Computer-assisted surgery as indication of choice: total knee arthroplasty in case of retained hardware or extra-articular deformity

Domenico Tigani · Gilberto Masetti · Giacomo Sabbioni · Rida Ben Ayad ·
Mattia Filanti · Matteo Fosco

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Abstract

Purpose The use of traditional cutting guides during knee arthroplasty in some cases could be extremely difficult, if not impossible, because of angular deformities, IM sclerosis, long-stemmed hip implants, or hardware within the femoral canal that cannot be removed. In these difficult cases navigation-assisted knee arthroplasty should be considered as an effective and appealing option.

Methods We present 14 cases in which ideal mechanical and prosthetic alignment was achieved with different image-free, computer-assisted navigation systems, because of an extra-articular deformity (group A, nine patients) or because of a retained implant or hardware (group B, five patients).

Results After a mean follow-up of 28 months (range 12–53 months), the average knee score increased overall from a mean of 33 points (range 12–63) to 78 points (range 63–90). The average functional score improved from a mean of 32 points (range 10–65) to 72 points (range 40–90). The post-operative mechanical axis ranged between 3° of varus and 3° of valgus. There was an implant revision in one patient who had a traumatic rupture of medial collateral ligament, which occurred 27 months after the index procedure.

Conclusions Based on our results we think that the navigation-assisted technique provides an alternative approach to the traditional instrumentation for treating these difficult patients in an effective and less invasive manner.

Introduction

Component alignment is considered a crucial step for long-term survival of a total knee arthroplasty (TKA). To achieve this goal standard mechanical instrumentation and computer assisted surgery (CAS) have been developed [1, 2].

Traditional cutting guides rely on intramedullary (IM) femoral instruments and either IM or extramedullary (EM) tibial instruments to obtain proper axial alignment [3]. Although there is constant refinement in manual instrumentation systems to improve the accuracy of implant alignment, errors continue to occur [4], especially in cases of deformity [5] or when extramedullary or short intramedullary femoral guides are used [3].

CAS is a new technology that has been developed to overcome some limitations of standard mechanical instrumentation. Despite a number of studies [6, 7] which have suggested that there is an improved alignment when this technology is used, a great debate still exists. Some surgeons have not reported these advantages [8, 9] whereas others have found difficulties in demonstrating improvement in clinical results when CAS is used [10]. Finally, some authors observed that even if a large variation in coronal plane alignment exists, revision and loosening rates can be extremely low [11, 12]; this challenges the premise of the advocates of CAS in total knee arthroplasty, who assert that well-aligned total knee arthroplasties (TKAs) have better survival than those which are not. In spite of these controversies, in patients with knee osteoarthritis associated with pre-existing

D. Tigani
Department of Orthopaedic Surgery,
Santa Maria alle Scotte Hospital,
Siena, Italy

G. Masetti
Department of Orthopaedic Surgery, Hospital of Vignola,
Modena, Italy

G. Sabbioni · R. Ben Ayad · M. Filanti · M. Fosco (✉)
First Ward of Orthopaedic, Rizzoli Orthopaedic Institute,
Bologna, Italy
e-mail: matteofosco27@gmail.com

femoral or tibial extra-articular deformity, or when retained hardware that cannot be removed are present, navigation should be considered as an effective and appealing option. Alternatively the use of extramedullary instrumentation or short intramedullary guides have been recommended but in these cases there are a high percentage of suboptimal results [13, 14]. There are few reports in the literature that have addressed the topic of computer-assisted navigation for TKA in cases of extra-articular deformity. Bottros et al. [15] illustrate a case series of nine computer-assisted TKA in which the postoperative mechanical axis deviated medially by a mean of $1.38^\circ \pm 0.98^\circ$ (range 0.28 – 2.58°) in spite of a great pre-operative extra-articular deformity. They also achieved a significant improvement in postoperative Knee Society scores. Klein et al. [16] reported on five patients, with restoration of an almost normal mechanical axes of the tibia and femur in all patients. In a retrospective series, Fehring et al. [17] collected ten patients with extra-articular femoral deformities who underwent TKA from three institutions; they were able to achieve good mechanical axes in nine of the ten cases.

We present 14 cases in which ideal mechanical and prosthetic alignment was achieved with different image-free, computer-assisted navigation systems.

Materials and methods

From March 2004 to August 2009, at first ward of the Rizzoli Orthopedic Institute in Bologna the senior author (DT) performed 197 primary total knee arthroplasties using CAS. From these were identified all those patients where femoral IM instrumentation was not possible, owing to severe post-traumatic femoral deformity or as a result of retained hardware

that would be difficult or inadvisable to remove. The inclusion criteria were that the angular deformity should involve the femoral or tibial shaft or distal metaphysis without involving the articular surface of the knee joint or any hardware closer than 22 cm from the articular surface.

Fourteen patients were identified and divided into two groups according to the characteristics of the pre-operative data. In group A were patients affected by an extra-articular deformity, whereas in group B the cases were those with a retained implant or hardware.

The data for this investigation were collected and analysed in compliance with the procedures and policies set forth by the Helsinki Declaration, and all patients gave their informed consent to surgery.

Group A consisted of nine patients. There were eight women and one man; the average age was 61 years (range 36–77 years) at the time of the operation. The deformity followed a fracture in five cases, three on the femur and two on the tibia, whereas in one patient it was secondary to a supracondylar femoral osteotomy with a history of poliomyelitis involving the lower limbs (Fig. 1); in another case the deformity was both in femur (10° of valgus) and tibia (15° of valgus), due to sequelae of vitamin D-resistant rickets. The last two patients had post-traumatic femoral deformities with an ipsilateral femoral hip stem. The angulation of the deformities are reported in Table 1. The location of the deformity in the femur was situated from 1.8–18.7 cm (mean 9.1 cm) from the condylar surface. Three patients had tibial deformities (one patient together with femur deformity) situated 1.5 cm, 9.4 cm, and 12.6 cm from the tibial plateau. Two patients had combined femoral deformities in both coronal and sagittal planes.

In group B there were five patients (three women and two men). The average age of patients at the time of surgery was

Fig. 1 A 77-year-old woman with 24° varus femoral deformity secondary to a supracondylar osteotomy with a history of poliomyelitis involving the lower limbs. **a** A knee prosthesis had been implanted maintaining an acceptable mechanical axis. **b** Although there was a co-existent 15° femoral recurvatum deformity, a rotating hinged prosthesis was implanted obtaining good component positioning

Table 1 Patients radiological data

Group	ID patient	Notes	Deformity (<i>F</i> femur, <i>T</i> tibia)	Distance ^a	Pre-op HKA (-valgus)	Post-op HKA (-valgus)	FFC	FTC	LFC	LTC
A	1		F (10°varus)	5.2 cm	15	−2	98	90	10	87
	2		F (10°varus, 14°recurvatum)	18.7 cm	11	−1	96	91	6	86
	3		F (12°varus)	14.3 cm	9	0	99	91	9	85
	4		T (17° varus)	9.4 cm	6	−1	97	90	7	90
	5		T (20°valgus)	12.6 cm	3	−2	96	88	4	87
	6	Femur, Tibia deformity	F (10°valgus), T (15°valgus)	1.8 cm	−17	−1	95	90	11	87
	7	Polio sequelae	F (24°varus, 15° recurvatum)	8.4 cm	2	−3	95	92	13	92
	8	Deformity & hip prosthesis	F (24°varus)	7.6-cm deformity 22-cm prosthesis	19	3	99	90	19	87
	9	Deformity & hip prosthesis	F (13°varus)	4-cm deformity 27-cm prosthesis	15	−1	90	91	11	93
B	10	Blade-plate		3.3 cm	−10	−1	100	85	9	86
	11	Buttress plate		16 cm	3	−1	97	90	9	86
	12	Hip prosthesis		17 cm	−26	−1	84	90	7	86
	13	Hip prosthesis		12.4 cm	−14	−1	96	90	7	85
	14	Hip prosthesis		8.3 cm	−7	−3	94	87	9	88

HKA hip-knee angle (mechanical axis), FFC frontal femoral component angle, FTC frontal tibial component angle, LFC lateral femoral component angle, LTC lateral tibial component angle

^a Distance of deformity/tip of stem prosthesis from condylar line

67 years (range 59–76 years). Three of these patients had prior ipsilateral complicated primary or revised long-stem hip arthroplasty, where the apex was situated at 8.3 cm, 12.4 cm and 17 cm from the condylar surface, respectively. The last two patients had been previously submitted to reduction and rigid internal fixation of the femur, with a blade plate in one case (Fig. 2) and a buttress plate in the other one, respectively, 30 years and two years before. The location of the hardware or intramedullary implants from previous surgeries in all cases precluded the use of a standard (22 mm) femoral intramedullary rod [11].

Surgical data

Knee arthroplasty was carried out through a medial parapatellar arthrotomy in all patients. The navigation system was used to assist surgeons in making accurate bony cuts, orient the implants, and assess the soft tissue balancing. During the period of study five different image-free infrared devices were used, depending on their availability in the operating room. The OrthoSoft Universal Knee Navigation System (Zimmer, Warsaw, USA) was used to perform eight cases: seven posterior stabilized Nex Gen prostheses (LPS, Zimmer, Warsaw, USA) and one rotating hinged prosthesis (RHK, Zimmer, Warsaw, USA). The remaining six cases were performed using the OrthoPilot Navigation System and Columbus implant (B.

Braun Aesculap, Tuttlingen, Germany) in two cases, PiGalileo Navigation System with TC-PLUS Solution Knee prosthesis (PLUS-Orthopedics, San Diego, USA) in one patient, the Gp System navigation system with Cinetique knee prosthesis (Medacta, Switzerland) in two cases, the Fast Nav Simplified Knee Prosthesis Navigation System with Scorpio knee prosthesis system (Stryker Orthopaedics, Kalamazoo, USA) in the last case. The femoral and tibial trackers were placed outside or inside the skin incision in all cases, and according to the system we employed two 3.2-mm pins or one 5-mm screw, implanted using a drill. A measured resection approach was used independently depending on the type of navigation system employed. In all cases the rotational alignment of the femoral component was guided by one or more of the following landmarks: epicondylar line, Whiteside line or posterior condylar line.

Postoperative assessment

Patients were carefully followed-up through periodic clinical and radiological examinations. Standard radiograms were performed at 30 days postoperatively and at three-months intervals, until 12 months; after that, annual radiological controls were performed. All patients were followed for at least 12 months.

The American Knee Society Score (AKSS) was used to assess clinical results [18]. AKSS is supported by three

Fig. 2 Sequelae of sovracondylar fracture with hardware positioned very far from the joint line (33 mm) and with 10° valgus deviation of the knee (a). Computer-assisted surgery allowed good component positioning with correction of mechanical axis (b)

general categories, depending on whether other joints are involved or medical infirmity is present. The scoring system provides two scores: an objective knee score and a functional score. According to these parameters, an excellent score is over 85, good is between 70 and 84, and fair is between 60 and 69 whereas below 60 is poor. Hospital for Special Surgery (HSS) patellar score was employed to evaluate patello-femoral outcome which consists of both subjective and objective tests [19].

Radiological measurements were performed according to Bthis et al. [20]. On the long-leg X-ray the hip-knee-angle (HKA) or mechanical axis, the frontal femoral component (FFC) angle and the frontal tibial component (FTC) angle were recorded (see Table 1). Determination of the malposition of the knee in the presence of femoral deformity or tibial deformity was performed according to Wolff et al. [14]. The sagittal measurement was performed on lateral radiographs 20×40 cm in size. The lateral femoral component (LFC) angle and the lateral tibial component (LTC) angle were measured. All intra and postoperative complications were recorded.

Results

In this series there were no cases who required conversion from computer-assisted surgery to the conventional technique. In just one case there was rupture of a reference pin during removal; the broken part was left in place without compromising bone integrity. One patient, belonging to group B, reported the traumatic rupture of a medial collateral ligament 27 months from the index procedure (Fig. 3); she underwent revision of the implant with a rotating hinged prosthesis. This patient was not considered in the final results. One other patient underwent revision of the ipsilateral hip prosthesis due to aseptic failure; nevertheless, he didn't complain of any symptoms in knee, showing good alignment of the knee implant. Results of this patient were not considered for functional analysis.

According to the American Knee Society Score general categories, four patients belonged to type A, one to type B and nine to type C category (see Table 2).

After a mean follow-up of 28 months (range 12–53 months), average postoperative AKSS improved significantly. The average objective knee score increased from a mean of 33 points (range 12–63) to 78 points (range 63–90). The average functional score improved from a mean of 32 points (range 10–65) to 72 points (range 40–90). Patellar score also improved from 30 points pre-operatively (range 10–60) to 76 points postoperatively (range 60–85). Range of motion (ROM) improved from an average mean of 68° (range 20–120°) pre-operatively to 81° (range 65–120°) postoperatively.

Pre-operatively, the mean anatomical axis angle ranged between 26° of valgus and 19° of varus angulation; after the index procedure no case exceeded the ideal value of 180° of more than ± 3° (Fig. 2). Angles of positioning of the prosthetic components are given in Table 1.

Discussion

Correct lower limb alignment directly correlates with long-term success in total knee arthroplasty [1, 2, 21]. This is accomplished when the mechanical axis of the lower limb passes through or very near the centre of the knee. To achieve this goal, standard mechanical instrumentation and computer-assisted surgery (CAS) have been developed. In the cases presented in this study, instrumentation of the medullary canal of the femur would have been extremely difficult, if not impossible, because of the presence of angular deformities, IM sclerosis, long-stemmed hip implants, or hardware within the femoral canal. The use of conventional methods for such patients would have required short intramedullary or extramedullary alignment guides on the femur, as well as one-step or staged corrective osteotomy [13],

Fig. 3 A patient with bilateral hip prosthesis and severe valgus of the left knee (**a**), underwent left knee prosthesis (**b**). Although good correction of limb axes and correct positioning of the prosthesis, after repetitive trauma, she experienced medial collateral ligament rupture (**c**)

potentially leading to a less predictable clinical and radiographic outcome [6].

The rationale of the use of computer-assisted navigation systems in such cases is unquestionable because they allow establishment of the mechanical axis irrespective of local bone morphology or deformity and do not need hardware removal.

However, dealing with navigated TKA in the presence of hardware obscuring the femoral canal or femoral and/or tibial bone deformity, some technical aspects must be considered in formulating a treatment plan for the management.

First, the distance between the retained hardware and the articular surface is a topical question to be taken into

Table 2 Patients clinical data

Group	ID patient	Age (years)	Class of disability	Pre-op KSS	Post-op KSS	Pre-op KFS	Post-op KFS	Pre-op patellar score	Post-op patellar score	Notes	Follow-up (months)
A	1	76	C	12	63	10	40	25	80		48
	2	65	C	28	75	25	70	30	70		27
	3	36	A	31	77	30	75	45	85		30
	4	58	B	53	88	50	85	50	85		53
	5	52	A	45	90	50	90	25	77		37
	6	61	C	51	88	55	80	25	75		32
	7	77	A	30	83	35	80	45	85		14
	8	68	C	25	75	25	75	10	60		12
	9	56	C	25	78	20	75	25	70	Reference pin rupture	17
B	10	75	C	18	75	20	50	15	70		24
	11	76	C	28	68	20	\	25	70	Ipsilateral hip revision	24
	12	59	A	31	\	35	\	20	\	Knee revision	16
	13	68	C	63	83	65	80	30	80		48
	14	61	C	30	75	20	65	60	85		16

KSS knee objective score, KFS knee functional score

consideration for the feasibility of the procedure. Normally in the case of long-stemmed ipsilateral hip implants (three cases in our series) there are no problems in regards to implantation of the knee femoral component when CAS is used; in our series the distance of the stem tip was of 8.3 cm, 12.4 cm and 17 cm, respectively. Also particular attention should be allowed in cases of a previous implanted buttress or condylar plates used for the management of distal femur fracture and when hardware removal is problematic or impossible. In this situation it is important to calculate the real distance between the plate or screws and the joint line, because the distal portion of the hardware is usually close to the intercondylar notch. The surgeon should be aware that in addition to the 9–11 mm of usual resection on the distal femur a supplementary distance of at least 12–17 mm of femoral bone, according to the size and type of prosthesis, is necessary for the central box housing of the posterior stabilized prosthesis [22]. If a cruciate-retaining design is used it is possible to be more conservative because the femoral peg's length, situated on both sides of the femoral condyles, usually doesn't exceed 12 mm in length even in larger sizes. In our series the closest hardware was a condylar blade plate, implanted 30 years before, with its blade located just 3.3 cm from the condylar surface (Fig. 2). Another case with a buttress plate used for a periprosthetic hip fracture showed no problem during implantation of a knee prosthesis with CAS; the distal tip of the plate was located 16 cm from the condylar surface.

In case of extra-articular deformity, simultaneous or staged corrective osteotomy and total knee arthroplasty have been advocated to achieve normal alignment of the long bones and better ligament balancing [13]. However, this technique may be associated with substantial complications, including nonunion at the osteotomy site and arthrofibrosis [13]. An alternative to the combined osteotomy/TKA approach is to perform intra-articular bone resection and soft-tissue balancing. This procedure may be appropriate when the insertion of the collateral ligaments of the knee would not be jeopardized by the intra-articular bone resection, as demonstrated previously [14, 23]. The limits of intra-articular correction of an extra-articular deformity have been elucidated by Wang and Wang [23], who have advised that in pre-operative planning if a line perpendicular to the mechanical axis of the femur at the femoral condyles does not pass through the insertions of the collateral ligaments, correction of the extra-articular deformity by intra-articular bone resection at the time of the total knee arthroplasty is indicated. On the basis of this principle, these authors retrospectively reviewed, at an average follow-up of 38 months, 15 patients with extra-articular deformity and found that intra-articular resection without osteotomy was successful for patients with an average of 20° of coronal plane deformity in the tibia and femur.

In our series we treated nine knees with extra-articular deformities by different image-free computer-assisted surgery. The femur was involved in seven cases and its pre-operative deformity ranged from 24° of varus to 10° of valgus in the coronal plane, with deformities of 14° and 15° of recurvatum in the sagittal plane in two cases. Although pre-operative mechanical alignment in our series was between 26° of valgus and 19° of varus angulation, after the index procedure with navigation-assisted TKA we were able to restore the ideal alignment; the results obtained in all cases were within the pre-operatively planned alignment of neutral $\pm 3^\circ$. Moreover, we were able to achieve a considerable improvement in function assessed by KSS (mean postoperative functional score 72 points, range 40–90 points).

Nevertheless this study has several shortcomings. The principal limitation was the lack of a control group in which a standard technique using intra-operative radiographs and EM jigs were used when femoral IM instrumentation was contraindicated. Another restraint included the limited accuracy in measuring angles on plain radiographs according to inherent measurement errors [24]. Finally, another important limitation was the relatively small number of patients treated and the retrospective nature of the study. However, contrary to others reports on the same subject, all cases were consecutively performed at one institution and by the same surgeon (DT). Moreover, our study is one of the largest case series reported until now using computer navigation. In a previous similar series by Mullaji et al. in which 34 patients with angular deformities had been analysed, the majority of patients had excessive coronal bowing of the femoral or tibial shaft, a condition characteristic of the Asian populations [25]. This condition is completely different from an extra-articular deformity in which multiplanar deviations of the axis could be present. Moreover, the same authors performed adjunctive corrective osteotomy in more severe deformities, on the basis that excessive bone resections could compromise the collateral attachments. Nevertheless, in our series we were able to correct to 24° varus deformity in the femur and 20° valgus deformity in the tibia. The only reported postoperative collateral ligament failure was in fact due to a traumatic event; all other cases showed good medial–lateral stability at the end of follow-up.

Computer navigation may be considered as the indication of choice in TKAs for knee arthritis where accurate restoration of limb alignment may be challenging because of a deformed tibia or femur or in the presence of retained hardware. This technique provides an alternative approach to the traditional instrumentation for treating these difficult patients in an effective and less invasive manner.

Conflict of interest The authors declare that they have no conflict of interest.

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