Comparison of functional and radiological outcomes after computer-assisted versus conventional total knee arthroplasty: a matched-control retrospective study

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ABSTRACT

Purpose. To compare the radiological and functional outcomes of patients who underwent either computer-assisted or conventional total knee arthroplasty (TKA).
Methods. Two groups of 50 patients each underwent either computer-assisted or conventional TKA were retrospectively studied. Patients were matched according to body mass index (BMI), gender, and age. Three senior orthopaedic surgeons with comparable experience performed all surgeries, using 3 different prostheses. The surgical approach and peri- and post-operative regimens were the same. The mechanical axis and the tibial and femoral angles were measured using standardised long-leg weight-bearing radiographs. Overall function was assessed using the Short Form-12 (SF-12) and International Knee Society (IKS) scores.
Results. No intra-operative technical difficulties were encountered in either group. The computer-assisted group resulted in more consistent and accurate alignments in both the coronal and sagittal planes and better SF-12 and IKS scores. In obese patients (BMI≥30 kg/m^2), computer-assisted TKA provided better alignment than the conventional technique.
Conclusion. Computer-assisted TKA improves implant positioning, limb alignment, and overall functional outcome. It may be particularly advantageous for obese patients.

Key words: *arthroplasty, replacement, knee; surgery, computer-assisted*

INTRODUCTION

Long-term survival of total knee arthroplasties (TKAs) depends on patient selection, implant design, surgical technique, soft-tissue balancing, and peri-operative care. Mal-positioning/orientation of the prosthesis may result in premature mechanical loosening of components and patellofemoral problems.[1–4] Mal-alignment of >3º of the mechanical axis is associated with accelerated implant wear and poor function.[4,5] Restoration of the mechanical axis during TKA improves long-term survival of the implant.[6–9]

The accuracy of alignment in conventional TKAs depends on the skill of the surgeon and the anatomy of the femur and tibia. Correct location of crucial

alignment landmarks (centres of the femoral head and ankle joint) for determination of the mechanical axis can be difficult to achieve.[10]

Computer-assisted TKA has been developed to improve alignment and implant positioning, to increase accuracy and reproducibility of the operative technique, to enable real-time kinematic analysis and soft-tissue balancing, and to reduce the risk of fat embolism and blood loss by not entering the intramedullary space.[11,12] It is especially advantageous in obese patients or those with severe preoperative mal-alignment, in whom identification of anatomic landmarks and soft-tissue balancing can be particularly difficult.

Computer-assisted TKA provides more accurate alignment in all planes than do conventional techniques.[13–16] Nevertheless, it remains unclear whether it confers better functional outcome and long-term survival. We aimed to compare functional and radiological results in patients who underwent either computer-assisted or conventional TKA, and to assess the role of computer-assisted TKA in obese patients.

MATERIALS AND METHODS

Two groups of 50 patients each underwent either computer-assisted or conventional primary TKA at our hospital between December 2003 and March 2005 were retrospectively reviewed. Patients were matched according to body mass index (BMI), gender, and age. In the computer-assisted (18 men and 32 women) and conventional (17 men and 33 women) groups respectively, the mean patient ages were 69 and 71 years, and the mean BMIs were 30 and 32 kg/m^{2}.

Three senior orthopaedic surgeons with comparable experience performed all surgeries (conventional, 23+22+5; computer-assisted, 21+25+4), with a goal to achieve a neutral coronal alignment—a 0° mechanical axis and a 3° posterior slope on the tibia. The surgical approach (a standard medial parapatellar incision and arthrotomy) and peri- and post-operative regimens (a 24-hour course of intravenous antibiotics and deep vein thrombosis prophylaxis) were the same.

For computer-assisted TKA, a proximal tibial and a distal femoral reference array each with 3 reflector spheres were inserted via 2 Schantz pins. For some patients, the incision was extended or a separate mini-incision made to insert the arrays. The mechanical axis and the severity of the deformity were visualised using a 'morphing' algorithm to create a virtual image on the computer display of the non–radiograph-based navigation system (Ci System; Depuy, Leeds, UK, Fig. 1). The bone cuts were navigated (except for the patella) and the size, orientation, and alignment of the total condylar prosthesis (PFC Sigma, Depuy, Johnson and Johnson, Leeds, UK) were assigned by the computer algorithm. Fine-tuning and alteration was allowed at any stage as deemed appropriate by the surgeon. Pre-osteotomy and post-implantation alignment measurements were recorded.

For conventional TKA, standard intramedullary and extramedullary guides were used to align the femoral and tibial components, respectively. Most patients had the Scorpio total knee prosthesis (Stryker Howmedica), and the rest received the Natural-knee prosthesis (Zimmer).

Data for blood transfusion were not collected. Physiotherapy was commenced on the day after the operation, and patients were allowed to weight bear as tolerated. Patients were followed up at 6 weeks, 3 months, 6 months, and yearly thereafter. Overall function was assessed using the Short Form-12 (SF-12) and the International Knee Society (IKS) scores. The SF-12 is a multidimensional generic measurement of health-related quality of life, consisting of a mental and a physical component. The IKS score consists of a knee and a function score.

Long-leg weight-bearing radiographs were taken with a graduated grid before and after the operation and at each follow-up. The legs were fully extended and positioned on a custom-made Perspex footrest that enables the tibial tuberosities to face forward and the lateral malleoli to be 30 cm apart.[17] The mechanical axis and coronal alignment of the prosthesis were measured on the anteroposterior radiographs, whereas the tibial and femoral angles in the sagittal plane were measured on the lateral radiographs (Fig. 2). The mechanical axis was determined by the angle between a line connecting the centres of the femoral head and knee and a line connecting the centres of the knee and ankle.

Three independent observers measured the mechanical axis on 3 different occasions. Any major discrepancy was resolved by consensus. The inter- and intra-observer variability was assessed using the intraclass correlation coefficient (ICC), which is a measure of the proportion of the variance attributable to individuals. A coefficient of one indicates perfect agreement. Patient characteristics measured on a continuous scale and limb alignment angles were compared using the non-parametric Mann-Whitney *U* test. Categorical data were analysed using Fisher's exact test. A p value of ≤0.05 was considered statistically significant.
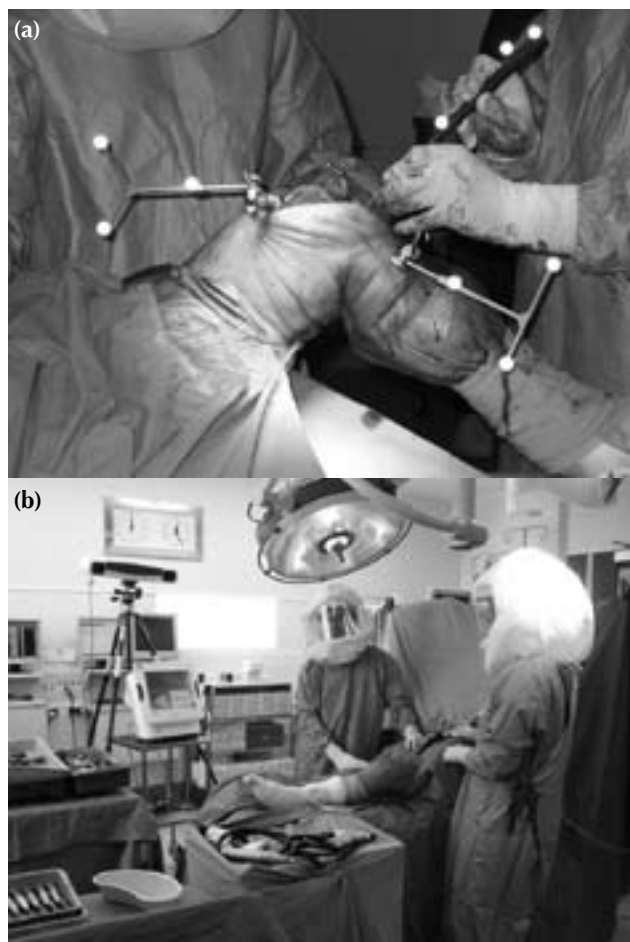
Figure 1   **(a)** The reference frames are attached to the distal femur and proximal tibia. A pointer with calibrated reflector spheres is used to define a series of anatomical landmarks. **(b)** An infra-red camera and computer monitor are set up adjacent to the surgeon.

Figure 2   Long-leg weight-bearing radiographs showing **(a)** the sagittal femoral and tibial angles, and **(b)** the mechanical axis and coronal femoral and tibial angles.

RESULTS

No intra-operative technical difficulties were encountered in either group. In the computer-assisted and conventional groups respectively, the mean operating times were 122 and 108 minutes (p=0.002); the mean peri-operative blood losses (postoperative minus preoperative haemoglobin levels) were 33 and 32 g/l (p=0.8); the mean follow-up periods were 23 and 18 months (p=0.2). The agreements in intra-observer (ICC=0.924±0.43) and inter-observer (ICC=0.949±0.31) variability were good.

The computer-assisted group resulted in more accurate alignments in both the coronal and sagittal planes and better functional outcomes (Table). In the computer-assisted and conventional groups respectively, the mean mechanical axis (coronal)
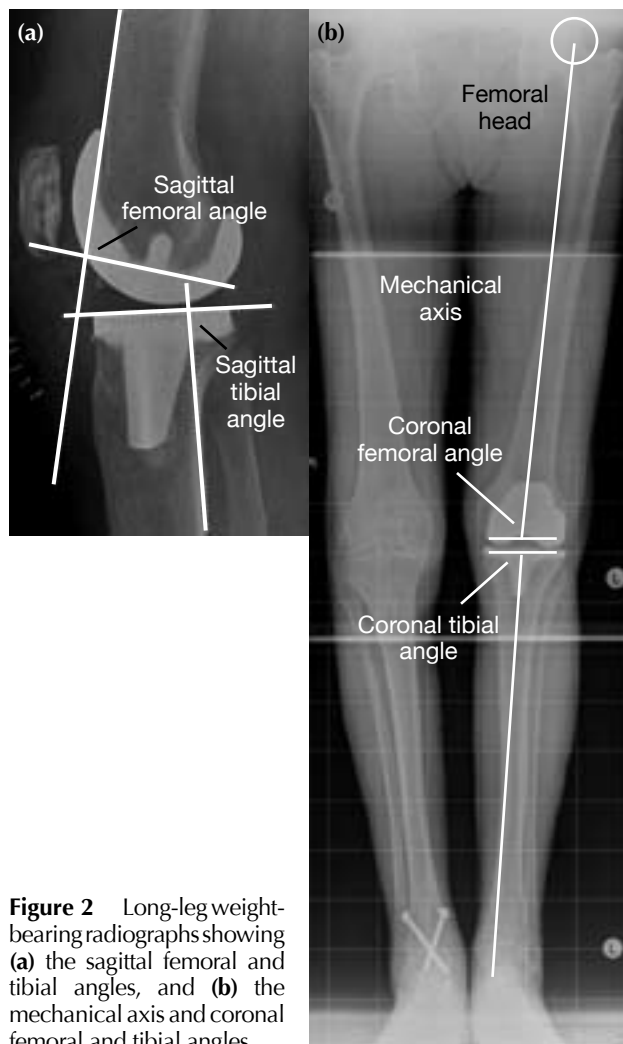
alignments were 0.64° and 0.67° (p=0.86), the numbers of TKAs with a deviation of >5° were 0 and 5 (p=0.002), the numbers of TKAs within 3° of neutral were 39 and 31 (p=0.046), the mean deviations from neutral were 1.9° and 3.1° (p=0.02), the mean tibial axis (coronal) alignments were 90.0° and 89.6° (p=0.41), the mean femoral axis (coronal) alignments were 90.1° and 88.9° (p=0.02), the mean tibial slopes (sagittal alignments) were 89.8° and 85.8° (the optimal being 87°, p<0.001), the mean femoral slopes (sagittal alignments) were 89.9° and 87.8° (p=0.003), the mean SF-12 physical component scores were 41 and 37 (p=0.04), the mean SF-12 mental component scores were 50 and 49 (p=0.7), the mean IKS knee scores were 84 and 77 (p=0.05), the mean IKS function scores were 66 and 58 (p=0.07), and the mean overall IKS scores were 164 and 106 (p=0.002).

To determine whether computer navigation improved implant position in obese patients, the

Table
Characteristics and outcomes in the 2 total knee arthroplasty (TKA) groups*

Characteristics	Computer-assisted TKA (n=50)	Conventional TKA (n=50)	p Value
Age (years)	69.3±8.9 (49–85)	70.9±10 (55–85)	-
Gender			
Male	18	17	-
Female	32	33	-
Body mass index (kg/m²)	30.2±5.8 (22–45)	32.1±5.7 (19–44)	-
Operating time (minutes)	122±27 (80–185)	108±14 (75–135)	0.002
Blood loss (g/l)	32.5	32.0	0.8
Follow-up period (months)	23±6 (12–32)	18±3 (12–29)	0.2
Mechanical axis alignment	0.64°±2.4°	0.67°±4.4°	0.86
No. (%) of TKA with a deviation of >5°	0 (0)	5 (10)	0.002
No. (%) of TKA within 3° of neutral	39 (78)	31 (62)	0.046
Deviation from neutral	1.9°±1.5°	3.1°±3.2°	0.02
Tibial axis alignment	90.0°±2.8°	89.6°±1.7°	0.41
Femoral axis alignment	90.1°±1.7°	88.9°±2.9°	0.02
Tibial slope	89.8°±2.0°	85.8°±3.4°	<0.001
Femoral slope	89.9°±3.5°	87.8°±3.6°	0.003
Short Form-12			
Physical component score	41±9	37±8	0.04
Mental component score	50±11	49±12	0.7
International Knee Society			
Knee score	84±15	77±19	0.05
Function score	66±27	58±15	0.07
Overall	164±67	106±43	0.002

* Data are presented as mean±SD (range), unless otherwise stated

coronal alignments of obese (BMI≥30 kg/m², n=22+36) and non-obese (BMI<30 kg/m², n=28+14) patients were compared. There was no significant difference in the mean deviation from neutral between obese and non-obese patients in the computer-assisted or conventional groups (p=0.23 and p=0.3, respectively). The computer-assisted group achieved significantly more accurate alignments in non-obese patients (1.8°±1.4° vs 3.3°±3.1°, p=0.01), but not in obese patients (2.9°±3.3° vs 2.1°±1.6°, p=0.15). The computer-assisted group had significantly higher percentages of patients within the optimal ±3° of neutral in both the obese (80% vs 64%, p=0.02) and non-obese (84% vs 64%, p=0.002) groups.

DISCUSSION

Failure of TKA is attributed to poor alignment of the mechanical axis. In a study of 3152 TKAs, 41 tibial components were revised for 3 different reasons[18]: varus tibial component alignment of >3°, BMI of >33.7 kg/m², and overall varus mal-alignment.[19] In 421 TKAs, aseptic loosening was more commonly found in patients with varus mal-alignment.[1] The 10-year survival of the prostheses was 90% when the mechanical axis was within 0° to 4° valgus. It

dropped considerably to <73% when there was a mal-alignment of >4° varus or valgus.[6]

With respect to the sagittal tibial alignment, in our study it is unclear why a more neutral slope was achieved with computer guidance despite aiming for a planned angle of 87°. As the referencing of the tibia in the sagittal plane is based on the probe at a point within the posterior aspect of the footprint of the anterior cruciate ligament, variability may be introduced into the system if the reference point is placed more anteriorly. The decrease in tibial slope did not have a negative effect on the range of knee flexion. We recognised that a positive tibial slope may result in a greater degree of tibial flexion in cruciate-retaining knees than those with a more neutral slope. A cruciate-substituting prosthesis with excessive tibial slope may result in a loss of extension. All surgeons were experienced and recognised the necessary requirements to insert either cruciate-retaining or -substituting implants.

In addition to the increased risk of mechanical failure and implant wear, malpositioning of components adversely affects functional outcome by reducing range of movement and stability as a result of poor soft-tissue balancing. Better functional outcomes may be attributed to more accurate implant positioning and alignment, but requires long-term

studies to confirm.

Computer-assisted TKA may be particularly advantageous for obese patients. High body weight increases the stress transferred through the TKA to the surrounding bone,[20] and may be exaggerated in mal-aligned knees, hence leading to premature wear and high failure rates.[21–24]

The limitations of our study were related to its retrospective nature. Although 3 different prostheses were used in the 2 TKA groups, all aimed at maximising function and have excellent track records in the short and intermediate terms.[25–27] It is unlikely that the differences in the 3 prostheses had any major impact on the short-term functional results. Randomised prospective controlled trials are needed to examine the role of computer-assisted surgery for improving alignments and outcomes for obese patients undergoing TKA.

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