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Knee kinematics in medial arthrosis. Dynamic radiostereometry during active extension and weight-bearing

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Abstract

We studied the kinematics of the knee during weight-bearing active extension in 14 patients with medial osteoarthrosis (OA) and in 10 controls using dynamic radiostereometry. Between 50° and 20° of extension the OA knees showed decreased internal tibial rotation corresponding to less posterior displacement of the lateral femoral flexion facet center. The midpoint between the two tips of the tibial intercondylar eminence occupied a more posterior position within the range of motion analyzed. The observed changes were similar to those previously recorded in chronic tear of the anterior cruciate ligament. Patients with medial arthrosis of the knee joint show a specific and abnormal pattern of joint motion.

Keywords: Knee; Arthritis; Kinematics; Radiostereometry; Weight-bearing

1. Introduction

The relationship between the anatomy of the normal knee and its pattern of motion was studied in cadaveric specimens more than 100 years ago (Iwaki et al., 2000; Pinskerova et al., 2001). During the last two decades there has been an increased interest in this field stimulated by the evolution of new techniques to study the detailed kinematics in vivo. Investigations based on anatomical observations, magnetic resonance imaging (MRI), and dynamic radiostereometry have focused on the behaviour of the living knee (Hill et al., 2000; Kärrholm et al., 2000; Nakagawa et al., 2000). In cases with anterior cruciate ligament rupture, the "normal" tibial internal rotation accompanying flexion is decreased as reflected mostly by a different pattern of anterior–posterior translations of the lateral femoral condyle (Brandsson et al., 2001). In cases with total knee replacement there are more pronounced changes, which, to some extent, relate to the design of the prosthesis (Nilsson et al., 1990, 1991, 1997; Uvehammer et al., 2000a). Such observations have also been documented using dynamic fluoroscopy (Stiehl et al., 1995, 1997; Banks et al., 1997; Dennis et al., 1998; Walker et al., 2002).

Degenerative disease of the knee joint is associated with changes of the gait pattern (Goh et al., 1993; Hilding et al., 1996; Lee et al., 1999; Hurwitz et al., 2000, 2002; Kaufman et al., 2001; Walker et al., 2001; Baliunas et al., 2002), but less is known about the influence of this disease on the detailed pattern of motion between the tibia and the femur. Rupture of the knee ligaments may initiate a degenerative process in the knee, because the femoral condyles do not articulate against the tibia in a normal way (Brandsson et al., 2002). Further, the pattern of knee motion observed in the replaced knee might at least partly originate in motion abnormalities already acquired before the operation due to pathological changes of the ligaments, the joint capsule and the articulating surfaces. Because the location and grade of the degenerative changes on the tibial and femoral condyles may vary depending on the presence of medial or lateral arthrosis, these variations of knee arthrosis may have different effects on the motion of the femoral condyles during knee movement.

We used dynamic radiostereometry to study the kinematics during weight-bearing active extension of knees with medial arthrosis. Our hypothesis was that this disease would increase the varus angulation of the

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tibia with increasing flexion and also induce altered motions of the medial femoral condyle.

2. Methods

2.1. Radiostereometry

Fourteen patients, six men and eight women, (median age, 62 years, range, 50–73) with non-inflammatory, non-traumatic medial arthrosis of the knee and ten controls (median age 26 years, range, 16–41) were studied. The grade of gonarthrosis was classified according to Ahlbäck (1968). Four patients had grade 1, five grade 2, two grade 3, two grade 4 and one patient had grade 5 arthrosis. The patients were recruited on a volunteer basis from the waiting list for knee replacement or tibial osteotomy. At least 3 months before the operation due to gonarthrosis, four to eight spherical tantalum markers (size, 0.8 mm) were inserted into the distal femur and the proximal tibia. Local, general or spinal anesthesia was used according to patient's desire. Adequate marker positioning was confirmed with fluoroscopy. The operation was performed as an outpatient procedure. The control knees were marked during arthroscopy of the contralateral side as a part of a preoperative evaluation before reconstruction of the anterior cruciate ligament.

The dynamic radiostereometric study was performed at least two weeks after the insertion of markers to avoid any discomfort or pain caused by the insertion of markers. In all patients a reference or starting position was recorded. A pair of stereoradiographs were exposed in the supine position at 0° extension and with the knee aligned to the cage (the laboratory coordinate system) according to a standardized method (Nilsson et al., 1997). The supine position was chosen to minimize the effects caused by malalignment (kinematic cross-talk, Piazza et al., 2000). It has been found difficult to obtain standardized alignment between the tibia and femur in relation to the calibration cage when the patient is standing. All motions presented were therefore related to a supine position with the knee in 0° extension/flexion.

During the studies of knee kinematics, the patients and the controls ascended a 16-cm high platform. Before starting the studies of active motion, they did several trial extensions. The foot was placed in a neutral position on the platform and, the patients and controls were asked to flex the examined knee. The amount of flexion achieved varied depending on the length of the lower leg. The patients slowly extended their knee as much as possible in order to keep a constant speed in the course of 3–4 s.

After some trial extensions, the knee motions were recorded using simultaneous and sequential exposures (2–4/s) from two ceiling-mounted tubes with a 90° angle to each other. Two film-exchangers were used to enable recordings on sequentially exposed X-ray films. Each series comprised a mean of 11 pairs of radiographs (range, 5–15 pairs). Reference plates and a calibration examination were used to obtain a sufficient amount of space during knee motion (Kärrholm 1989; Uvehammer et al., 2000a, b).

Tibial rotations and the AP translations of the center of the tibial plateau were recorded using the same method as presented by Nilsson et al. (1991) and Uvehammer et al. (2000a). In these analyses, the femoral markers were used as a fixed reference segment.

In the analysis of femoral translations, the markers in the proximal tibia were used as a fixed reference (Brandson et al., 2001; Kärrholm et al., 2000). Femoral translations were represented by the displacements of the posterior circular center of the medial and lateral femoral condyles (the medial and lateral flexion facet centers). These circular centers were measured, identified, and marked using circular templates on the lateral reference radiograph with the knee in full extension. The distance between these circular centers and the distal edge of each femoral condyle was measured. These distances were used to identify each condylar center on the AP view of the reference position. The tips of the tibial condylar eminence were marked on the AP view of the reference radiograph. The plotting was only done on one pair of stereoradiographs in each individual.

The plotted points were measured as tantalum markers and their three-dimensional coordinates were recorded. Thereafter these points were transformed to the other examinations using the rigid body defined by tantalum markers in the proximal tibia and the distal femur, respectively. In a previous study (Uvehammer et al., 2000b) the repeatability (one standard deviation) between two step-ups performed by one patient was calculated at 1.6–2.3° and from 1.2 to 2.2 mm for rotations and translations, respectively. The Ethics committee of the Göteborg University approved the study.

2.2. Conventional radiographic measurements

The anterior–posterior position of the tibia in relation to the femur was measured on the lateral reference radiograph as previously described by Nilsson et al., (1991). We also measured the flexion angle, and the angle between a centerline through the tibia and femur. All these measurements were done on the reference stereoradiographs in 0° extension/flexion since the position of the knee in relation to the coordinate system and the relative positions of the bones on the 0° exposure (reference position) were crucial for the interpretation of motions related to cardinal axes.