Knee motion after tibial osteotomy for arthrosis

Kinematic analysis of 7 patients

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The in vivo kinematics of the knee in 7 patients with moderate medial gonarthrosis was analyzed before and 6 months after high tibial osteotomy using roentgen stereophotogrammetric analysis. The inclination of the femorotibial helical axis of rotation did not change with knee flexion or after surgery. The femorotibial rotation increased after surgery. No consistent change in patellar position after surgery was found. Patella translated laterally as the knee was flexed with a maximum patellar translation of about 15 mm and rotated internally with a maximum patellar internal rotation of about 15°. There was no significant change in patellar translation or rotation after surgery. There was a good concordance regarding the size of the tibial wedge removed during surgery, calculated from the Hip-Knee-Ankle radiographs and from the roentgen stereophotogrammetric measurements.

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We have analyzed knee kinematics with roentgen stereophotogrammetric analysis (RSA) in patients with moderate medial gonarthrosis before and after high tibial osteotomy.

Patients and methods

7 patients with medial gonarthrosis Stages I–III, free of symptoms from their hips or ankle joints (Ahlbäck 1968), were all operated on with a high tibial closing wedge osteotomy (Coventry 1973). Clinical and radiographic examinations, including measurements of the Hip-Knee-Ankle angle (HKA) from whole-leg weight-bearing radiographs, were performed before and 1 year after surgery (Tjörnstrand et at. 1981). We aimed at an overcorrection of the Hip-Knee-Ankle angle (HKA) to 4° of valgus. Patients' data are presented in Table 1. Before surgery four 0.8 mm tantalum markers were implanted in the distal femur, 4 markers in patella and 8 markers in the proximal tibia using local anesthesia (Figure 1). RSA was conducted before and 6 months after the operation. Before examination of a patient, a

Table 1. Patients' data

A	B	C	D	E	F	G	H	I
1	67	M	L	severe	2	5–100	13	5
2	63	M	L	severe	3	0–120	14	–5
3	60	M	L	moderate	2	5–130	7	–5
4	56	F	L	severe	1	0–125	3	–5
5	53	M	R	severe	1	0–125	6	–10
6	58	F	L	severe	1	0–120	6	–8
7	62	M	L	moderate	2	5–130	5	–1

A Case
B Age
C Sex
D Op. side
E Knee-pain during walking
F Stage of gonarthrosis, according to Ahlbäck (1968)
G Range of motion (degrees)
H HKA angle before surgery (– denotes valgus)
I HKA angle 1 year after surgery (– denotes valgus)

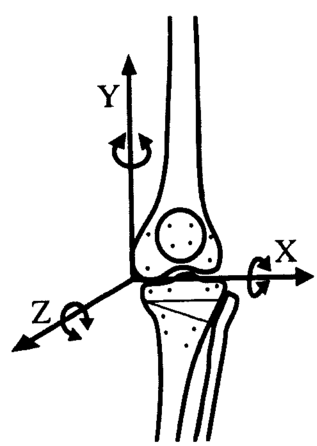

Figure 1. AP-projection of the knee showing the tantalum markers, the calculated tibial wedge, and the coordinate system.

Table 2. The knee flexion in position F1 and F2 (degrees) and the inclination of the femorotibial helical axis of rotation (FT-axis) before and after surgery

	Preop				Postop			
Case	F 1	FT-axis	F2	FT-axis	F 1	FT-axis	F2	FT-axis
1	8.6	93	18.9	90	19.2	101	30.8	101
2	8.7	112	38.8	106	28.7	95	48.6	95
3	14.3	99	41.3	99	10.2	92	32.2	100
4	20.0	124	44.2	111	19.6	108	41.0	109
5	33.2	62	45.1	71	25.4	71	54.9	76
6	19.9	119	45.9	109	25.0	117	42.8	108
7	9.6	99	19.2	108	20.5	111	48.9	107

Table 3. Femorotibial rotation (degrees) around the vertical axis before and 6 months after surgery

Case	Preop range	Postop range
1	1.3	2.4
2	12.9	16.1
3	3.7	9.3
4	9.2	10.0
5	8.9	15.6
6	1.5	9.3
7	3.7	4.4

Table 4. Patellar lateral translation (mm) and internal rotation (degrees) with femorotibial flexion from 0° to F2, before and 6 months after surgery

Case	Translation		Rotation	
	Preop	Postop	Preop	Postop
1	0.1	4.1	2.5	5.4
2	2.0	8.0	4.9	10.4
3	3.6	1.1	0.5	6.2
4	6.8	7.0	9.7	7.0
5	3.9	4.5	2.6	10.2
6	11.3	15.2	12.7	15.8
7	3.5	5.7	8.5	11.0

calibration cage was radiographed with 2 reference plates. The 4 walls of the calibration cage contained tantalum balls in known positions which defined the laboratory coordinate system, and were used to calculate the position of the roentgen foci (Selvik 1989). During the examination the patient stood with full weight bearing on the leg that was scheduled for surgery. The following positions were examined: neutral position with the knee extended, maximum voluntary inward rotation of the body with the knee extended, i.e., external knee rotation, maximum voluntary outward rotation of the body with the knee extended, i.e., internal knee rotation, approximately 15° flexion of the knee measured with a short-arm goniometer, denoted as position F1, and approximately 30° flexion of the knee measured with a short-arm goniometer, denoted as position F2.

The evaluation of the radiographs was performed according to standard RSA procedure (Kärrholm et al. 1984, Lundberg 1989, Selvik 1989). The movements of the segments were calculated in relation to the neutral extended position. The inclination of the femurotibial helical axis, the femorotibial rotation around the vertical axis, the change in patellar position after surgery, the rotation around the vertical axis and the translation of the patella, and the size of the tibial wedge were determined. The size of the tibial wedge was also calculated from the whole leg weight-bearing radiographs as the difference between the pre- and postoperative HKA angles.

Statistics

The Student's *t*-test and linear regression analysis were used for statistical analyses.

Results

The inclination of the femorotibial helical axis of rotation did not change with knee flexion or after surgery (Table 2). The femuorotibial rotation increased after surgery ($P < 0.05$) (Table 3). The patella translated in the lateral direction as the knee was flexed with a maximum patellar translation of about 15 mm and rotated internally with a maximum patellar internal rotation of about 15°. There was no significant change in patellar translation or rotation after surgery (Table 4). There was a good concordance between the size of the tibial wedge calculated from the HKA radiographs and from the RSA measurements (r^2 0.87) (Table 5). In 1 case

Table 5. Tibial wedge angle, assessed by HKA and RSA

Case	HKA	RSA
1	8	7.5
2	19	16.5
3	12	10.1
4	8	–
5	16	11.3
6	14	14.1
7	6	6.0

the tibial wedge could not be calculated from the RSA measurements because all the markers in the distal tibial segment could not be identified. No consistent change in patellar position after surgery was found.

Discussion

Gait analysis as well as biomechanical tests in anatomical specimen knees have been used to study the kinematics of the knee joint (Kettelkamp and Jacobs 1972, Kettelkamp et al. 1976, Chao et al. 1980). RSA offers a 3-dimensional method of investigation which is applicable in vivo and may increase the knowledge of the arthrotic knee joint kinematics before and after high tibial osteotomy. The patients in the present study had an average postoperative overcorrection of leg alignment of 5° which is close to previous recommendations (Tjörnstrand et al. 1981). When leg alignment is changed by high valgus tibial osteotomy, the knee joint load is known to be shifted towards the lateral compartment (Weidenhielm et al. 1992) and an increased lateral translation of the patella can be expected. This might affect the kinematics of the knee joint. However, we found that the inclination of the femorotibial joint axes of rotation were unchanged after surgery. This is probably explained by the fact that the high tibial osteotomy is an extraarticular procedure and that the operated knees were clinically stable. There was a slight increase in the femorotibial rotation after surgery, probably due to decreased knee pain. From a clinical point of view, the kinematics of the femorotibial articulation was not disturbed by a valgus osteotomy. The patella translated laterally during knee flexion and rotated internally towards the center of the body around its vertical axis. After surgery there was no significant change in patellar translation or rotation during knee flexion, indicating that the kinematics of the femoropatellar joint was mainly unaffected by the valgus position of the knee. The patella position depends on the tension of the quadriceps muscle. We did not measure the quadriceps tension and the patients rceeived no instructions to contract or relax their quadriceps muscles during the examinations. This might explain the inconsistent changes in patellar position after surgery. The high conformity between the size of the tibial wedges, calculated from HKA radiographs and those calculated from the RSA measurements indicates that measurements from HKA radiographs are a reliable and accurate way of assessing surgical correction after high tibial osteotomy. This is in agreement with the results presented by Jeffery et al. (1991) that the error is 2° when calculations are made from HKA radiographs.

In conclusion, we found that the kinematics of the knee joint was mainly unaffected by high tibial osteotomy and that measurements of the HKA angle from whole-leg weight-bearing radiographs is a reliable way of assessing surgical correction after high tibial osteotomy.

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