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ORIGINAL STUDY

An analysis of intra-operative variation in femorotibial alignment in the coronal plane during computer navigated total knee replacement

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A prospective study was performed to assess the intra-operative variation in femoral and tibial axis alignment during navigated total knee replacement. The intra-operative initial, trial and final mechanical axis alignments were recorded from the navigation system. The mean variation and correlation coefficient were calculated and analysed.

There were 40 patients (24 females, 16 males), with ages ranging from 37 to 89 years. The average initial alignment was 0.03° valgus, trial 0.64º varus and final 0.25° varus. Average deviation from initial to trial angle was 0.97º, from trial to final angle 0.74º and from initial to final angle 1.08º. The correlation coefficient between the initial and trial alignment was 0.25, between trial and final alignment 0.43 and between initial and final alignment 0.09.

This study highlights a significant variation in femorotibial alignment in the coronal plane between the different stages of navigated total knee replacement. Constant vigilance is necessary to monitor the parameters during surgery to achieve a desired final alignment.

Keywords : navigation ; total knee replacement ; mechanical axis ; intra-operative variation.

INTRODUCTION

Computer assisted navigation systems are increasingly used to improve the accuracy of implant positioning in total knee replacement (TKR). Several studies have shown superior overall mechanical axes alignment with the use of navigation for TKR *(2,3,7)*. However, concerns remain in computer navigated surgery regarding potential errors due to inadequate tracker or array fixation, cutting guide block movements, saw blade deviation and variations in implant position during cementing. This could affect the overall femorotibial alignment, and this study aims to highlight the variations in femorotibial alignment during various stages of navigated TKR.

MATERIALS AND METHODS

All consecutive patients who underwent computer navigated TKR from May 2006 to Dec 2007 were included in the study. An informed consent was obtained from all patients. The operation was performed using an anterior midline medial parapatellar approach, using PFC Sigma®, posterior cruciate retaining, fixed bearing total knee replacement (Depuy Orthopaedics Inc, Cork,

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Ireland) or posterior cruciate retaining Scorpio NRG® fixed bearing total knee replacement (Stryker Ltd, Limerick, Ireland). Computer navigation was carried out using imageless Stryker® navigation system II-Cart (precision 3.0) (Stryker Leibinger GmbH & Co.KG, Germany) and tracker pins inserted in femur and tibia. All prostheses were cemented using one-stage high viscosity radioopaque cement with gentamicin (Palacos® R+G, Heraeus, Heraeus Medical GmbH, Hanau, Germany).

The data was collected prospectively during the procedure. Any data sets with inadequate or missing data were excluded from the study. The parameters measured were the initial, trial and final intra-operative hip-knee-

Table I. — Table showing demographics and HKA angles measured at successive stages of navigated total knee replacement

No	Age (years)	Sex	Side	Initial	Trial	Final
1	76	F	R	0.5	-1	-1
2	57	F	R	0.8	-0.9	-0.9
3	60	F	R	0	-1	-1
4	62	F	R	0	0	0.5
5	66	F	R	1	-0.5	0.5
6	68	F	L	-0.5	-2	-2
7	68	F	R	1	1	1
8	70	M	R	0	-0.5	0.5
9	70	M	R	-0.4	-0.5	-0.5
10	70	F	R	-0.5	0	0
11	73	M	L	-0.5	-1.5	-2.5
12	75	F	R	-0.5	-0.5	0
13	77	F	R	0.5	0.5	1.5
14	79	M	L	-0.5	-2	-4
15	80	F	R	0.5	0	-0.5
16	53	F	L	0.5	0.5	3
17	60	M	L	-1	-2.5	-1.5
18	56	M	R	0	0	0
19	75	F	R	0.5	-2.5	-1
20	51	F	R	-1	0	0
21	64	M	L	-0.6	-0.7	-0.8
22	59	M	L	0	-3	-2
23	59	M	R	-1	-1.5	-1
24	71	M	R	0	-1.5	0
25	86	M	L	-1	-1.5	0
26	73	F	L	0.5	1	1
27	61	M	R	3	1.5	0
28	74	F	R	1	0	0
29	89	F	R	1	1	1
30	61	F	R	0.5	0	0
31	82	M	R	-0.5	0	-1
32	78	F	L	0.5	0	2
33	49	M	R	-1	0	-1
34	71	F	R	-0.5	1	4
35	71	M	L	-1	-0.5	-0.5
36	85	F	R	0.5	-2.5	-2.5
37	68	F	L	-3	-2.5	-1.5
38	37	M	R	1.5	-2	1
39	85	F	L	0.5	-1	-1
40	70	F	R	0.5	0	0

[F-Female ; M-Male ; R-Right ; L-Left ; - is varus in degrees ; + is valgus in degrees].

ankle angle (HKA) from the navigation system (table I). The initial axis was derived by addition of the axial alignment angles of the distal femoral and proximal tibial bony cuts made through jigs placed under navigation guidance. The trial alignment was recorded directly after placement of the trial implants, and the final alignment was obtained following cementing the components in place before closure of the wound. Standard soft tissue correction techniques were employed where necessary. The variation between successive alignments was measured with comparison of their correlation coefficients.

RESULTS

There were 40 patients, of which 24 were females and 16 males with ages ranging from 37 to 89 years (average : 68.4). The right knee was replaced in 27 and the left knee in 13 patients. The mean initial HKA angle was 0.03° valgus (range : 3° varus to 3° valgus), trial 0.64º varus (range : 3º varus to 1.5º valgus) and final 0.25° varus (range : 4° varus to 4° valgus) (table I). Average deviation from initial to trial HKA angle was 0.97º, from trial to final angle was 0.74º and from initial to final angle was 1.08º (table II). The correlation coefficient between the initial and the trial alignment was 0.25 ; it was 0.43 between trial and final alignment and 0.09 between initial and final alignment.

DISCUSSION

Computer assisted surgery is increasingly used for total knee replacement due to improved accuracy of component placement and limb alignment *(2,7)*. There are many studies comparing intra-operative axis alignment after navigated total knee replacement and post-operative mechanical axes using long leg radiographs and CT scan *(2,4-6,8)*. This study highlights the potential for intra-operative variation in alignment of mechanical axes of the femur and tibia during various stages of navigated TKR.

The average final alignment of femoral and tibial mechanical axes in our study was 0.25° varus, which was well within the range suggested by Rand and Coventry, who reported 90% 10-year survivorship when the mechanical axes alignment was within 4° varus or valgus *(10)*. However, there was a mean variation of 0.97° between initial and trial axis alignment and 0.74° between trial and final axis alignment.

This variation could be due to potential errors inherent to the use of computer-assisted surgery. Firstly, as with any computer system, 'information in is information out' and hence emphasis should be given for accurately localising the landmarks for

Table II. — Table showing variations in HKA angles (degrees) between successive stages of navigated total knee replacement

No	Initial/Trial	Trial/final	Initial/Final
1	1.5	0	1.5
2	1.7	0	1.7
3	1	0	1
4	0	0.5	0.5
5	1.5	1	0.5
6	1.5	0	1.5
7	0	0	0
8	0.5	1	0.5
9	0.1	0	0.1
10	0.5	0	0.5
11	1	1	2
12	0	0.5	0.5
13	0	1	1
14	1.5	2	3.5
15	0.5	0.5	1
16	0	2.5	2.5
17	1.5	1	0.5
18	0	0	0
19	3	1.5	1.5
20	1	0	1
21	0.1	0.1	0.2
22	3	1	2
23	0.5	0.5	0
24	1.5	1.5	0
25	0.5	1.5	1
26	0.5	0	0.5
27	1.5	1.5	3
28	1	0	1
29	0	0	0
30	0.5	0	0.5
31	0.5	1	0.5
32	0.5	2	1.5
33	1	1	0
34	1.5	3	4.5
35	0.5	0	0.5
36	3	0	3
37	0.5	1	1.5
38	3.5	3	0.5
39	1.5	0	1.5
40	0.5	0	0.5

optimum and desired mechanical axes alignment. Yau *et al* have shown intra and inter-observer errors in localising anatomical landmarks during navigated total knee replacement (*11*).

Secondly, the surgeon is dependent on parameters or values displayed on the navigation system, rather than pre-determined fixed angle jigs for making appropriate cuts. Pearle had suggested that computer assisted surgery is based on quantitative data for decision making instead of surgeon feel and intuition (*9*). Thirdly, proper tracker placement with little disturbance during surgical procedure is crucial, as mild tracker micro-movement may cause significant changes in the axes measured. Other factors include saw blade deviation and variation in position during cementing, which can occur in non-navigated TKR as well. Biant *et al* have reported the movement of pins and saw blade oscillation to be variables out of control of the computer navigation system (*1*).

The correlation coefficient between trial and final axis alignment was 0.43. However the poor correlation coefficient of 0.09 between initial and final axes highlights the need for vigilance with each step of navigated total knee replacement. This may potentially avoid sources of error and improve the overall mechanical axes alignment during navigated TKR.

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