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Original article

Same-stage total knee arthroplasty and osteotomy for osteoarthritis with extra-articular deformity. Part I: Tibial osteotomy, prospective study of 26 cases

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ABSTRACT

Background: In patients with advanced knee osteoarthritis and extra-articular knee deformity (EKD), ligament balance may be difficult to achieve during total knee arthroplasty (TKA). Treatment options include two-stage surgery with the first stage involving correction of the EKD and same-stage TKA and tibial osteotomy (1S-TKA-TO). The objective of this study was to assess outcomes in 26 patients managed with 1S-TKA-TO.
Hypothesis: 1S-TKA-TO produces satisfactory clinical and anatomical outcomes and is not associated with higher morbidity rates compared to TKA alone or two-stage TKA-TO.
Material and methods: A prospective study was conducted in 25 patients (26 knees) managed with 1S-TKA-TO between 1995 and 2014. There were 16 males and 9 females with a mean age of 64 years (range, 29–80 years) and a mean body mass index of 29.6 (range, 24–49). The EKD was constitutional in 14 knees, post-traumatic in 5 knees, and induced by TO in 7 knees. None of the patients received a hinged knee implant. In each patient, the clinical International Knee Society (IKS score) was assessed and the hip-knee-ankle angle (HKA), tibial mechanical angle (TMA), and femoral mechanical angle (FMA) were measured on radiographs before surgery and at last follow-up.
Results: The mean IKS score increased significantly, from 70 before surgery to 170 at the end of the mean 9-year follow-up. Mean flexion range increased from 98° to 107°. The clinical and anatomical outcomes were satisfactory in 25 patients. In the remaining patient, who had a history of multiple surgeries for Blount disease and a body mass index of 49, a severe complication consisting in massive skin necrosis followed by infection occurred; this was the only patient who required revision surgery with implant removal.
Discussion: These findings are consistent with the satisfactory outcomes observed in earlier studies, most of which included small numbers of patients. The alternatives to 1S-TKA-TO are under evaluation. The best indication for 1S-TKA-TO may be knee osteoarthritis with a greater than 10° intra-osseous deformity.
Level of evidence: IV, prospective observational cohort study.

1. Introduction

Advanced knee osteoarthritis may be accompanied with severe extra-articular knee deformity (EKD) involving either the femur or the tibia. EKDs are often mild and amenable to correction during total knee arthroplasty (TKA) by adjusting the bone cut to balance the ligaments and release the concave side of the joint. With severe EKD, in contrast, correction via the usual bone cuts requires extensive resection on the convex side, which may induce laxity or exacerbate pre-existing laxity. EKD correction at its extra-articular site of occurrence, by performing a tibial osteotomy (TO), deserves consideration in this situation. In patients with osteoarthritis involving all three-knee compartments, as well as

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Table 1
The series: 25 patients (26 knees).

Patient #	DOB	Sex	Age, y	BMI	Year of surgery	Cause	Deformity	Side
1	1930	F	65	26	1995	ATT transfer	Flexion 30°	R
2	1931	M	66	26.1	1997	Constitutional	Varus 21°	L
3	1930	M	69	25.9	1999	Constitutional	Varus 21°	L
4	1928	M	71	29.4	1999	Constitutional	Varus 22°	R
5	1922	F	78	27.5	1999	Trauma	Valgus 30°	L
6	1932	F	67	31.6	2000	Trauma	Varus 22°	L
7	1930	M	70	23.7	2000	Constitutional	Varus 30°	R
8	1942	M	59	23.4	2001	Constitutional	Varus 22°	R
9	1931	F	71	26	2002	Constitutional	Varus 14°	L
10	1950	M	53	28.1	2003	Multiple epiphyseal dysplasia and osteotomy	Valgus 12° Recurvatum 30°	R
11	1950	F	56	32	2006	Osteotomy	Valgus 16°	R
12	1949	M	58	33	2007	Constitutional	Varus 22°	L
13	1947	M	60	46.2	2007	Constitutional	Valgus 17°	R
14	1947	M	62	46.2	2009	Constitutional	Valgus 16°	L
15	1948	F	60	31.2	2008	Trauma	Varus 30°	R
16	1948	M	60	31.2	2008	Constitutional	Valgus 15°	L
17	1941	M	67	32	2008	Constitutional	Varus 24°	L
18	1932	M	78	29	2010	Previous osteotomy	Valgus 30°	R
19	1934	F	76	31	2010	Previous osteotomy	Valgus 11°	L
20	1937	F	73	29.5	2011	Previous osteotomy	Valgus 11°	R
21	1931	M	80	26	2011	Trauma	Varus 15°	R
22	1946	F	65	29	2011	Constitutional	Valgus 12°	R
23	1940	M	72	27	2011	Constitutional	Varus 19°	L
24	1978	M	34	49	2012	Constitutional, Blount desease	Varus 25°	L
25	1944	M	70	25.5	2014	Previous osteotomy	Valgus 13°	R
26	1995	M	29	23.8	2014	Trauma	Translation	L

DOB: date of birth; F: female; M: male; BMI: body mass index; ATT: anterior tibial tuberosity.

in elderly individuals, EKD correction can be combined with TKA alone, in one or two stages. In 1991, Wolff and Hungerford [1] reported the first case of same-stage TKA and TO (1S-TKA-TO) and highlighted the limitations of intra-articular EKD correction. Anecdotal case-reports and small case-series were published subsequently [2–5]. In 2002, Radke [6] reported good clinical outcomes and a low morbidity rate in 10 patients managed by 1S-TKA-TO.

The objective of this study was to assess clinical and anatomical outcomes, as well as morbidity, in 26 patients managed with 1S-TKA-TO. The working hypothesis was that 1S-TKA-TO produces satisfactory clinical and anatomical outcomes and is not associated with higher morbidity rates compared to TKA alone or two-stage TKA-TO.

2. Material and methods

2.1. Material

Between 1995 and 2014, 26 1S-TKA-TO procedures were performed in 25 patients who were followed-up for at least 3 years (Table 1). The EKDs were classified using a simplified variant of the Hungerford and Krackow classification [7], as follows [8]: type 1, isolated wear; type 2, wear and laxity; type 3, wear and intra-osseous deformity; and Type 4, wear, intra-osseous deformity, and laxity. All 26 knees had Type 3 deformity with greater than 10° of intra-osseous angulation. Of the 26 procedures, 24 were performed by the same surgeon (YC) working successively in three different centres.

There were 16 males and 9 females with a mean age at surgery of 64 years (range, 29–80 years) and a mean body mass index of 29.6 (range, 24–49). In the Ahlbäck classification of knee osteoarthritis, 5 knees were grade 2, 13 knees were grade 3, and 8 knees were grade 4. The intra-osseous EKD consisted in an at least 10° angulation in the coronal plane in 23 knees. There was 1 case each of combined valgus and recurvatum, sagittal EKD with a 30° tibial slope, and proximal tibial mal-union with major translation. Malalignment in the coronal plane was noted in 24 knees, in which the mean hip-knee-ankle angle (HKA) was 158° (range, 150–166°) for the subgroup with pre-operative varus and 197° (range, 191–210°) for the subgroup with pre-operative valgus. The EKD was constitutional in 14 knees; in the remaining 12 knees, the cause was mal-union due to trauma ($n = 5$) or osteotomy ($n = 7$). Of the 14 constitutional EKDs, 10 were varus deformities, including 1 due to Blount disease and 1 due to multiple epiphyseal dysplasia; the remaining 4 were in valgus.

The same operative technique was applied for all 26 knees. The first step was implantation of the femoral component. TO was then performed and fixed temporarily using staples. A long-stemmed tibial implant was then inserted after reaming using a rigid reamer to allow a tibial cut perpendicular to the tibial axis. The type of osteotomy varied with the type of EKD: an opening wedge TO was performed for the 13 knees with tibial varus, a closing wedge TO for the 10 knees with tibial valgus (Figs. 1 and 2), an anterior closing wedge TO after anterior tibial tuberosity section in a knee with intra-osseous flexion deformity (knee #1), varus and flexion TO in a patient with both tibial valgus and recurvatum (Fig. 3), and lateral translation TO after anterior tibial tuberosity elevation in a patient with translation due to mal-union (Fig. 4).

Tibial fixation was performed for 21 knees. A long-stemmed tibial implant was used in all but 1 case (knee #1); stem length was usually 10 cm (15 cm for 6 knees) and the stem was either straight ($n = 14$) or offset ($n = 11$).

The degree of constraint was determined pre-operatively. For 23 knees, a posterior-stabilised implant with a fixed tibial plateau was used. The 3 remaining knees were replaced with a posterior-stabilised condylar knee implant featuring an extended cam (CCK type). No hinged implants were used.

Post-operative care consistently included weight-bearing starting on the first post-operative day and early joint mobilisation. An extension splint was worn during walking for the first 45 days.

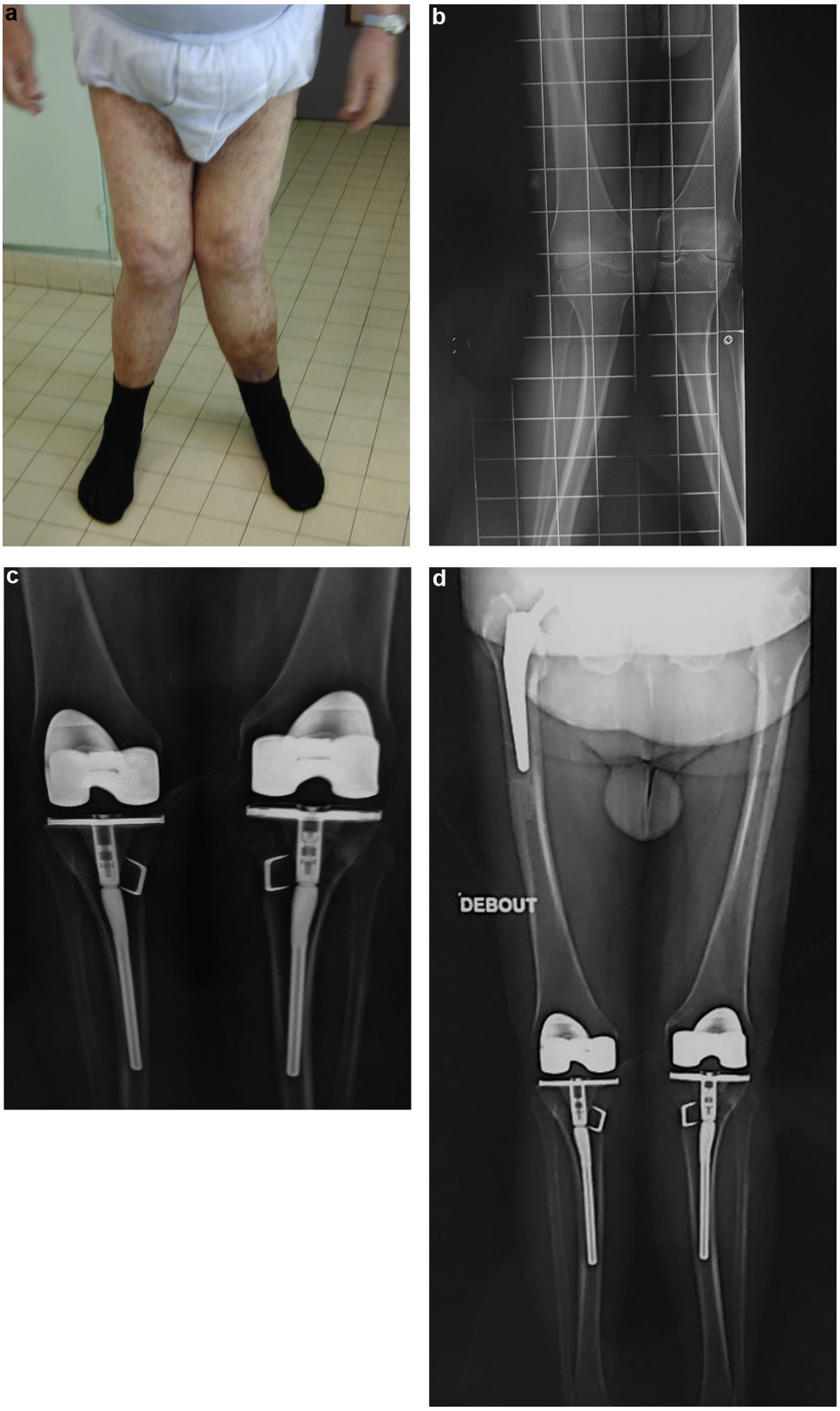

Fig. 1. a: knees #13 and #14, 60-year-old male with knee osteoarthritis complicating bilateral constitutional tibial valgus deformity; b: long-leg radiograph before surgery; c: total knee arthroplasty and bilateral tibial medial closing-wedge osteotomy; d: long-leg weight-bearing radiograph after surgery on the second knee showing a very good outcome.

2.2. Methods

Clinical and radiographic parameters were recorded before and after surgery. The clinical parameters included the body mass index (BMI), range of knee flexion and extension, and the International Knee Society (IKS) knee and function scores. Laxity in varus and valgus was sought. The radiographic parameters were measured on antero-posterior and lateral single-leg

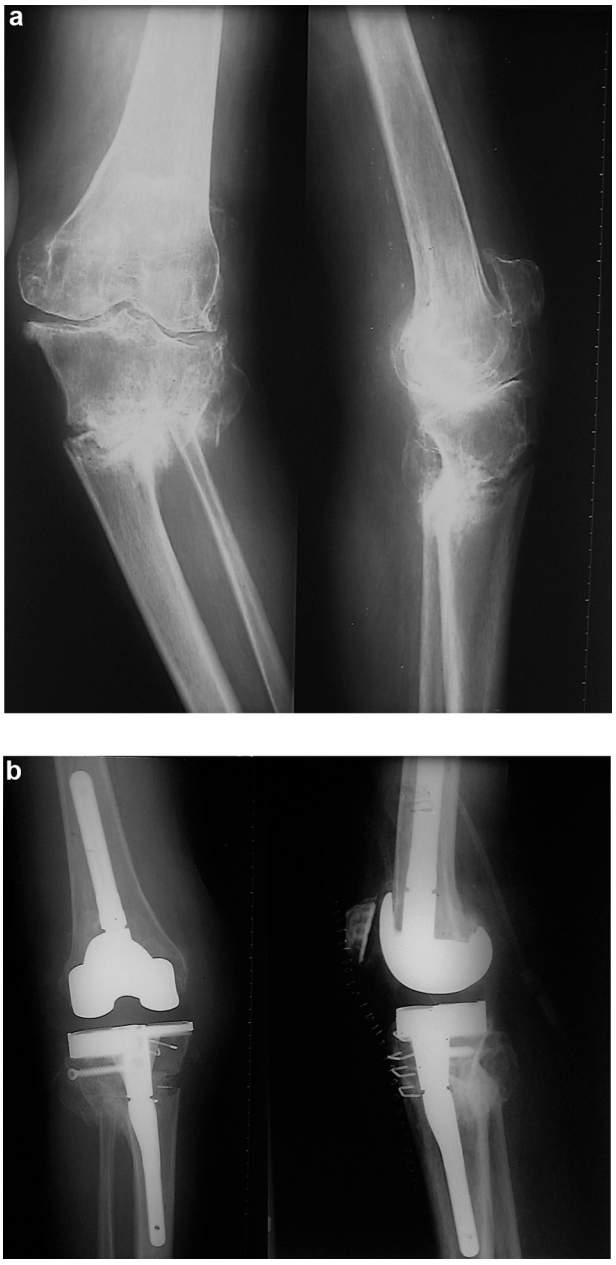

Fig. 2. a: knee #5 in a 78-year-old female with 30° of varus deformity after a proximal tibial fracture 10 years earlier; b: radiographs taken 1 year after surgery.

weight-bearing views, an antero-posterior schuss view, a 30° skyline view, and a long-leg view; starting in 2010, the long-leg view was replaced by EOS imaging. Computed tomography was performed for knees with rotational malalignment or post-traumatic mal-union. The following radiological parameters were measured: HKA, formed by the mechanical axes of the femur and tibia; femoral mechanical angle (FMA) on the medial side of the intersection between the mechanical axis of the femur and the bicondylar line, to assess the femoral intra-osseous EKD, with values of 90° to 94° classified as normal; and tibial mechanical angle (TMA) subtended by the mechanical axis of the tibia and the line tangent to the normal plateau, to assess the tibial intra-osseous EKD, with values of 86° to 90° classified as normal.

For each patient, intra-operative, immediate post-operative, and delayed post-operative complications were recorded, as well as any revision procedures. The patients attended follow-up visits 45 days, 6 months, 1 year, 2 years, and 5 years after surgery then once every 5 years.

2.3. Statistical analysis

Variable distribution was tested for normality by applying the Ryan-Joiner and Shapiro-Wilk tests. Normally distributed variables between two groups with similar variances were compared by applying Student's *t* test. For non-normally distributed variables and for variables whose variances differed between groups, the non-parametric Mann-Whitney test was used. Values of *p* smaller than 0.05 were taken to indicate significant differences.

3. Results

For 24 patients (25 knees), follow-up ranged from 3 to 18 years, with a mean of 9 years (Table 2). The remaining patient died of heart failure 1 year after surgery.

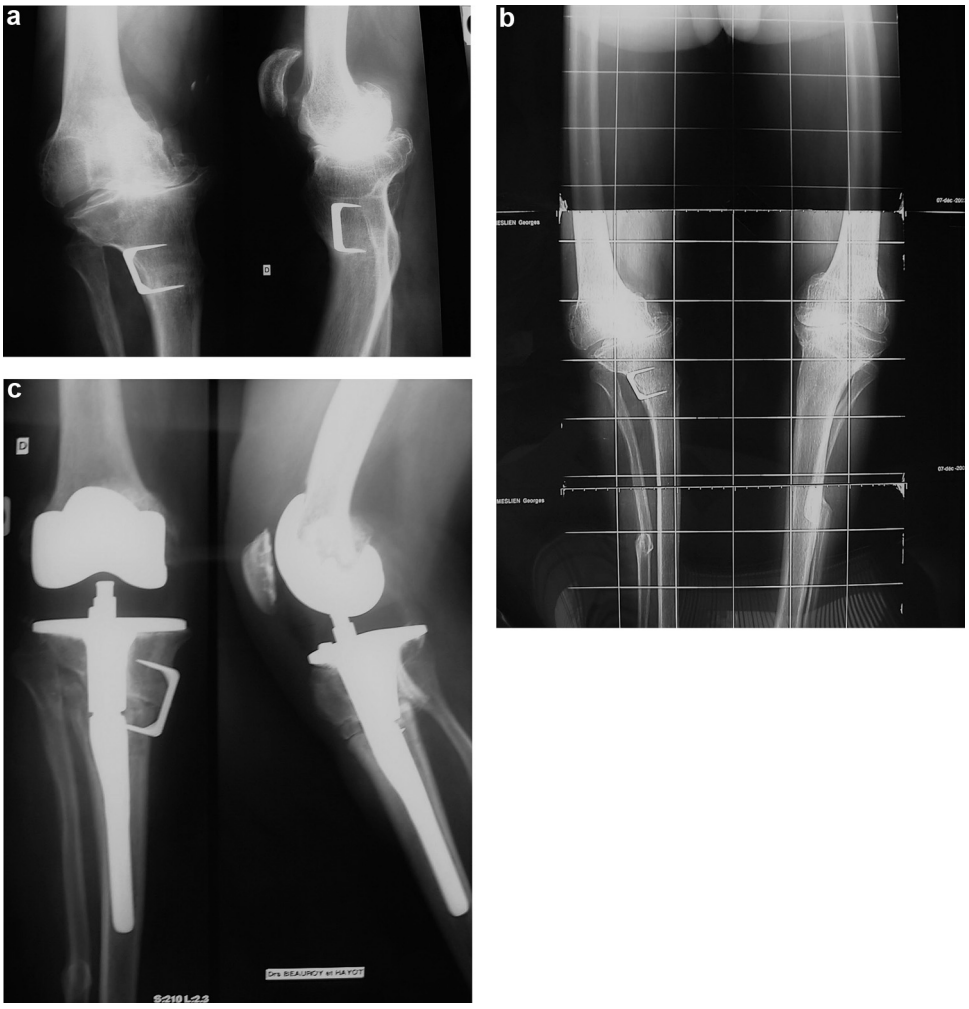

Fig. 3. a: knee #10 in a 53-year-old male with multiple epiphyseal dysplasia and a history of tibial osteotomy during childhood; b: valgus and recurvatum; c: appearance 14 years after long-stemmed total knee arthroplasty and tibial osteotomy: good clinical outcome.

3.1. Clinical outcomes

The mean total IKS score increased from 70 (range, 29–104) pre-operatively to 170 (range, 126–190) post-operatively, yielding a significant mean increase of 98.9 ± 17.6 ($p < 0.0001$). The IKS knee score increased from 28.5 (range, 10–59) before surgery to 84 (range, 56–99) after surgery. Range of flexion increased from 98° (range, 5–120°) before surgery to 107° (range, 0–130°) after surgery, yielding a significant mean increase of $16.3 \pm 8.3°$.

3.2. Radiological outcomes

After surgery, the HKA was $180 \pm 3°$ for 24 knees. The remaining 2 knees had HKA values of 175° and 184°, respectively.

Before surgery, the mean FMA was 90.5° (range, 82–93°). Marked femoral varus (82°) in the patient with multiple epiphyseal dysplasia resulted in post-operative varus (HKA, 175°).

For the 13 knees with varus deformity, the mean TMA was 74° (range, 67–79°) before surgery and 89° (range, 87–92°) after surgery. Corresponding values for the 11 knees with valgus deformity were 105° (range, 100–118°) and 89.7° (range, 87–94°), respectively.

3.3. Complications and revision procedures

The only intra-operative complication was a secondary tibial fracture line, which occurred in 4 patients but had no influence on the final outcome.

A single patient (#24) experienced a severe post-operative complication. This 40-year-old male with morbid obesity (BMI, 49) and a history of three surgical procedures on the same knee in childhood to treat Blount disease had major functional impairment, marked knee stiffness (flexion range, 60° with 15° of fixed flexion deformity), and a severe EKD (TMA, 69°). TKA with opening-wedge valgus TO was performed. Extensive skin necrosis developed and was managed by a medial gastrocnemius flap. However, the site became infected, requiring implant removal followed by knee fusion. Despite this severe complication and the permanent loss of knee mobility, a substantial clinical improvement was obtained (IKS score, 50 before and 126 after surgery).

Six other post-operative complications were recorded: deep vein thrombosis in 2 cases, haematoma in 2 cases including 1 that requiring drainage, extensor hallucis deficiency that resolved within 1 year, and a 15° extension lag that persisted at last follow-up (patient #5). No patient experienced secondary displacement,

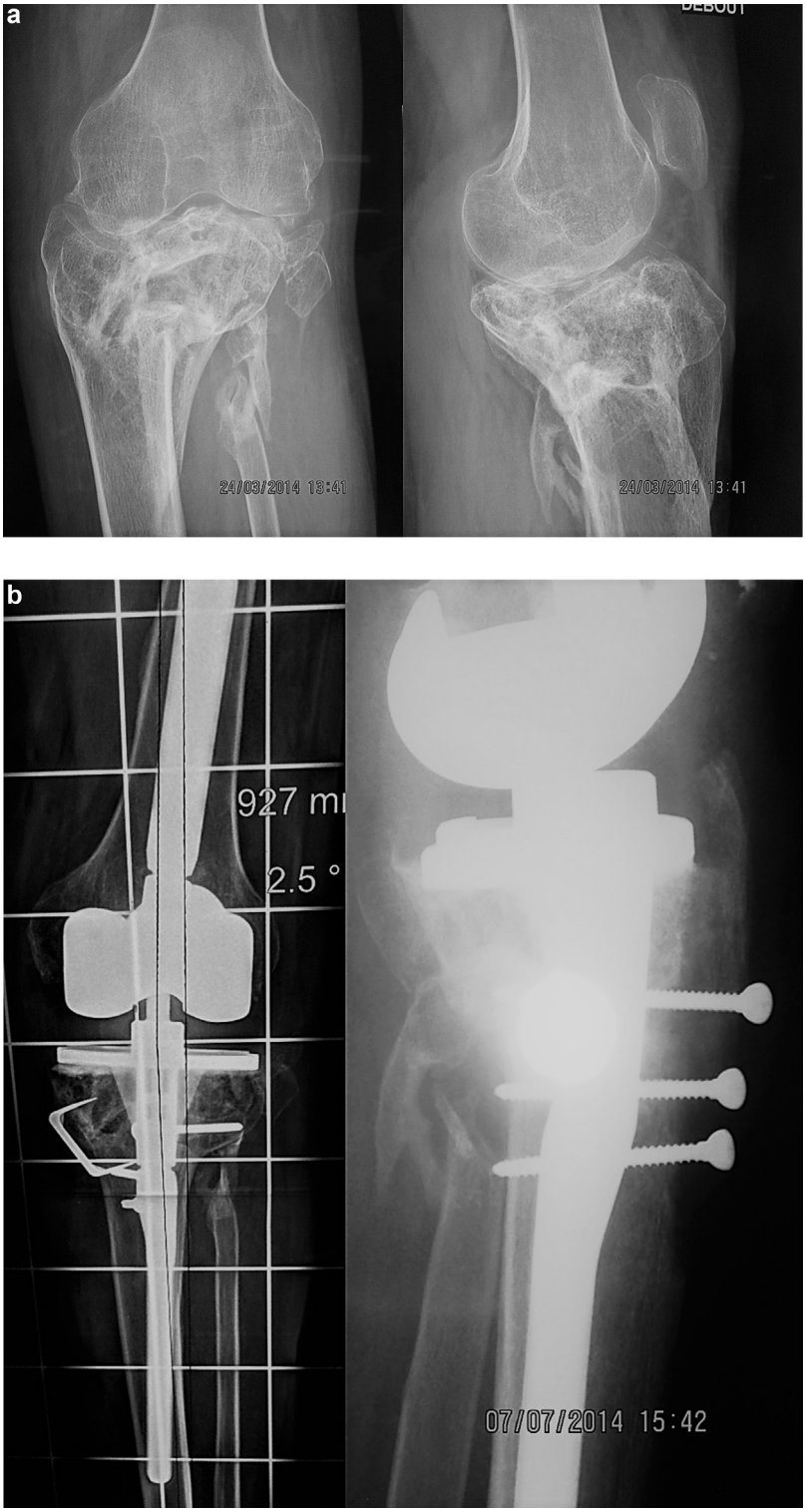

Fig. 4. a: knee #26, pre-operative antero-posterior and lateral radiographs in a 29-year-old male who had post-traumatic mal-union resulting in major tibial translation, with severe functional impairment and only 5° of knee flexion; b: good clinical outcome 3 years after posterior-stabilised extended cam total knee arthroplasty with release of the joint; 85° of flexion, IKS score 170.

Table 2
Type of procedure and pre- and post-operative data in the study population.

Case	Technique	Fixation	Constraint	Year of surgery	HKA pre-op.	HKA post-op.	TMA pre-op.	FMA pre-op.(°)	TMA post-op.
1	Ant CWO	Screw	PS stem	1995	182	181	88°	92°	91
2	Ant OWO	Staple	PS stem	1997	159	179	77°	91	89
3	Ant OWO	Plate	PS stem	1999	159	179	67°	92	90
4	Ant OWO	Plate	PS stem	1999	158	181	78°	91	90°
5	Med CWO	None	PS stem	1999	210	184	118°	92	94°°
6	Ant OWO	Plate	PS stem	2000	158	179	75°	86	89°
7	Ant OWO	None	PS stem	2000	150	181	79°	86	90°
8	Ant OWO	None	PS stem	2001	158	179	75°	91	89°
9	Ant OWO	Staple	PS stem	2002	166	178	77°	92	89°
10	Med and post CWO	Staple	CCK	2003	192	175	100°	82	88°
11	Med CWO	Staple	PS stem	2006	196	182	102°	91	91°
12	Ant OWO	Staple	PS stem	2007	158	178	79°	91	89°
13	Med CWO	Staple	PS stem	2007	197	182	101°	92	91°
14	Med CWO	Staple	PS stem	2009	198	183	104°	92	94°
15	Ant OWO	None	PS stem	2008	150	183	68°	92	92°
16	Med CWO	Staple	PS stem	2008	195	178	101°	92	88°
17	Ant OWO	Staple	PS stem	2008	166	181	68°	91	91°
18	Med CWO	Staple	PS stem	2010	210	182	112°	92	90°
19	Med CWO	Staple	PS stem	2010	191	181	101	90	90°
20	Med CWO	Staples	PS stem	2011	191	178	101°	88	89°
21	Ant OWO	Plate	PS stem	2011	165	175	79°	91	87°
22	Med CWO	Staples	PS stem	2011	190	171	101°	92	90°
23	Ant OWO	None	PS stem	2011	161	177	70°	90	87°
24	Ant OWO	Plate	CCK	2012	155	179	69°	93	88°
25	Med CWO	Staples	LPS stem	2014	193	179	102°	91	89°
26	Trans.	Staples	CCK	2014	186	182	96°	91	89°

Case	ROM pre-op.	ROM post-op	IKS pre-op.	IKS post-op.	Complications	Revision	Year of last FU	FU, y	
1	110°	100°	70	178	None	No	2001	7	Died in 2002
2	110°	115°	45	175	Deep vein thrombosis	No	2015	18	Died in 2016
3	120°	120°	78	180	None	No	2013	14	
4	90°	100°	68	130	None	No	2000	1	Died in 2000
5	90°	110°	33	147	Secondary fracture line	No	2010	11	Died in 2011
6	90°	100°	61	145	None	No	2015	15	
7	100°	110°	88	180	None	No	2015	15	
8	120°	120°	79	179	Haematoma	Drainage	2015	14	
9	110°	120°	77	179	None	No	2016	13	
10	110°	120°	94	184	None	No	2017	14	
11	115°	120°	78	180	None	No	2017	11	
12	90°	90°	75	168	None	No	2012	5	Died in 2015
13	120°	120°	72	150	None	No	2016	9	Died in 2016
14	110°	115°	65	155	None	No	2016	7	Died in 2016
15	100°	110°	55	183	None	No	2017	9	
16	120°	120°	54	155	None	No	2016	8	
17	120°	130°	82	178	None	No	2009	8	
18	100°	100°	68	180	None	No	2017	7	
19	100°	120°	85	180	None	No	2018	8	
20	120°	120°	70	175	None	Removal of a staple	2017	6	
21	100°	110°	104	190	None	No	2017	6	
22	120°	120°	89	189	None	No	2016	5	
23	105°	110°	73	185	Haematoma, secondary fracture line	No	2017	6	
24	60°	0°	50	126	Necrosis and infection	Fusion	2018	6	
25	120°	125°	80	173	15° extension lag secondary fracture line	No	2018	4	
26	5°	85°	29	170	Secondary fracture line	No	2017	3	

HKA: hip-knee-ankle angle; TMA: tibial mechanical angle; FMA: femoral mechanical angle; ROM: range of motion; IKS: International Knee Score; FU: follow-up; ant: anterior; post: posterior; med: medial; CWO: closing-wedge osteotomy; OWO: opening-wedge osteotomy; trans: translation; PS: posterior-stabilised; CCK: Constrained Condylar Knee (posterior-stabilised extended cam); Pre-op: Pre operatively; Post-op: operatively.

loosening, or non-union. In 1 patient, the staples protruded under the skin and were therefore removed.

4. Discussion

4.1. Results

The results confirm the working hypothesis. The mean flexion range of 107° after 1S-TKA-TO was more limited than in case-series studies of patients with usual forms of knee osteoarthritis but was comparable to values in patients with marked EKDs and post-traumatic osteoarthritis [9]. The smaller pre-operative flexion range (mean, 98°) compared to studies of standard TKA procedures is worth noting. Flexion range was particularly limited in the subgroup of 5 patients with post-traumatic EKD (mean, 77°), in whom the mean flexion gain was 28°, versus 9° in the overall population.

The good overall alignment (HKA and TMA values) after surgery may be related to the use of a long-stemmed implant that necessarily produced alignment on the reaming guide then on the stem after the osteotomy.

4.2. Comparison with earlier data

4.2.1. Operative technique

An uncemented long stem was used on the side of the osteotomy in 25 knees in our study (the exception being knee #1). The TO

was consistently performed before implantation of the tibial component. Several other techniques have been described. Lerat et al. [10] used a tibial implant with either a short stem or anchoring pegs, which they inserted before performing the TO under the tibial implant, during the same stage. The clinical outcomes were good in 8 patients managed by TO reversal, although 1 patient required grafting to treat non-union and the mean time to healing was 5 months [10]. Vielpeau et al. [11] described TO via a lateral approach after eversion of the anterior tibial tuberosity. Fixation was ensured by an intramedullary extension rod. The clinical outcomes were good, despite early construct disassembly in 1 of the 14 patients. The authors stated that this technique should be reserved for EKDs greater than 8°.

4.2.2. Other treatment options for extra-articular knee deformities (EKDs)

Most authors use cuts at a 90° angle combined with soft-tissue release on the concave side [12,13]. It has been suggested that this technique is always feasible [14]. In some cases, however, an osteotomy must be performed, either before or concomitantly with TKA (Figs. 3 and 4). Release of the concave side is often feasible but has limitations that vary with the site and severity of the deformity [1]. Rather than overall lower limb malalignment (as assessed by the HKA), emphasis should be put on the tibial deformities (TMA). There is general agreement that release is not appropriate when the TMA is below 80° or above 100°.

4.2.3. Comparisons with the literature

The outcomes in our study cannot be readily compared to those obtained using hinged implants or TKA with extensive release, as few studies report long-term TKA outcomes in patients with severe EKDs. In addition, the available short-term studies provide little information on post-operative laxity [15].

Similarly, although many studies have investigated the outcomes of TKA performed after TO, none focused exclusively on patients with severe EKDs in whom TKA was performed as the second stage. Nevertheless, primary osteotomy seems reasonable in patients younger than 65 years of age, as it may substantially delay the need for TKA. When TKA is necessary due to major functional impairment with involvement of all three knee compartments, multi-stage surgery with primary osteotomy, a waiting period until healing is achieved, removal of the fixation material if needed, and finally TKA requires considerable time and is often poorly accepted by patients [6].

4.2.4. Complications

The occurrence in one of our patients of a severe complication that required joint fusion surgery illustrates the risks potentially associated with combined TKA and osteotomy. Revision surgery with implant exchange was not required in any of the other patients during the mean follow-up of 9 years. More specifically, no patient experienced treatment failure due to residual laxity.

5. Conclusion

1S-TO-TKA is a satisfactory option in patients with advanced knee osteoarthritis and severe EKD (overall deformity usually > 20° and intra-osseous deformity ≥ 10°). This procedure avoids the laxity on the convex side seen when a 90° tibial cut is performed at the site of an intra-osseous deformity.

The use of a semi-constrained long-stemmed knee prosthesis ensures proper tibial alignment, bone healing within a reasonable timeframe, and satisfactory clinical outcomes. 1S-TKA-TO is only rarely necessary, however, and intra-articular correction of the deformity by release of the concave side remains the most widely indicated option. The post-operative morbidity associated with 1S-TKA-TO is acceptable given the clinical and radiological outcomes obtained. Nevertheless, early osteotomy remains the best treatment of EKDs, as it prevents or delays the development of osteoarthritis.

Disclosure of interest

YC: royalties from Biomet.
ESA: royalties from Symbios.
JLR: consultant for Fournitures Hospitalières.
AW: designer of Amplitude and De Dienne.
HPM: royalties from Euros.
FK declares that he has no competing interest.

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None.

Contributions

YC: performed the surgical procedures, provided patient follow-up, and drafted the manuscript.
ESA: performed the statistical analysis and provided patient follow-up.
FK: provided patient follow-up and created the tables.
JLR: provided patient follow-up.
AW: provided patient follow-up.
HPM: head of the orthopaedics department of the Pitié-Salpêtrière university hospital.

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