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ORIGINAL PAPER

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Total knee arthroplasty implanted with and without kinematic navigation

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Abstract Between September 2000 and February 2002 we inserted 120 total knee arthroplasties. In 60 patients we used the standard technique, and in 60 patients we used the OrthoPilot navigation system. Postoperatively all patients had standing long radiographs of the lower extremity from the hip joint to the ankle. We considered the ideal value of the anatomic lateral tibiofemoral angle (LTFA) to be 174°. In the standard group the mean value of LTFA was 174.9° and in the navigation group 174.3°. A deviation between 0° and 2° from the ideal value was seen in 42 cases in the standard group and in 53 cases in the navigation group. In the standard group 18 cases had a deviation of more than 2.1°, whereas there were only seven cases in the navigation group with a deviation exceeding 2.1°. There were no complications related to the use of the navigation system. The system affords a possibility to place femoral and tibial components precisely with less axis deviation than with the conventional technique.

Résumé Entre septembre 2000 et février 2002 nous avons implanté 120 arthroplasties totales du genou. Chez 60 malades nous avons utilisé la technique standard et chez 60 malades nous avons utilisé le système de navigation OrthoPilot. Après l'opération tous les malades avaient une grande radiographie du membre inférieur, de la hanche à la cheville. Nous avons considéré que la valeur idéale de l'angle tibiofémoral latéral (LTFA) était de 174°. Dans le groupe standard la valeur moyenne de LTFA était 174.9°, dans le groupe navigation de 174.3°. Une déviation entre 0° et 2° de la valeur idéale a été notée dans 42 cas dans le groupe standard et dans 53 cas dans le groupe navigation. Dans le groupe standard 18 cas avaient une déviation de plus que 2.1°, alors qu'il y avait seulement 7 cas dans le groupe navigation avec une déviation dépassant 2.1°. Il n'y avait pas de complications relatives à l'usage du système de navigation. Le système offre une possibilité de placer les composants fémoral et tibial précisément avec moins de déviation de l'axe qu'avec la technique conventionnelle.

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Introduction

Proper component alignment is an essential step in the performance of a total knee replacement. Today it is possible to provide an accurate reproduction of anatomic axes and angles of the affected limb with the use of a navigation system. There are three different types of orthopaedic navigation systems. The purpose of this prospective study is to compare the roentgenographic results in patients who had a total knee arthroplasty (TKA) using the OrthoPilot kinematic CT-free navigation system with those of a matched group of patients who had the same type TKA implanted using the conventional procedure.

Material and methods

We studied 120 patients with a total of 120 TKAs implanted between September 2000 and February 2002. The patients were selected at random as they came for their first evaluation. The indications were primary osteoarthritis in 78 cases and secondary osteoarthritis in 42 cases. Details are given in Table 1.

In 60 cases the prosthesis was implanted using the conventional procedure (group 1), while in another 60 cases it was implanted using the OrthoPilot navigation system (group 2). All operations were performed by two experienced surgeons (RH and MJ). The surgical technique was the same in both groups. The patients were followed for an average of 15 (6–24) months.

Table 1 Details of patients in the two groups

	Group 1	Group 2
Men	10	16
Women	50	44
Mean age and range (years)	68.8 (55.3–81.5)	69.1 (46.2–80.0)
Operated side right/left	20/40	30/30

Table 2 Post-operative value of measured angles (mean and range)

	Group 1	Group 2
Anatomic lateral tibiofemoral angle (LTFA)	174.9° (172—179°)	174.3° (170–179°)
Anatomic lateral distal femoral angle (LDFA)	83.7° (81–87°)	83.5° (76–88°)
Anatomic medial proximal tibial angle (MPTA)	89.2° (86–92°)	88.9° (84–93°)
Anatomic posterior distal femoral angle (PDFA)	88.4° (84–91°)	88.5° (82–93°)
Anatomic posterior proximal tibial angle (PPTA)	88.3° (84–92°)	88.9°(82–91°)

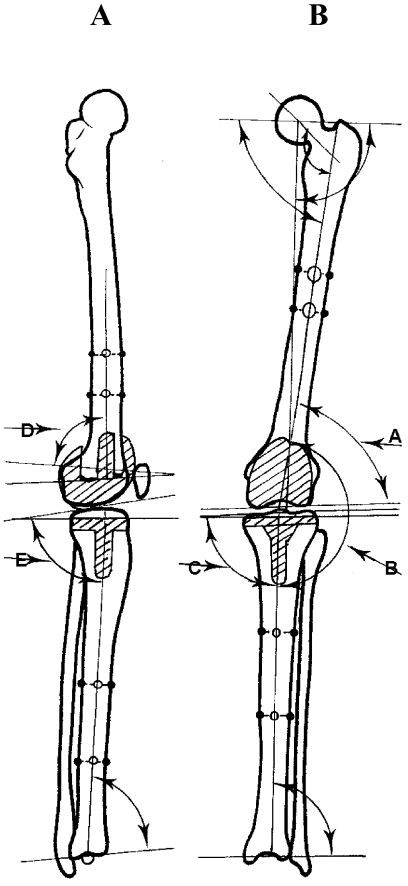

Fig. 1 Diagrams showing the measured angles. *A* anatomic lateral distal femoral angle (LDFA) is formed by intersecting the femoral anatomic axis with the tangent to the femoral condyles in the frontal plane. *B* anatomic lateral tibiofemoral angle (LTFA) is formed by intersecting the femoral anatomic axis with the tibial anatomic axis in the frontal plane. *C* anatomic medial proximal tibial angle (MPTA) is formed by intersecting the tibial anatomic axis with the tangent to the tibial plateau in the frontal plane. *D* anatomic posterior distal femoral angle (PDFA) is formed by intersecting the femoral anatomic axis and Bloomensaat's line (pre-operative) or the tangent to the distal femoral cut (post-operative) in the sagittal plane. *E* anatomic posterior proximal tibial angle (PPTA) is formed by intersecting the tibial anatomic axis and the tangent to the tibial plateau in the sagittal plane

In the patients in group 1 the femoral component was implanted after bone resection performed with the use of an intramedullary-placed femoral rod. The tibial component was inserted after proximal tibia resection with the use of an extramedullary alignment rod.

The OrthoPilot kinematic navigation system was used for patients in group 2. This is a CT-free system based on infrared data transmission between rigid bodies and camera. It needs no special pre-operative planning. The centres of the hip, knee and ankle joints were estimated kinematically. The tibial resection was then made by means of the special tibial cutting block with attached mobile rigid body and controlled by the navigation system. The special femoral cutting block with attached mobile rigid body was used for the distal femoral resection. The block gave the required valgus-varus position and anteversion-retroversion at the same time and was put into a correct position by means of computer navigation. The navigated implantation of a prosthesis lasted 10–15 min longer than the conventional procedure.

Table 3 Post-operative deviation of the anatomic lateral tibiofemoral angle (LTFA) from the ideal value of 174°

Deviation	Group 1 (n=60)	Group 2 (n=60)
None	6	10
0.1–2.0°	36	43
2.1–4.0°	14	3
>4.1°	4	4

Radiographs used for evaluation were long and encompassed the entire lower extremity from the hip joint to the ankle. They were taken with the patient standing, trying to take weight equally on both feet, with the knee in maximal extension and facing the X-ray tube at a distance of 180 cm. For anteroposterior exposure the patient's patellae pointed strictly forward to guard against rotational error. A 100 mA, 0.05 s. exposure was used at 100–115 kV, depending on leg thickness; 105×35.5 cm films were used. Inter-observer variability was insignificant. Angles were measured to the nearest whole degree using the same goniometer throughout the study. Measured angles are shown in Fig. 1.

Results were classified according to the deviation of the anatomic lateral tibiofemoral angle (LTFA) from the "ideal" value of 174° into four groups: no deviation, deviation between 0.1° and 2.0°, deviation between 2.1° and 4.0° and deviation above 4.1°.

The Mann-Whitney U test was used for average comparison and the Bartlett test for standard deviation comparison.

Results

On the pre-operative radiographs there was no statistically significant difference of the measured angles between the groups. In group 2 we measured a mean anatomic LTFA=184.2° (160–195°) while the computer, with use of the kinematic examination, showed a mean LTFA=184.8° (162.4–194.1°). Post-operatively the mean LTFA for patients in group 2 using the computer was 174.7° (170.6–179°).

The post-operative measured values are given in Table 2. Post-operatively the Mann-Whitney U test revealed the only statistically significant difference between the groups, which was in the anatomic posterior proximal tibial angle (PPTA) (slope of the tibial component) (p<0,001). Statistical analysis using the Bartlett

test found a significant difference in the deviation of LTFA from the ideal value (174°) between the two groups (p<0,02) (Table 3).

Discussion

Today it is possible to provide a more accurate reproduction of anatomical axes and angles of the affected limb with use of a navigation system or robot [4]. The advantage of these new systems seems to be useful, especially in complicated conditions [7, 16, 18, 21]. Radiographic assessment of the knee alignment after TKA has been presented in many studies [11]. Patel [12] compared axial alignment on short and long radiographs and concluded that short radiographs are adequate only for routine assessment in a busy out-patient clinic. Limb rotation and knee flexion have a significant effect on the measured anatomical axis [8]. Prakash et al. [14] described new computer software for measurement of limb alignment on scanned radiographs.

Lotke [9] and Townley [19] studied the influence of prosthesis positioning in total knee replacement and found a positive correlation between a good clinical result and a well-positioned prosthesis. Jeffery [5] concluded that accurate coronal alignment after total knee replacement is an important factor in the prevention of loosening. By correlation of laboratory and clinical observations, Bargren [1] found that the incorrect inserted tibial component fails under lower loads than the properly aligned component. Waugh [20] found a significant failure rate in cases with extreme varus or valgus alignments. The failure risk was lowest for knee replacements with an alignment between 2° of varus and 12° of valgus.

There are several radiographic studies on post-operative alignment of total knee replacements. Elloy [3] studied the accuracy of a system using intramedullary alignment: The mean error was 0.67° of valgus deviation from the mechanical axis; the maximum error was 6.68° valgus and 4.62° varus. Ritter [15] assessed the anatomic alignment: Kaplan-Meier survival curves showed significantly worse results in the varus group. Petersen and Engh [13] evaluated short and long radiographs: The mean tibiofemoral angle measured on the short films was 5.8° (range 4° varus to 13° valgus) and on the long films 7.2° (range 3° varus to 16° valgus).

Computer-assisted TKA has been mentioned only rarely [2]. We found only one study comparing radiographic assessment of alignment of the same components implanted with the use of a navigation system and in a standard manner [6]. The authors implanted 40 TKAs with use of the OrthoPilot navigation system and 40 using a classical technique. Better results were seen for the coronal and sagittal orientation of both tibial and femoral components in the navigated group. Mielke compared the results of different types of implants [10].

In contrast to Jenny and Boeri [6], we found a statistically significant difference between the groups in the post-operative value of the anatomic PPTA only. The more precise tibial component positioning in the sagittal plane (slope) was achieved with the use of the navigation system. A difference of less than 2° of the anatomic LTFA from the ideal value of 174° was achieved in nearly 90% of cases in group 2, whereas the navigation system was used in "only" 70% of cases in group 1.

Kinematic navigation affords a possibility to place both femoral and tibial components very precisely without risk of any greater axis deviation from the ideal value. This is especially important for the inexperienced orthopaedic surgeon. The OrthoPilot navigation system is safe. There were no complications related to its use in our study, and post-operative pain and knee function was not affected by the use of this computer-based alignment system.

Stulberg [17] performed 35 TKAs with use of a manual femoral and tibial intramedullary alignment system. In contrast to our study, there were substantial discrepancies between the alignment determinations obtained with use of the conventional radiographic measurements and those obtained with use of the intraoperative computer-assisted measurements. The average discrepancy between the radiographic and OrthoPilot pre-operative measurements of the tibiofemoral angle was 3.5° in Stulberg's study and 0.6° in our study. The average discrepancy between the radiographic and OrthoPilot post-operative measurements was 2.1° in Stulberg's study and 0.4° in our study.

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