < 5° group)	–	5,5	Bristol Knee Score = 81 points Equal clinical results between the groups
Ritter et al. [12]	82	Varus and valgus > 20°	Yes (varus or valgus < 20° group)	98%	6,5	IKS knee = 87.8 points Difference ns
Mullaji et al. [14]	173	Varus > 20°	No	96%	2.6	IKS score = 163.2 points IKS knee = 91.1 points IKS function = 72.1 points
Liu et al. [20]	52	Varus > 15°	Yes (varus < 15° group)	100%	3	IKS score = 182 points IKS knee = 90 points IKS function = 92 points No difference in clinical scores or alignment
Kim et al. [21]	50	Varus > 20°	Yes (varus < 20° group)	100%	1	IKS score = 174.3 points IKS knee = 93.3 points IKS function = 81 points No difference in clinical scores or alignment
Czekaj et al. [22]	170	Varus and valgus > 10°	No	99.4%	6.6	IKS score = 177.9 points IKS knee = 93.8 points IKS function = 82.4 points
Saragaglia et al. [23]	150	Varus > 10°	No	98.7%	8.7	IKS score = 180 points IKS knee = 93.5 points IKS function = 86.5 points
This study	63	Varus > 10°	No	94.7%	10.9	IKS score = 156 points IKS knee = 91 points IKS function = 65 points

with an inclusion criterion of varus greater than 10° with long-term results (8.7 years) similar to ours in terms of function and survival. The results of these series were good with a correction of the HKA angle judged as good and comparable to our results. The survival rates cannot be compared to ours because of a variable and lower follow-up. For the five studies with a control group [10–12, 20, 21], clinical results were equal with a persistence of the varus deformity in the varus group [10]. Ritter et al. [12] included great deformities in varus and valgus and compared them to a group with less deformities: no difference was found in the clinical scores between the group "deformity > 20°" and the group "deformity < 5°". They concluded that the importance of the initial deformity did not impact the results contrary to Teeny et al. [10].

Regarding radiological results, the two main endpoints were the HKA angle and the existence of radiolucent lines. Only one case (1/63, 1.6%) of non-evolutive radiolucent lines and free of symptoms was observed with an 11-year follow-up. Comparison to other studies is impossible because the existence of radiolucent lines is rarely assessed. Saragaglia et al. [23] reported a 6.6% rate of non-evolutive radiolucent lines without clinical consequences. Argenson et al. [9] showed no radiolucent lines in 846 TKAs with a ten year mean follow-up, which was confirmed by Hofmann et al. [24] with a series of 176 TKAs with a 12-year mean follow-up.

The survival rate was 94.7% at ten years, which is similar to the survival rate of TKAs "for all deformities" with the same follow-up. Rand et al. [4] found a survival rate of 91%, Argenson et al. [9] a 92% survival rate, and Sundberg et al. [7] a 97% rate in the Swedish register. The initial deformity seems not to impact the implants' survival.

The secondary objective was to search for risks factors for failure. Three were found: (1) age ($p = 0.001$), (2) weight ($p = 0.04$) at time of surgery, and (3) insufficient correction of the HKA angle in immediate post-operative radiographs ($p = 0.05$). These three risk factors are already described in the literature [2–4, 8, 12, 25] but for lesser deformities. To our knowledge, this is the first description of risk factors in the specific case of great varus.

There is a high increase of failure risk when age at time of surgery is under 69 (RR = 30), which matches the literature data [2–4, 7, 8, 13, 25]. An important physical or professional activity is often suggested as an explanation. The RR was also increased when the weight exceeded 89.5 kg (RR = 4.7). Obesity is a well-known factor for bad results regarding survival and function. Abdel et al. [26] showed an increase of revision rate for aseptic loosening for patients with a body mass index (BMI) exceeding 35 kg/m^2 despite a similar mechanical alignment with the control group. Fehring et al. [27] showed an increased tibial component loosening in obese patients and proposed the use of tibial stems when BMI exceeds 35 kg/m^2. Finally, the post-operative HKA angle appears as the third risk factor for aseptic loosening when it remains inferior to 175° (RR = 7.7), confirming the literature data [1, 25]. The mechanical explanation is simple since in a varus superior to 3° the medial tibial plateau supports 70 to 77% of the load [28], explaining the asymmetrical polyethylene wear and tibial loosening.

Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

PA: consulting activity for Depuy-Synthes
FB: consulting activity for Serf, Amplitude
ME: consulting activity Depuy-Synthes, Newclip, Lepine
BP, DE, HF: None

References

1. Ritter MA (2009) The anatomical graduated component total knee replacement: a long-term evaluation with 20-year survival analysis. J Bone Joint Surg (Br) 91B:745–749. https://doi.org/10.1302/0301-620X.91B6.21854
2. Fernandez-Fernandez R, Rodriguez-Merchan EC (2015) Better survival of total knee replacement in patients older than 70 years: a prospective study with 8 to 12 years follow-up. Arch Bone Joint Surg 3:22–28
3. Rand JA, Ilstrup DM (1991) Survivorship analysis of total knee arthroplasty: cumulative rates of survival of 9200 total knee arthroplasties. J Bone Joint Surg Am 73A:397–409
4. Rand JA, Trousdale RT, Ilstrup DM, Harmsen WS (2003) Factors affecting the durability of primary total knee prostheses. J Bone Joint Surg Am 85A:259–265
5. Furnes O, Espehaug B, Lie SA, Vollset SE, Engesaeter LB, Havelin LI (2002) Early failures among 7,174 primary total knee replacements: a follow-up study from the Norwegian Arthroplasty Register 1994–2000. Acta Orthop Scand 73:117–129. https://doi.org/10.1080/000164702753671678
6. Lygre SH, Vollset SE, Furnes O (2011) Failure of total knee arthroplasty with or without patella resurfacing. Acta Orthop 82:282–292
7. Sundberg M, Lidgren L, W-Dahl A, Robertsson O. Swedish Knee Arthroplasty Register ; Lund University. http://www.myknee.se/pdf/SVK
8. Gøthesen O, Espehaug B, Havelin L, Petursson G, Lygre S, Ellison P et al (2013) Survival rates and causes of revision in cemented primary total knee replacement: a report from the Norwegian Arthroplasty Register 1994–2009. Bone Joint J 95:636–642
9. Argenson JN, Boisgard S, Parratte S, Descamps S, Bercovy M, Bonnevialle P et al (2013) Survival analysis of total knee arthroplasty at a minimum 10 years' follow-up: a multicenter French nationwide study including 846 cases. Orthop Traumatol Surg Res 99:385–390
10. Teeny SM, Krackow KA, Hungerford DS, Jones M (1991) Primary total knee arthroplasty in patients with severe varus deformity. A comparative study. Clin Orthop Relat Res 273:19–31
11. Karachalios T, Sarangi PP, Newman JH (1994) Severe varus and valgus deformities treated by total knee arthroplasty. J Bone Joint Surg Br 76:938–942
12. Ritter MA, Faris GW, Faris PM, Davis KE (2004) Total knee arthroplasty in patients with angular varus or valgus deformities of > or = 20 degrees. J Arthroplast 19:862–866. https://doi.org/10.1016/j.arth.2004.03.009

13. Harrysson OL, Robertsson O, Nayfeh JF (2004) Higher cumulative revision rate of knee arthroplasties in younger patients with osteoarthritis. Clin Orthop Relat Res 421:162–168
14. Mullaji AB, Padmanabhan V, Jindal G (2005) Total knee arthroplasty for profound varus deformity: technique and radiological results in 173 knees with varus of more than 20 degrees. J Arthroplast 20:550–561
15. Charnley J (1972) The long-term results of a low-friction arthroplasty of the hip performed as a primary intervention. J Bone Joint Surgery (Br) 54:61–76
16. Devane PA, Robinson EJ, Bourne RB, Rorabeck CH, Nayak NN, Horne JG (1997) Measurement of polyethylene wear in acetabular components inserted with and without cement. A randomized trial. J Bone Joint Surg Am 79:682–689
17. Insall JN, Dorr LD, Scott RD, Scott WN (1989) Rationale of the knee society clinical rating system. Clin Orthop Relat Res 248:13–14
18. Murray DW, Fitzpatrick R, Rogers K, Pandit H, Beard DJ, Carr AJ et al (2007) The use of the Oxford hip and knee scores. J Bone Joint Surg (Br) 89:1010–1014
19. Ornetti P, Perruccio AV, Roos EM, Lohmander LS, Davis AM, Maillefert JF (2009) Psychometric properties of the French translation of the reduced KOOS and HOOS (KOOS-PS and HOOS-PS). Osteoarthr Cartil 17:1604–1608
20. Liu HC, Kuo FC, Huang CC, Wang JW (2015) Mini-midvastus total knee arthroplasty in patients with severe varus deformity. Orthopedics 38:e112–e117
21. Kim MS, Koh IJ, Choi YJ, Kim YD, In Y (2017) Correcting severe Varus deformity using trial components during total knee arthroplasty. J Arthroplast 32:1488–1495
22. Czekaj J, Fary C, Gaillard T, Lustig S (2017) Does low-constraint mobile bearing knee prosthesis give satisfactory results for severe coronal deformities? A five to twelve year follow up study. Int Orthop 41:1369–1377
23. Saragaglia D, Sigwalt L, Gaillot J, Morin V, Rubens-Duval B, Pailhé R (2017) Results with eight and a half years average follow-up on two hundred and eight e-Motion FP® knee prosthesis, fitted using computer navigation for knee osteoarthritis in patients with over ten degrees genu varum. Int Orthop. https://doi.org/10.1007/s00264-017-3618-8
24. Hofmann AA, Evanich JD, Ferguson RP, Camargo MP (2001) Ten- to 14-year clinical follow up of the cementless natural knee system. Clin Orthop Relat Res 388:85–94
25. Roberts VI, Esler CN, Harper WM (2007) A 15-year follow-up study of 4606 primary total knee replacements. J Bone Joint Surg (Br) 89:1452–1456
26. Abdel MP, Bonadurer GF, Jenning MT, Hanssen AD (2015) Increased aseptic tibial failures in patients with BMI ≥35 and well-aligned total knee arthroplasties. J Arthroplast 30:2181–2184
27. Fehring TK, Fehring KA, Anderson LA, Otero JE, Springer BD (2017) Catastrophic varus collapse of the tibia in obese total knee arthroplasty. J Arthroplast 32:1625–1629
28. Kim YH, Park JW, Kim JS, Park SD (2014) The relationship between the survival of total knee arthroplasty and postoperative coronal, sagittal and rotational alignment of knee prosthesis. Int Orthop 38:379–385