# Contents

2  List of papers  
Abbreviations  
3  Summary  
4  Introduction and background  
  Epidemiology  
  Etiology  
6  Morphology  
7  Biomechanics  
9  Diagnostics  
  Conventional radiography  
  Reliability  
  Validity  
11  Aims of the study  
12  Patients and methods  
19  Statistics  
20  Results  
32  Discussion  
35  Future  
37  Conclusions  
39  Summary in Swedish – svensk sammanfattning  
41  Acknowledgements  
42  References
This thesis is based on the following papers:


This thesis aimed to study osteoarthritis (OA) of the knee and its subgroup with lateral wear (valgus knees). Anatomy, kinematics and kinetics (movements and moments) of the hip and knee joint and the sensitivity and specificity of diagnostic procedures were evaluated. Our hypothesis was that there are biomechanical reasons for development of either lateral or medial OA.

The wear pattern of the tibial plateau and the femoral condyles was delineated in 42 patients. The diagnostic accuracy of standing knee radiographs was validated in 34 and reproducibility and validity of the Ahlbäck classification was studied in 48 patients. The influence of working conditions or gender on the prevalence of uni or bilateral knee OA was evaluated in 990 patients from 2 hospitals (Varberg and Halmstad) operated during 1985–1994 with knee arthroplasty or proximal tibial osteotomy. For each patient, 3 age- and gender-matched controls were found. Studies of the anatomy of the hip and pelvic regions and the motions and moments in the hip and knee in medial and lateral OA were performed. The detailed kinematics of the knee during active extension in lateral OA were recorded using dynamic radiostereometry (RSA).

In both medial and lateral OA the central part of the tibial plateau showed the most pronounced wear (p<0.001), followed by the anterior part in medial OA (p=0.02) and the posterior part in lateral OA (p=0.001).

In medial OA the observed difference between the 2 radiographic methods was small and acceptable (median; p=0.05; 0–0.5 mm). In lateral OA there was no consistent underestimation, but larger scatter (median; p=0.04; -0.1–1.2 mm) suggesting less precise determination.

The repeatability of the Ahlbäck classification for one observer was fair (kappa: medial OA: 0.15–0.65; lateral OA: 0.59–0.76), but between observers it was poor (kappa: 0.1). The validity revealed an acceptable sensitivity in both medial (67–95%) and lateral (43–86%) OA but the specificity was low (medial: 11–67%; lateral: 25–75%).

Farmers (RR: 1.7; p<0.0005) and building workers (RR: 1.4; p=0.047) run increased risk to undergo surgical treatment because of OA of the knee. Unilateral disease was 3.7 times more common among men.

Patients with lateral knee OA had a 14 mm wider pelvis (p=0.001) and those with medial knee OA an 11 mm higher offset (p=0.005). In the gait analysis they showed more outward rotation of the hip (p=0.001) and more inward rotation of the tibia than did patients with medial OA (p=0.001).

In lateral OA, the medial femoral condyle translated 7–8 mm forward with 45° flexion whereas controls translated 4 mm less (p=0.03), without any difference of the lateral femoral condyle.

Conventional radiographs do not give sufficient information for correct grading, especially in lateral OA where the scatter is high. The joint space can often be seen on radiographs despite presence of bone attrition as observed on the preparations. Increased incidence of unilateral disease in men and building workers suggests that this joint disease more commonly originates from previous trauma. Our findings suggest that the occurrence of medial or lateral OA has a biomechanical background originating from pelvis and hip anatomy.
Introduction and background

The word ‘arthrosis’ has been used in Scandinavia to describe radiographic changes of a joint with a narrowing or obliteration of the joint space associated with subchondral sclerosis and presence of osteophytes. Clinical symptoms in terms of pain, swelling, stiffness and instability may vary over time. Occasionally they can be minimal or even absent, but more often moderate to severe with a variable tendency to progression. The term ‘arthritis’ has been used for chronic inflammatory joint disorders such as rheumatoid/psoriatic arthritis and acute joint disorders such as reactive and septic arthritis. I have chosen to use the international term ‘osteoarthritis’. I personally think that arthrosis is more descriptive since it questions the inflammatory origin of the disease.

Osteoarthritis (OA) of the knee has been used in many studies in reference to the medial variety of the disease. Cases with lateral knee OA have often been either excluded or considered the same as those with medial OA. However, it seems reasonable to suppose that because of the differences in both clinical appearance and location, lateral knee OA may have another origin. This thesis aimed to evaluate diagnostic problems related to knee OA and especially the location of the disease. Studies of prevalence, anatomy, biomechanics and factors related to the location of OA were also conducted to evaluate whether or not these variables could indicate etiological differences between the medial and lateral varieties of the disease.

Epidemiology

OA is more common in women. One study shows a much worse functional status prior to total knee arthroplasty in women than in men (Katz et al. 1994). Because not all people have symptoms, the prevalence of radiographic knee OA is higher than those who seek medical attention. The definition of OA is not clear. Different radiographic criteria may be used in addition to other methods. Clinical symptoms may or may not be recorded. In the ages 55–64 years, Bagge et al. (1991) found a prevalence of radiographic knee OA of 41% in the women and 30% in the men (Kellgren-Lawrence grade 2 and larger: definite osteophytes and possible joint narrowing). In the age range 75–79 years, these figures became equal (55%). In the Chingford study, Spector et al. (1991) found symptomatic radiographic knee OA in 2.9% of the women aged 45–65 years. All epidemiological studies have shown a higher prevalence of osteoarthritis among Caucasian than in other ethnic groups, but despite claims that these studies are biased, it seems that the difference is real. In a study comparing a Chinese population in Beijing with a corresponding white population in Framingham with adjustment for age and frequency of squatting (a risk factor for developing knee OA) the prevalence was 9.5% higher among the Chinese women and 7% lower in Chinese men (Zhang et al. 2004).

Etiology

Some authors have suggested positive correlations between knee OA and hypertension, hypercholesterolemia and blood glucose (Hart et al. 1995) as well as free estrogens (Spector et al. 1991), whereas others found no such relationships (Bagge et al. 1991, Samanta et al. 1993). Obesity is a recognized risk factor for development of knee OA in women (Bagge et al. 1991, McAlindon et al. 1992, Hart and Spector 1993, Cicuttini et al. 1997). In men, a high body mass index (BMI) does not seem to have the same influence on the risk of developing knee OA (Felson et al. 1988, 1997b). Even normal BMI (20–24) seems to double the risk of developing knee OA compared to low BMI (17–19) in men (Järnvilson et al. 2005). BMI during the second decade of
life (at 20 years of age) has been found to relate to the severity of OA in women with varus deformity, but not in those with valgus knees (Sharma et al. 2000). High BMI at the age of 40 increases the relative risk (RR) with 9 in women and 4 in men (Sandmark et al. 1999). Obesity has been described as a stronger predictor than knee injury (Odds Ratio (OR): 6 vs. 3) in cases with the bilateral disease, but not in those with unilateral OA (OR: 3.4 vs. 16 in the right knee, and 2.4 vs. 11 in the left knee) (Davis et al. 1989). A stronger association has been found in men than in women between knee injury and OA (McAlindon et al. 1996). Previous tear of the anterior cruciate ligament (ACL) and meniscectomy increase the risk of development of OA (Kannus and Järvinen 1989, Roos et al. 1995, 1998). The mechanisms behind this development are not completely understood. Altered joint kinematics (Jonsson and Kärrholm 1994, Brandsson et al. 2001) absent or deformed menisci, changed contact area (Maquet et al. 1975) and instability cause altered load distribution, increase of peak pressures and joint subluxations, all of which may initiate and/or accelerate the disease.

Some authors have found an association between bone mineral density (BMD) and knee OA (Sowers et al. 1996). High BMD might be associated with increased risk of developing knee OA, at the same time as the risk of progression of a radiographic knee OA may decrease (Zhang et al. 2000). Increased BMD of the spine (Hordon et al. 1993, Hart et al. 1994) and the femur (Hannan et al. 1993) has been found in women with knee OA. High density of the bone is not equal to optimum quality. Ding et al. (2001) studied the mechanical properties of post-mortem bone in tibias with early-stage osteoarthritis. They observed that increase in bone tissue did not compensate for loss of mechanical properties, which indicates deterioration of bone quality in OA. In the Chingford study, women with a previous fracture (mainly in the distal forearm and vertebrae) had reduced risk of developing knee OA independent of BMD status. These results suggest a possible common role of bone turnover and bone repair in the early manifestation of OA (Hart et al. 2002).

One study (Terauchi et al. 1998) has discussed the idea that osteoporosis in the lower extremity results in angular deformity of the knee because of structural changes in the proximal tibia. Low intake of calcium and D-vitamin as well as smoking lowers the quality of the bone. Smokers have lower risk of knee OA (Felson et al. 1989, Bagge et al. 1991, Felson et al. 1997b). It has been suggested that environmental causes in the first year of life may influence the development of OA later in life. Fonnebo (1995) proposed that sunlight exposure prior to a crucial period in skeletal development could be a possible cause. A study from Tromsø, Norway found a higher risk for April compared to November births (1.5/0.4), but only in women, who subsequently developed both hip and knee OA.

Exposure to long lasting and heavy work especially including stair climbing and knee bending (agricultural workers, fireman, post clerks, blue collar workers, building workers) increases the risk of degenerative changes on plain radiographs (Lindberg and Montgomery 1987, Vingård et al. 1991, Coggon et al. 2000, Sandmark et al. 2000). The risk of knee OA is elevated if a person has a job that entails more than 30 minutes of squatting per day (OR: 7), kneeling (OR: 3) or climbing more than 10 flights of stairs per day (OR: 3) (Cooper et al. 1994a). It was also elevated in men, whose jobs required knee bending and at least medium physical demands (OR: 2.2) (Felson et al. 1991). Zhang et al. (2004) found that prolonged squatting in daily life at age 25 was more strongly associated with medial knee OA than with lateral disease in men, but had a similar effect on both knee compartments in women.

Sports, but only highly demanding activities such as weightlifting and soccer at competition level, are positively correlated to OA (Kujala et al. 1994, 1995, Vingård et al. 1995, Spector et al. 1996b). Lane et al. (1986) could not show any certain association between knee OA and long distance running.

In a twin study, Spector et al. (1996a) showed a genetic influence in hand and knee OA in women ranging from 39–65%, independent of known environmental or demographic confounders. In a review the same authors (Cicuttini and Spec-
Lateral osteoarthritis of the knee
Jonas Weidow

6

Lateral osteoarthritis of the knee

Jonas Weidow

996) suggested an association with the HLAA- A1B8 and HLA-B8 and co-inheritance with primary
generalised OA and the gene for type II
pro-collagen (CAOL2A1) on chromosome 12.
They discuss the genetic influence in OA, which
may involve a structural defect (collagen) or alter-
ations in cartilage or bone metabolism for devel-

opment OA.

Recently Lohmander et al. (2005) studied sub-
jects with high (upper tertile) plasma stromelysin
(MMP-3: matrix metalloproteinase 3) at baseline.
They had 4-fold increased risk of developing
progression of joint space narrowing (JSN) after
16 months follow up compared to those with low
(lower tertile) MMP-3.

Anatomical factors such as skeletal and joint
morphology and leg alignment will have influ-
ence on the gait and thereby the moments acting
over the joint and the load on the articulating
cartilage. Varus and valgus alignment at baseline
predicts progression of knee OA (Sharma et al.
2001, Cerejo et al. 2002) as well as knee adduc-
tion moment (Sharma et al. 1998, Miyazaki et
al. 2002).

**Morphology**

Osteoarthritis is a degenerative disease of the
joint where the cartilage thickness is decreased.
In addition, there are often osteophytes as well
as subchondral sclerosis and cysts. Ahlbäck (Ahl-
böck 1968, Ahlbäck and Rydberg 1980) used the
decreased joint width for staging, whereas Kell-
gren and Lawrence focused on the other crite-
ria.

Keyes et al. (1992) showed an anterior and
middle part tibial cartilage lesion in early OA
of the knee. In more advanced disease when the
anterior cruciate ligament was invariably dam-
aged the lesion extended to the posterior margin
of the medial tibial plateau. White et al. (1991)
showed that in cases selected for unicompartment-
mental arthroplasty with intact ACL the degen-
erative changes were located in the anterior part
of the medial compartment. In varus knees with
deficient ACL selected for TKR, Harman et al.
(1998) found maximum wear to be positioned
4 mm more posterior than in OA knees with

intact ACL (48% the distance from the posterior
device compared to 55% in the anterior cruciate
ligament intact varus knee). Lateral plateau wear
was located an average of 1 mm posterior to the
centre of the lateral plateau (40% the distance
from the posterior edge), independent of ante-
orior cruciate ligament integrity.

These observations are in line with studies
where the distribution of bone strength between
the medial and lateral condyles was found to be
dependent on knee alignment (Hvid and Hansen
1985, Hvid 1986). In varus OA knee, maximum
tibial bone strength was recorded in the medial
compartment centrally. Anteriorly, tibial bone
strength was intermediate and the bone was weak-
est posteriorly. In valgus OA knee the correspond-
ing order was posterior, central and anterior in
the lateral compartment. As expected, bone attri-
tion was associated with high strength of the bone
(Hvid and Hansen 1986).

It has been suggested that the relative con-
tribution of the mechanical and constitutional
factors in the pathogenesis of knee OA varies
depending on compartment involved. Obesity
and meniscectomy might be stronger risk factors
for the development of medial tibiofemoral dis-

ease, while Heberden’s nodes and family history
were more closely associated with patellofemoral
OA (Cooper et al. 1994b). In contrast, Cicuttini
et al. (1997) showed a strong correlation (OR: 7)
between arthrosis in the distal interphalangeal
joint and isolated tibiofemoral OA and a positive
correlation between high BMI and all types of
OA, which was further supported by McAlindon
et al. (1996).

**Biomechanics**

The kinematics of the normal knee during dif-
ferent types of activities reflects the anatomy of
the knee joint including multiple factors such as
the configuration of the joint area, the position
and anatomy of the ligaments, the joint capsule
and tendons and muscles acting over the knee
joint. The forces acting over the joint are also
influenced in a complex way by the anatomy of
more proximal and distal parts of the body.

The three major joints of the lower extremity
represent three different kinds of joints. The hip is a “ball-in-socket joint” with 3 degrees of freedom (DOF). The knee joint is a “condylar joint” with essentially 2 DOF. It moves mainly in one plane (flexion/extension) and permits translatory movements in another plane (translation). The ankle joint is closer to a hinge with mainly 1 DOF. In reality these joints allow other types of movements, but these motions are normally small.

The contact areas in the hip joint and ankle joint are comparatively large. Most of the cartilage is in contact during the flexion/extension, abduction/adduction and rotation of the hip joint, as well as in flexion/extension in the ankle joint. In the knee joint the rather small cartilage contact is expanded with the menisci, which act as a shock absorber and transmit the load to a larger area. In normal knees the contact area ranges from about 20 to 12 cm² from extension to flexion, and from 12 cm² to 6 cm² after removal of the menisci (Maquet et al. 1975).

The moments acting over the hip and knee joint are 4–5 times higher than the ground reaction force (i.e. the body weight) during walking (Andriacchi 1994, Vaughan et al. 1999). One reason is that the joint is not in line with the perpendicular axis of the body mass centre. Muscular moments are acting on the joint to stabilize the pelvis and the thigh and shank segments, and the moment arms partly depend on the anatomy of the pelvis, the hip and the HKA-angle (hip-knee-ankle-angle).

The forces are passing through the centre of the ankle joint, which may explain why this joint develops osteoarthritis less frequently. The rather big joint area (10 cm²) and its configuration (hinge joint with small rotations) are other explanations. At the end of the gait cycle (close to toe-off), the force in the joint rises beyond the weight of the body. However, this moment increases more slowly than in the knee during early stance/midstance, after the foot has hit the ground.

Efforts have been made to define the axial lower limb alignment (Weyers et al. 1982, Moreland et al. 1987, Cooke et al. 1989, Hsu et al. 1990, Cooke et al. 1994, 1997). In addition, Cooke et al. (1997) identified differences in knee joint anatomy between medial and lateral OA. In medial OA of the knee (varus) there was abnormal femoral geometry in terms of less valgus inclination, whereas the tibial surface geometry was the same as in the normal knees. In lateral OA (valgus) the situation was reversed with abnormal tibial geometry (lesser plateau varus), but normal femoral geometry. Similar findings have been made by us (unpublished observations).

Anatomical measurements may be used for the calculation of static forces over the joint. Such forces are defined by a specific moment, where all the forces acting over a joint are in equilibrium when the joint does not move. Calculation of forces at one-legged stance is such an example (McLeish and Charnley 1970). Non-invasive recordings of dynamic forces during activity can be obtained by measuring of joint angles and ground reaction forces in gait analysis.

Studies performed in gait laboratories have identified no (Harrington 1983) or small (Weidenhielm et al. 1994) correlation between angular deformity of the knee measured on radiographs and the force distribution in the knee joint. Dynamic measurements have indicated a higher load on the medial side, even though the angle of the knee was more valgus than neutral (Johnson et al. 1980). The adduction moment over the knee joint has been found to be the best single predictor of the medial-lateral ratio of proximal bone mineral content (bone distribution), except for cases with valgus malalignment (Hurwitz et al. 1998). In the valgus knees the medial/lateral distribution of strength was unpredictable. Higher medial strength was occasionally found even with severe valgus malalignment (Hvid and Hansen 1985, 1986). Presence of knee adduction moment during gait has been frequently reported in the literature. Its magnitude in midstance (Weidenhielm et al. 1994) as well as its peak value (Andrews et al. 1996, Baliunas et al. 2002, Hurwitz et al. 2002) seem to positively correlate to the degree of OA.

In addition to varus/valgus malalignment there may also be a rotational malalignment. Men have been observed to have inward tibial torsion (-5°) compared to women (+11° outward rotation) (Yoshioka et al. 1989). Patients with
medial OA have been claimed to have 12° more internal tibial torsion than those without knee OA, and the difference seems to increase in cases with more severe disease (Yagi 1994). According to Takai et al. (1985) lateral OA is associated with 5° more outward tibial torsion than observed in cases with medial OA. Reduced femoral torsion has also been observed in cases with knee OA (Moussa 1994), but without any difference related to the primary location of the disease (Takai et al. 1985).

Different methods have been used to study the kinematics of the knee. At 20° of knee flexion ultrasonic investigations have reported reduced internal tibial rotation of about 3° in early grade 1 OA compared to controls (Nagao et al. 1998). This abnormality was the initial pathological rotational change in osteoarthritis of the knee joint. The external rotation at maximal extension and the rotation of the screw-home movement proportionately decreased with progression of medial compartment osteoarthritis. Iwaki et al. (2000) used magnetic resonance imaging (MRI) to study the kinematics of unloaded cadaver knees without any previous injury or disease. They found that the femur rotated externally with increasing flexion corresponding to a posterior translation of the lateral femoral condyle, whereas the medial condyle showed almost no anterior-posterior translation at all. About 5° of this external femoral rotation occurred from 0° to 10° flexion, thereafter little rotation occurred to at least 45°.

In an in vivo study based on orthogonal fluoroscopic images and MRI-based computer models the medial tibiofemoral contact points remained within the central portion of the tibial plateau in the anterior/posterior direction. Both the medial and lateral tibiofemoral contact points were located on the inner portions of the tibial plateau and femoral condyles. The total translation of the medial tibiofemoral contact point from full extension to 90° flexion was less than 1.5 mm in the anterior/posterior direction, whereas the medial/lateral movement was more than 5 mm. On the lateral side the AP movement was 9 mm with 4 mm in medial/lateral direction (Li et al. 2005). Kärrholm et al. (2000) used dynamic radiostereometry to study knee kinematics during active extension. They could confirm that knee flexion was associated with internal/external tibiofemoral rotations and posterior translation of the lateral femoral condyle. Contrary to the findings in the cadaveric knee, the medial condyle displaced anteriorly with flexion up to 50°. In addition these authors also found that the internal tibial rotation during knee flexion disappeared if the foot was placed in maximum external rotation. These observations were partially confirmed by Hill et al. (2000). Nakagawa et al. (2000) studied the kinematics of the maximally flexed and unloaded knee with MRI. Flexion over 90° was accompanied by 15 mm posterior translation of the lateral femoral condyle corresponding to internal tibial rotation. At 162° the lateral femoral condyle had reached a position posterior to the tibia. This was confirmed in a cadaveric study (McPherson et al. 2005) on 3 specimens, where an internal rotation of approximately 25° was observed at 120° of flexion.

In medial OA, dynamic radiostereometry (Saari et al. 2005a) has shown decreased or absent internal tibial rotation corresponding to less posterior displacement of the lateral femoral condyle, a kinematic abnormality which also has been observed in knees with anterior cruciate ligament rupture (Kärrholm et al. 1988). The centre of the tibia plateau (relative to a fixed femur) had a more posterior position from 50° to 20° of knee flexion, during active extension.

A number of studies have shown that the kinematics of the knee is altered after insertion of a total knee arthroplasty (D’Lima et al. 2000, Uvehammer et al. 2001, Catani et al. 2003, Dennis et al. 2004, Komistek et al. 2004). According to some studies (Uvehammer et al. 2000a, Uvehammer et al. 2000b, Saari et al. 2003), there is a variation between different joint area designs, but so far there is no total knee arthroplasty which has been found to articulate as the normal knees.
Diagnostics

**Conventional radiography**

In an epidemiological study Spector et al. (1993) found that the best predictors of pain caused by knee OA were the presence of osteophytes and the grade of OA according to Kellgren and Lawrence. It has been suggested (Felson et al. 1997a) that a knee should be characterized as having radiographic OA if there are either grade 2–3 osteophytes or moderate to severe joint space narrowing (≥ 2 on a 0-3 scale; Kellgren-Lawrence scale used).

Much effort has been spent on evaluating and optimizing the radiographic procedure and joint positioning to facilitate the diagnosis of knee OA (Wevers et al. 1982, Cooke et al. 1991, Siu et al. 1991, Buckland-Wright 1994, Buckland-Wright et al. 1996, Ravaud et al. 1996, Buckland 1999). In 1968 Ahlbäck described the advantage of performing knee radiography during weight bearing, especially when the patient was asked to walk for some time immediately before examination to prevent the patient from active avoidance of articulation of the most worn and painful parts of the joint. Ahlbäck worked as a radiologist at the Lund University Hospital. In this hospital further measures were taken to improve the detection of cartilage wear, but these were probably never published. A pillow was placed either between the knees to detect medial OA or between the ankles to detect lateral OA. In addition a strap was placed around the ankle or the knee to force the knee joints into varus or valgus for optimum visualization of any joint space narrowing.

The advantage of weight-bearing radiographs was further confirmed in 1970 by Leach et al. Later, Marklund and Myrner (1974) recommended examination in the semiflexed position to ascertain detection of cartilage wear. In 1991 Dacre et al. found no significant difference in joint space size between weight bearing and non-weight bearing healthy women. This finding supported Ahlbäck’s criteria for knee OA in terms of decreased joint width with weight-bearing. Recently, Deep et al. (2003) observed up to 2 mm wider joint space at weight-bearing extension compared with 30° flexion view in healthy subjects. Mazzuca et al. (2002) observed that reduced pain (after resumption of analgesic/nonsteroidal anti-inflammatory drugs after a washout period) increases the joint space narrowing (JSN) on weight-bearing and extended-view anterior-posterior (AP) radiographs, but not in the semiflexed position. They interpreted this finding as the avoidance of extension when pain increased and concluded that longitudinal variations in pain may confound the diagnosis of changes in the apparent thickness of the articular cartilage.

Several attempts have been made to further improve the radiographic diagnosis, mainly by variations of the degree of knee flexion at exposure. Messieh et al. (1990) recommended weight-bearing radiographs at 28°, others 45° or 60° (the so-called weight bearing tunnel view) (Resnick and Vint 1980, Rosenberg et al. 1988, Buckland-Wright et al. 1994). Today weight-bearing examination in the semiflexed position (20°–30°) is commonly used, and has shown high reproducibility (0.1–0.2 mm) (Peterfy et al. 2003).

**Reliability**

In a presentation of the Ahlbäck classification (Ahlbäck and Rydberg 1980) postulated that their staging was not based on cases with lateral OA. Nonetheless, today it is the dominating classification not only for medial, but also for lateral OA in the Nordic countries. The posterior/anterior weight-bearing radiographs of the knee have been shown to be reproducible. According to Boegård et al. (1997) radiographic joint-space narrowing of 3 mm or less should be present to diagnose OA based on comparison with cartilage defects visible on MR-images.

However, the reliability of radiographic diagnosis of lateral OA has been poor (Spector et al. 1993). Measurements of joint space width of cartilage thickness in knees with OA on plain films compared with double contrast macroradiography have revealed a highly significant correlation on the medial side, but not on the lateral side (Buckland-Wright et al. 1995).
Validity

Many studies have observed insensitivity of radiography to detect early articular cartilage loss in knee OA (DeHaven and Collins 1975, Lysholm et al. 1987, Brandt et al. 1991). Comparison with other more sensitive, but less specific methods such as scintigraphy has shown correlation with different radiographic features (McCrae et al. 1992). Increased uptake can be observed if the joint space is reduced by 75% or more (Egund et al. 1988). According to Dieppe et al. (1993) scintigraphy can predict progression of knee OA, even if joint pain and knee radiographic severity (Kellgren-Lawrence grade 3 and greater) is a better predictor (Mazzuca et al. 2005).
Aims of the study

This thesis had two overall aims. The first was to study diagnostic problems and epidemiological aspects of knee OA with special focus on lateral compartment disease. The second aim was to study anatomic, morphologic, kinematic and kinetic changes in patients with lateral or medial knee OA and controls to evaluate any biomechanical reasons for the location of the primary disease.

Study 1
We analyzed the joint area morphology (i.e. the wear of the tibia plateau and the femoral condyles) in medial and lateral OA to map out any specific wear patterns depending on the primary location of the disease. Our hypothesis was that there was more anterior wear in medial knee OA and a more posterior wear in lateral knee OA, reflecting the motions of the femoral condyles during flexion/extension.

Study 2
We assessed the diagnostic accuracy of standing knee radiographs to detect knee OA. Our hypothesis was that standing knee radiographs underestimate the joint width, particularly in lateral knee OA.

Study 3
We evaluated the reproducibility and validity of the Ahlbäck classification of knee OA. Our hypothesis was that the Ahlbäck classification had poor reproducibility and validity.

Study 4
We evaluated whether or not working conditions influenced the prevalence of knee OA requiring surgical treatment and if there was a sex related difference in presence of uni- or bilateral disease, which could reflect work related exposure to trauma. Our hypothesis was that occupations with high physical demands increased the risk of OA requiring surgical treatment and that men with unilateral disease were more common in this group.

Study 5
We evaluated whether or not any differences in anatomy of the hip and pelvic regions could support the theory that there are biomechanical reasons behind evolution of medial and lateral knee OA. Our hypothesis was that an increased risk of combined hip and lateral knee OA could be attributed to coxa valga and reduced lever arm in the hip resulting in increased abductor moment over the knee.

Study 6
We evaluated the motions and moments in the hip and knee in medial and lateral knee OA. Our hypothesis was that not only the kinetics and kinematics of the knee but also of the hip would differ between patients with medial and lateral knee OA and controls.

Study 7
We measured the detailed kinematics of the knee during active extension in lateral OA using dynamic radiostereometry. Our hypothesis was that the lateral femoral condyle would occupy a more posterior position in knees with lateral knee OA.
Patients and methods

Patients

Study 1–3

All patients (63 knees in 62 patients) were operated on at the Department of Orthopaedics, Halmstad Hospital from February 1998 to May 2003.

Study 1

42 knees (median age 73 (53–89) years, 30 women) were included. 32 knees (21 women) had medial (Group 1) and 10 lateral OA (Group 2; 9 women).

Study 2

34 knees were included: 29 patients from study 1 (corresponding to the last consecutive patients in study 1) and a further 5 patients with lateral OA. 22 knees had medial (14 women; median age: 73 (55–83) years; 8 men, 70 (55–89) years) and 12 women lateral OA (75 (59–83) years). The first 13 patients in study 1 were not available because of the later start of this study.

Study 3

33 of the 34 knees from study 2 were included. In a further 15 knees (7 with lateral, 8 with medial OA) only the maximum wear was recorded. In total, there were 48 knees: 30 knees with medial OA (18 women, median age: 73 (55–85) years; 12 men, median age: 71 (59–84) years) and 18 knees with lateral OA (all women, median age 74 (59–86) years).

Study 4

We identified 990 patients operated with knee arthroplasty or proximal tibial osteotomy at two hospitals (Varberg and Halmstad) 1985–1994. For each patient, 3 age- and sex-matched controls were identified. Information from 1970 about socio-economic grouping and work was obtained from the National statistical register (FoB 1970, Statistics, Sweden). In patients at one of the hospitals (Halmstad, n=546), the presence of unilateral or bilateral disease could be recorded in 451 patients based on information in case records and re-evaluation of radiographic examinations (Figure 1).

Study 5

Presence of bilateral knee OA was known in 451 patients from study 4 and were included in this study. Sequence of operations (left/right), presence of unilateral/bilateral and medial/lateral OA were recorded. The presence of OA was defined as joint space narrowing exceeding 50% (Ahlbäck Stage 1 or higher; Ahlbäck 1968). Bilateral OA was defined as the presence of at least Grade 1 OA on both sides. Lateral OA on both sides was only found in women. Therefore, we restricted our study to female sex (n=242), so as not to be biased by anatomical gender differences. Demographic data and grouping of this material is presented in (Table 1) and (Figure 1).

Pelvic radiographs of 14 women admitted during 2000–2001, because of failed femoral neck fracture on the left side, were used as controls to measure hip and pelvis distances and hip angles on the intact side (right side).

Study 6

5 women with lateral (unilateral/bilateral: 9/6) and 5 women with medial (unilateral/bilateral: 4/11; Fisher’s Exact Test: p=0.1) OA of the knee were identified on the waiting list for knee prosthesis surgery. Fifteen healthy women without any history of knee/hip pain or knee/hip trauma acted as controls (Table 10, page 25).

Study 7

Patients with lateral OA on the waiting list for total knee prosthesis surgery were asked to participate. During a period of 18 months, 5
Figure 1. There were 25 women with lateral OA (11 unilateral, 14 bilateral). Further 14 consecutive women operated during 1995–2000 with lateral OA (6 unilateral and 8 bilateral) were included to increase the number of observations. In the primary material we identified further 13 women with medial OA, who also had been operated because of OA of the hip. Further 5 consecutive patients with hip OA and medial OA of the knee from the period 1995–2000 were added to increase sample size resulting in a total of 27 cases to be studied (9 without and 18 with simultaneous hip and knee OA).

Table 1. Demographic data (Study 5)

<table>
<thead>
<tr>
<th></th>
<th>Lateral OA</th>
<th>Medial OA</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>median</td>
<td>(range)</td>
<td>p-value</td>
</tr>
<tr>
<td>Weight</td>
<td>35</td>
<td>72</td>
<td>0.04</td>
</tr>
<tr>
<td>Length</td>
<td>35</td>
<td>162</td>
<td>0.03</td>
</tr>
<tr>
<td>BMI</td>
<td>35</td>
<td>27.5</td>
<td>0.004</td>
</tr>
<tr>
<td>Age</td>
<td>39</td>
<td>74</td>
<td>0.21</td>
</tr>
</tbody>
</table>

*a Medial versus lateral OA. Mann Whitney U test  
*b Controls versus cases. Mann Whitney U test

patients (4 women and 1 man; 70 (62–74) years, Ahlbäck 3; (3–4) of 10 agreed to participate. The intact knee in 11 patients (8 men and 3 women; 26 (16–41) years) with anterior cruciate ligament rupture in the opposite knee acted as controls.

Methods

Study 1–3

The resected parts of the distal femur and proximal tibia were collected during operations with tricompartamental Freeman-Samuelson total knee replacements (Zimmer, USA – former Sulzer Company, Switzerland). Specimens were collected consecutively based on the willingness of the individual surgeons to participate. Standard instrumentation was used with intramedullar guide on the femoral and extramedullar guide on the tibial side. In all cases the cut could be placed a few millimetres below the level for the location of the most worn part of the medial or lateral compartment. The tibial part of the joint could always be obtained in one piece. The cartilage/bone pieces were marked for orientation and were stored at -70°C.
Analysis of joint area morphology (Figure 6, page 19) was performed after a median time of 6 months (maximum 12 months). When the pieces had thawed the medial and lateral parts of the femoral and tibial joint area were divided into 6 squares. In each of the 4 articulations a line was drawn from anterior to posterior in the middle of each area. Further two lines perpendicular to the first one separated each articulation into six regions of almost equal size. The degenerative changes were divided into 5 Grades: no visible changes (0), cartilage fibrillation (1), cartilage destruction without visible bone (2), bone without cartilage and no or minor attrition of bone (3) and obvious attrition of bone (4). In regions with varying types of degeneration, the dominating type of lesion was reported.

To study interobserver reliability two observers independently graded the cartilage/bone pieces from the femur and tibia in 11 patients. One of these observers was not informed about the purpose of the study. The specimens were oriented in a standardized way by marking the medial and lateral side. This marking was done during the operation and by the surgeon. The wear in each region was recorded using a standardized template printed on a paper. The observer estimated each region using the central line. Because of individual variations in the configuration of the removed articulation areas a standardized transparent template could not be used. Intraobserver variability could not be studied in an unbiased way because of dehydration of the specimens. 2–3 hours after thawing the specimens showed macroscopic changes, which made proper evaluation impossible.

**Study 2–3**

All measurements on radiographs were done with a magnifying lens (×10) fitted with 0.1 mm divisions. The minimum joint space width was measured on 3 radiographic examinations (weight-bearing, HKA, experimental set-up). The degree of magnification was evaluated by exposure of a steel ball (Ø = 10.0 mm). All values were corrected for magnification (6% on standing radiographs, 14% on HKA radiographs and 14% in the experimental set-up).

**Weight-bearing radiographs** were performed in all patients median 4 (1–29) days before surgery. The patients were standing with equal weight on both legs, and with their knees semi-flexed using the standard technique employed at the Department of Radiology, Halmstad hospital (Figure 2). The patients were told to stand with their toes approximately at a vertical line from the roentgen film and flex their knees until they touched the film cassette. The amount of knee flexion was estimated at 20–30 degrees.

**Joint width measurement.** The width of the affected joint was measured according to Buckland-Wright et al. (1994). On the femoral side we used the distal convex margin of the condyles. On the medial tibial side we used a line extending from near the tibial spine to the medial or outer margin, across the centre of the floor of the articular fossa in the mid-coronal plane of the joint. This line was defined by the superior margin of the bright radiodense band of the subchondral cortex, and appeared below the anterior and posterior articular margins of the tibial plateau. On the lateral side we used the proximal margin of the articular surface, defined by the superior margin of the bright radiodense band in the subchondral cortex extending from near the tibial spine to the lateral or outer margin.
**Study 3**

A standing radiographic view of the whole leg with full extension of the knee (Hip-Knee-Ankle or HKA examination) was exposed at the same time as the semi-flexed AP view. This image was used to evaluate the joint space at full extension.

**Testing equipment.** The bone/cartilage pieces were thawed and mounted anatomically in a jig (Plexiglas box) (Figure 3) adapted to the equipment used at our mammography laboratory. High density mammography films were used to obtain maximum resolution. The size of the box corresponded to the size of the envelopes to roentgen films to facilitate reproducible positioning of the specimens and constant distances between the x-ray tube, the object and the roentgen film.

A pneumatic piston designed for industrial use was employed. Its performance was controlled and found to be correct within ±0.2%.

This device produced a constant pressure of 400 kPa = 4 Bar on a piston with a diameter of 32 mm and act with a pressure of 324 N (approx equivalent with the force acting from a weight of 33 kg). The femoral bone pieces were allowed to slip into the deepest portion of the tibial plateau. An anterior-posterior view of the specimen was exposed.

**Study 4**

The socio-economic grouping and type of work were recorded for each patient using information from Statistics Sweden (SCB, Statistiska centralbyrån) collected in 1970 (FoB 1970).

**Socio-economic grouping** is constructed by Statistics Sweden based on type of work, education and income. It is classified into 10 groups in terms of e.g. self-employed farmer, farm worker, industry businessmen and entrepreneur in other activity, employed businessmen, office staff, laborer, service employees, military personal and unidentified work.

Work is further differentiated and embraces several hundreds of different items coded into a number. A number of occupations have been identified (Vingård et al. 1991) (Table 4, page 22), which theoretically could be associated with increased loading of the knee. Those occupations have been condensed into 7 groups, each representing a number of occupations, where the knee is supposed to be exposed to an equal amount of load. All other works could be classified as a “low-risk” group according to Vingård et al.

In our material most persons were (or had retired as) office workers (27%), blue-collar workers (25%) or farmers (13%). The high-risk-groups (nr 1–17) included mainly farmers (group nr 1, n=136) or building workers (group nr 7, n=57).

In the subgroup of 451 patients any relationship between gender, uni-/bilateral OA involvement and work was studied.
Study 5

All pelvic views were exposed supine with a fixed patient-film distance resulting in a standardised magnification of about 20%. At the radiographic evaluation we did not correct for magnification since only relative lengths and angles were measured. A small pillow was placed beneath the knees to obtain as standardised position of the pelvis as possible. All measurements were made using templates, pencil, set square and a ruler. (Figure 4).

Hip angles. Two lines were constructed, one in the centre of the femoral neck and one in the centre of the femoral shaft. These lines were used to construct the neck shaft angle. The distance between the centre of the femoral head and the point where these two lines intersected represented the femoral neck length (femoral neck length). The horizontal distance between the femoral head centre and the line through the centre of the femoral canal represented offset (head–shaft distance).

Pelvic distances. Three distances were measured. The first was the distance between the medial border of the right and left acetabulum (Ac–Ac distance). The second distance corresponded to the sum of the Ac–Ac distance divided by 2 added to the distance between the medial border of the acetabulum and the femoral shaft (midpelvis–shaft distance). The third distance was the sum of the Ac–Ac distance divided by 2 and the distance between the medial border of the acetabulum and the centre of the femoral head (midpelvis–caput distance).

To estimate the length of the lever arm a functional offset was calculated. This parameter was defined as the quotient between the midpelvis–caput distance and the distance between the femoral head centre and a central line in the proximal femur (offset).

Study 6

6 infrared cameras recording at 240 Hz (MCU 240 Qualisys Medical AB, Göteborg, Sweden) were used. The camera system was calibrated to a measurable volume of 9.2 m³ (2 m × 2 m × 2.3 m). 18 reflective spherical markers were attached to the skin over bony landmarks (acromion, 12th thoracic vertebra, sacrum, anterior superior iliac spine, lateral knee joint line, proximal to the superior border of the patella, tibial tubercle, heel, lateral malleolus and between the second and third metatarsals). Markers were placed bilaterally. The position of each marker was detected by the system corresponding to a resolution of 0.2 mm. We used a modification of the Helen Hayes marker set (Davis et al. 1991), which has been used previously by our group (Saari et al. 2004a, Saari et al. 2004b, Saari et al. 2005b). The positions of the markers were partly chosen to limit the effect of subcutaneous fat thickness.

The room coordinate system was defined with one axis pointing in the direction of walking and parallel to the floor. Its direction was thus based on the first and the last “frame” in each test (i.e. the first to the last position in the gait cycle). The next axis was perpendicular to the first one and the floor.

The relationship between the marker positions on the skin surface and the joint centres was based upon data published by Vaughan et al. (1992). Thus, the joint centres of interest were mathematically reconstructed based on marker positions. The obtained laboratory or technical coordinate system was transferred to a clinical...
coordinate system, which was aligned to palpable or indirectly identified skeletal landmarks within each body segment, i.e. hip, thigh, shank and foot (Davis 1997).

This implied that each segment had its own individual coordinate system. The marker set attached to the pelvis (sacrum and 2 markers on each of the two anterior superior iliac spines) was used to calculate the hip joint centres, as well as to align the coordinate system to the pelvis. The markers on the shank were used for detection of the knee joint as well as the ankle joints. The remaining body segments were defined using the computed joint centres as landmarks and as follows; the foot segment was identified using the heel and toe markers and the centre of the ankle joint. The anterior-posterior axis of the foot segment was pointing from the heel marker towards the toe marker. The shank segment was defined by the reconstructed knee and ankle joint centres with the longitudinal axis pointing from the ankle to knee joint (positive direction).

The reconstructed centres of the knee joint, the hip joint and the marker placed on the superior border of patella, determined the thigh segment. The thigh segment had its longitudinal axis pointing from the knee joint centre to the hip joint centre (positive direction). The anterior-posterior axis was perpendicular to the longitudinal one and passed through the suprapatellar marker (positive anterior direction). The transverse axis was perpendicular to these axes with positive medial direction. Corrections were made for marker offset, i.e. the distance from the centers of the markers to the skin surface. Zero degree position (start position) was defined when the patient is standing upright. In this position the coordinate systems are fixed to the different segments before any motion is initiated. The motion is presented as relative motions of the distal segment using the proximal segment as a fixed reference. The description of moments is calculated in the same way.

Two force plates (Kistler 9281C, Kistler Instruments AG, Winterthur, Switzerland) were used to record ground reaction forces during level walking. Eight piezoelectric sensors in each force plate recorded forces 3-dimensionally.

The ground reaction forces were calculated from the input of the 8 channels of each force plate. The standard equations provided from Kistler™ were used to compute force vectors, the moment about the normal axis of the force plate surface, and the location of the ground reaction force vector. The force vectors were then transferred from the internal coordinate system of each force plate into the global coordinate system for calculations of joint moments.

The joint moments were calculated using an inverse dynamics approach. The mass of each segment is calculated as a percentage of body weight. The moments over each joint were expressed as applied to the distal segment of each joint. The data from the 6 cameras and the forces were recorded synchronically.

Recordings of motion were achieved with the software, QtracC™ version 2.51 (Qualisys Medical AB, Göteborg, Sweden). Reconstruction from 2-dimensional into three-dimensional data was made with QtracV™ version 2.60 (Qualisys Medical AB, Göteborg, Sweden). QGait 2.0™ (Qualisys Medical AB, Göteborg, Sweden) was used for calculations of rotations in relation to the three cardinal axes.

The patients and the healthy controls were asked to walk without targeting on the force plates at a self-selected speed. Several trials preceded the actual measurements to define a start line, which facilitated stepping on both force plates according to the step length of the individual patient. Patients had the opportunity to test the walkway several times before recording was done. When patients felt that they were familiar with the situation and were able to perform the test without targeting the force plates, two measurements were completed. The most representative measurement was chosen for further analysis. This selection was made visually by comparing the walk tests prior to recording and the two recorded tests. In this study we evaluated flexion/extension, adduction/abduction and external/internal rotation of the hip joint (thigh vs. pelvis) and knee joint (shank vs. thigh). The 3 dimensional angles were calculated according to the Euler-angle method (Kadaba et al. 1990, Davis et al. 1991).
Internal moments are presented. Flexion, internal rotation and adduction have positive values. Moments were normalized to body weight (Nm/BW). The time between two consecutive heel-strikes was normalized for inter-subject comparison. Data were transferred into SPSS 11.5 (SPSS Inc. Chicago, Illinois, USA) for statistical analysis.

Information from both the right and left side were collected. Each patient contributed with one knee; the side with symptoms or in cases with bilateral symptoms the one with most symptoms. When comparing the left and right side in controls we found no differences. In this study only the right side was used.

**Study 7**

Our set-up for dynamic radiography during active extension of the knee has been presented previously (Kärrholm et al. 2000, Uvehammer et al. 2000b, Brandsson et al. 2001, Saari et al. 2005a). 2 to 4 weeks before the examination, spherical tantalum markers (0.8 mm) were inserted using local anaesthesia. 4 to 8 markers were placed in the proximal tibia and the distal femur respectively. In the controls, markers were inserted bilaterally during a preoperative arthroscopy of the injured knee.

To obtain a standardized starting position a pair of stereoradiographs were exposed supine at 0° extension with the knee inside a biplanar cage (RSA Biomedical, Umeå, Sweden). At this exposure the tibia was aligned with the longitudinal axis of the cage and the posterior cortex of the femoral condyles were positioned to project over each other. This meant that the transverse axis of the cage, which defined the reference coordinate system, was parallel with the posterior condylar plane.

At the recordings of the knee kinematics at active extension the patients mounted a 6 cm high platform after several trial procedures. The goal was to obtain a standardized speed during a period of 3–4 seconds. The exposures were done with two x-ray tubes designed for simultaneous and continuous exposures. They were placed at a 90° angle in relation to each other. We used a speed rate of 2–4 frames/s. The patients and controls started the active extension at median 57° flexion and ended at 2° hyperextension. During this motion 7 to 13 (median 10) exposures were available for analysis. Observations from all subjects were available between 45° and 15°. The median mean errors of rigid body fitting (marker stability indicator) and condition numbers (marker scatter indicator) were 0.14 and 0.09 mm (range 0.05–0.26, 0.05–0.22) and 83 and 82 (range 29–136, 39–166) for the femoral and tibial markers, respectively.

We used film-exchangers designed for conventional roentgen films. The films were scanned and measured digitally using our standard equipment (Bragdon et al. 2002, Bragdon et al. 2004).

At the evaluation we recorded the relative tibial rotations using the femoral markers as a fixed reference. Translations of the flexion facet centres in the medial and lateral femoral condyles and of a point localised in between the two tips of the tibial eminence were measured using the “point transfer technique” (Brandsson et al. 2001, Saari et al. 2005a). In order to reduce the amount of data, we focused on 7 parameters. Relative tibial rotations with fixed femur were recorded as flexion (+) / extension (−), internal (+) / external (−) rotation, varus (+) / valgus (−) angulation. Recordings of tibial translations were restricted to anterior (+) / posterior(−) motions of a midpoint between the two tips of the tibial intercondylar eminence relative to a fixed femur. We also recorded femoral translations with the tibia fixed at the flexion facet centres of the two condyles. Proximal (+) / distal (−) and anterior (+) / poste-
rior (-) translations are accounted for.

To evaluate the relative tibial position at the reference (starting) position corresponding to the stereoradiographic examination at 0º we used the lateral view according to Nilsson et al. (Nilsson et al. 1991). The quotient a/a+b x 100 (Figure 5) did not differ between the study group and controls (lateral OA: 23, 0–42; controls: 22, 10–25, median, range, p=0.8).

In a previous study in the same laboratory (Uvehammer et al. 2000b) the repeatability (1 SD) between two series in the same patient was found to be 1.6°–2.3° and 1.2–2.2 mm. This is about up to ten times the resolution of radiostereometry and means that despite a number of trials the patients were not able to exactly reproduce the same knee motion between two step ups.

**Statistics**

**Study 1**

Different patterns of cartilage wear in medial and lateral gonarthrosis. Friedman’s test and Mann-Whitney U-test were used. Values are median and range. The weighted kappa was calculated to determine interobserver reliability.

**Study 2**

Standing radiographs underestimate joint width: comparison before and after resection of the joint in 34 total knee arthroplasties. Non-parametric tests (Wilcoxon sign rank test, Kendall tau) were used.

**Study 3**

Ahlbäck grading of knee osteoarthritis. Reproducibility and validity based on visual inspection of the joint. The concordance between the different observations and observers regarding the radiographic classification was evaluated using Kappa statistics. In addition the sensitivity and specificity were determined using visual inspection of the resected joint as reference. Cases with medial and lateral OA were studied separately.

**Study 4**

Working conditions resulting in increased need for surgical treatment of knee OA. Independent-sample t-test, Chi-Square, logistic and linear regression analysis (SPSS 10.0.5 for Windows, MedCalc 5.0.0.19) were used.

**Study 5**

Medial and lateral osteoarthritis of the knee is related to variations of hip and pelvic anatomy. When comparing the values between the left and right sides, Wilcoxon Signed Ranks Test, and for demographic data Mann Whitney U test were used. The values are presented as median and range. For all other statistics T-test and Fisher’s Exact test were used and values are presented as mean and SD.

**Study 6**

Hip and knee joint rotations differ between patients with medial and lateral knee osteoarthritis. Gait analysis of 30 patients and 15 controls. Non-parametric tests were used. The two groups of patients with medial and lateral OA and the control group were analyzed using non-parametric ANOVA (Kruskal-Wallis test). If this test revealed the presence of a difference, further analyses between the groups were done using Mann-Whitney test. To reduce the risk of spuriously occurring significances, the significance level was set at p < 0.025.

**Study 7**

Changes of knee joint kinematics caused by lateral osteoarthritis. The observed motions were interpolated at 5° intervals in flexion/extension. Observations were collected at 10° to 50°. Mann-Whitney U-test was used for comparison at 45° and 15° of flexion. P-values less than 0.05 were regarded as significant.


Results

Study 1 – Different patterns of cartilage wear in medial and lateral gonarthrosis

Studies on 11 tibial plateau specimens by 2 observers revealed complete agreement in 55%, difference with 1 Grade in 43% and with 2 Grades in 2% of the 132 regions studied (weighted kappa= 0.52).

Tibia

The most pronounced changes in medial OA were located peripherally in the central part (central-peripheral-medial: cpm) followed by the anterior part (apm) (median values, cpm: 3.0, 2–4; apm: 1.0, 0–4; p<0.001, Friedman’s test including all regions medially) (Figure 6).

In lateral OA the most degenerative changes were also located in the central-peripheral region (cpl: 4.0, 3–4). The next region in term of severity of the changes was located posteriorly (ppl: 3, 2–4; p<0.001, Friedman’s test including all regions laterally).

Medial compartments in medial OA vs. lateral compartment in lateral OA: There were more degenerative changes in the anterior part in medial OA compared to lateral OA (regions apm vs. apl: p=0.02, Mann-Whitney U-test). In lateral OA there were more degenerative changes both peripherally and centrally than in medial OA (regions pcm vs. pcl: p=0.03; ppm vs. ppl: 0.001, Mann-Whitney U-test). The attrition of bone tended to be more pronounced in the peripheral and central region in the group with lateral arthrosis (cpm vs. cpl: p=0.04).

Femur

In medial OA the degenerative changes were rather evenly distributed (p=0.3, Friedman’s test including all regions medially). In lateral OA, the central and posterior regions showed more pronounced changes than the other regions (p=0.001, Friedman’s test including all regions laterally).

Comparison between the affected sides in both groups on femur: No obvious differences were seen (p=0.07–
0.7, Mann-Whitney u-test).

No difference were found between men and women either on the tibia or the femur in medial OA ($p=0.07–0.9$, Mann-Whitney u-test). Any influence of gender could not be studied in lateral OA, because of too few observations (1 male).

On the non-affected sides there was a macroscopically intact cartilage layer in all cases (median values = 0).

**Study 2 – Standing radiographs underestimate joint width: comparison before and after resection of the joint in 34 total knee arthroplasties**

The intra- and interobserver variability on the films on standing radiographs were ±0.20 mm (1 SD) and –0.25 ±0.40 mm (mean difference ±1 SD). The intraobserver variability on the films from the experimental set-up was 0.54 mm (1 SD).

**Evaluation of test equipment.** When the 2 series were compared the compartment with degenerative changes showed smaller variability than the opposite with no or less degenerative changes (nonaffected) using the same or different loads. Within the ranges of loads used the magnitudes of the errors were the same as the intraobserver variability (Table 2).

**Standing radiographs vs. experimental set-up.** On the affected side 17 cases had a joint space width less than 1 mm on standing radiographs, 10 cases had 1–2 mm and 7 cases more than 2 mm.

**Medial OA:** On the medial affected side weight-bearing radiographs revealed a wider joint width than in specimen (median difference=0.3 mm, $p=0.05$). In 10 of 22 cases the absolute difference exceeded 0.5 mm, with a wider joint line in 8 of these cases. On the nonaffected lateral side the difference was larger (median difference=1.8 mm, $p<0.001$).

**Lateral OA:** Standing radiographs also overestimated the joint width on the affected lateral side (0.2 mm, $p=0.04$). In 4 of 12 cases the absolute differences exceeded 0.5 mm, and in 3 cases the joint space width was 1.3 to 2.9 mm wider than observed on the radiographs of the specimens (Figure 7). On the non-affected medial side there were a wider joint space on clinical radiographs in all but one of the 12 observations (median difference: 0.4 mm, $p=0.003$).

The differences in joint space width tended to vary more in cases with lateral arthrosis (95% CI: lateral: 0.1 to -1.2 mm; medial: 0 to -0.5 mm). (Table 4)
Lateral osteoarthritis of the knee
Jonas Weidow

HKA radiographs vs. experimental set-up. HKA radiographs overestimated the joint width on the most worn side of the joint compared to the experimental set-up (median 0.5 mm in medial; p=0.002 and 1.5 mm in lateral OA; p=0.01).

HKA vs. standing radiographs. In the compartment with the most pronounced changes radiographic examination on the extended knee (HKA-radiographs) showed median 0.5 mm wider joint than on standing radiographs in cases with medial OA (p=0.02). The difference was more pronounced in cases with lateral OA (1.5 mm, p=0.02; medial vs. lateral differences: p=0.05) (Table 3).

In the compartment with no or less pronounced changes the measurement on the HKA radiographs did not differ from those obtained in the semi flexed position in either medial or lateral arthrosis (p≥0.2).

Study 3 – Ahlbäck grading of knee osteoarthritis. Reproducibility and validity based on visual inspection of the joint

Ahlbäck classification

The interobserver reproducibility when one of the 4 observers classified the radiographs 2 times, varied from high to comparatively low (0.15), but was in most instances acceptable or high (kappa: medial OA: 0.15–0.65, mean 0.46; lateral OA: 0.59–0.76, mean 0.67).

The interobserver variability was consistently low (combined kappa for all 4 observers: medial: 0.11; lateral: 0.12).

The sensitivity (comparison between radiographs and visual inspection of resected bone ends) was acceptable both in medial (67–95%) and in lateral (50–86%) OA.

The specificity for most comparisons was lower (medial: 11–67%; lateral: 25–75%).

Bone attrition (radiographic diagnosis vs. visual inspection of resected bone)

In medial OA the sensitivity to detect any tibial and femoral attrition varied between 53–94% and 63–95%, respectively. The corresponding variation of specificity for the different combinations of observers varied between 8–77% (tibia) and 36–73% (femur).

In lateral OA the sensitivity to detect tibial and femoral attrition varied between 38–92% and 25–87% (only one observer had higher value than 50%). The specificity varied between 40–80% (tibia) and 20–60% (femur) (Table 4).

Study 4 – Working conditions resulting in increased need for surgical treatment of knee OA

Sex, age and civil status. In the total material more female (n=540) than male (n=446) patients had received surgical treatment because of OA (p=0.002). The male patients were at an average 3.6 years younger age than the females: 65 (8.6) years (p<0.001). In the Hospital A material (256 men and 286 women) the difference was slightly higher: 66 (12) vs. 70 (8.6) years (p<0.001).

This was mainly an effect of lower average age in
Table 4. The two values for sensitivity and specificity refer to first and second observation, respectively

<table>
<thead>
<tr>
<th>Medial OA</th>
<th>Observer 1</th>
<th>Observer 2</th>
<th>Observer 3</th>
<th>Observer 4</th>
<th>All combined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahlbäck grading (kappa value)</td>
<td>0.45</td>
<td>0.65</td>
<td>0.59</td>
<td>0.15</td>
<td>0.11</td>
</tr>
<tr>
<td>Intraobserver variability</td>
<td>0.05</td>
<td>0.20</td>
<td>0.05</td>
<td>0.17</td>
<td>0.11</td>
</tr>
<tr>
<td>Sensitivity (%)</td>
<td>86 / 95</td>
<td>71 / 67</td>
<td>82 / 94</td>
<td>88 / 94</td>
<td></td>
</tr>
<tr>
<td>Specificity (%)</td>
<td>22 / 11</td>
<td>56 / 67</td>
<td>15 / 23</td>
<td>31 / 23</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. The number of patients and controls based on figures reported to Sweden Statistics in 1970. For each patient, 3 age- and gender-matched controls were identified by Sweden Statistics.

<table>
<thead>
<tr>
<th>Group</th>
<th>Selected occupations with high risk *</th>
<th>Number of controls</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Farmers, farm worker</td>
<td>354</td>
<td>120</td>
</tr>
<tr>
<td>2</td>
<td>Fisherman</td>
<td>12</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Woodman, log-fetcher</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Miner</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>Sorting clerk</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Hardener, smith, iron foundry</td>
<td>21</td>
<td>7</td>
</tr>
<tr>
<td>7</td>
<td>Building worker, piping worker, bricklayer, metal worker</td>
<td>152</td>
<td>46</td>
</tr>
<tr>
<td>8</td>
<td>Butcher</td>
<td>16</td>
<td>5</td>
</tr>
<tr>
<td>9</td>
<td>Stonemason</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>Labourer</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>11</td>
<td>Crane loader worker, truck worker</td>
<td>40</td>
<td>11</td>
</tr>
<tr>
<td>12</td>
<td>Working with packet</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>13</td>
<td>Stevedore</td>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>14</td>
<td>Store man</td>
<td>38</td>
<td>11</td>
</tr>
<tr>
<td>15</td>
<td>Fireman</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>16</td>
<td>Head waiter/waitress</td>
<td>43</td>
<td>9</td>
</tr>
<tr>
<td>17</td>
<td>Cleaner</td>
<td>85</td>
<td>27</td>
</tr>
<tr>
<td>Total sum</td>
<td></td>
<td>638</td>
<td>262</td>
</tr>
</tbody>
</table>

*High-risk exposure groups according to Vingård et al.

Table 5. The number of patients and controls based on figures reported to Sweden Statistics in 1970. For each patient, 3 age- and gender-matched controls were identified by Sweden Statistics.

- could not be evaluated

men operated with osteotomy. The mean age in men (n=137) and women (n=217) operated with uni-, bi- or tricompartmental prosthesis was the same: 73 (6.2) vs. 73 (5.9) years.

Work. 262 patients (638 controls) belonged to high-risk groups (Table 5). In two groups (farmers, farm workers and building-, piping-, bricklayer-, metal workers) we found statistically significant differences. People who in 1970 were reported to work in a farm (RR: 0.7, p=0.00) or as building worker group (RR: 0.4, p=0.047, Table 6) were 5 to 4 years later more often subjected to surgical treatment of their knee OA. However, the surgical intervention was obtained at a higher age in farm workers than in those who had other types of job: 69 vs. 67 years (p=0.003)

Socio-economic grouping (Table 7). Overall, patients who in 1970 had been employees in an office work or as businessmen had a lower risk to be operated due to knee OA (RR: 0.7, p=0.002). Farmers who owned their farm had an increased risk (1.4, p=0.004), whereas employees in a farming enterprise did not show any overrepresenta
Table 6. Observed risk ratio to receive surgical treatment of knee arthrosis in relation to occupation in 1970

<table>
<thead>
<tr>
<th>Work 1970</th>
<th>Risk analysis</th>
<th></th>
<th>Age at first surgical procedure</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RR</td>
<td>CI</td>
<td>p-value</td>
<td></td>
</tr>
<tr>
<td>High risk – all groups</td>
<td>1.45</td>
<td>1.20–1.76</td>
<td>&lt;0.0005</td>
<td>67.7 (9.0)</td>
</tr>
<tr>
<td>Farmer workers</td>
<td>1.66</td>
<td>1.33–2.07</td>
<td>&lt;0.0005</td>
<td>68.0 (7.5)</td>
</tr>
<tr>
<td>Building workers</td>
<td>1.40</td>
<td>1.01–1.96</td>
<td>0.047</td>
<td>66.2 (10.8)</td>
</tr>
<tr>
<td>Low risk – all groups</td>
<td>0.92</td>
<td>0.78–1.09</td>
<td>0.32</td>
<td>67.8 (9.8)</td>
</tr>
</tbody>
</table>

Table 7. Observed risk ratio to receive surgical treatment of knee arthrosis in relation to socioeconomic belonging in 1970

<table>
<thead>
<tr>
<th>Socioeconomic belonging 1970</th>
<th>Risk analysis</th>
<th></th>
<th>Age at first surgical procedure</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers, employed</td>
<td>0.86</td>
<td>0.49–1.52</td>
<td>0.61</td>
<td>65.5 (9.9)</td>
</tr>
<tr>
<td>Farmers, own business</td>
<td>1.51</td>
<td>1.11–1.72</td>
<td>0.004</td>
<td>69.3 (7.2)</td>
</tr>
<tr>
<td>Employees</td>
<td>0.75</td>
<td>0.62–0.90</td>
<td>0.002</td>
<td>66.9 (9.3)</td>
</tr>
</tbody>
</table>

**Uni-versus bilateral OA.** There were 20% more women than men with bilateral OA (p<0.001). Men treated with surgery because of knee OA had about 3 times more often unilateral OA (33/199) than had women (11/217) (p<0.001). In a logistic regression analysis with uni- and bilateral OA as a dependent variable we found a stronger correlation with gender (p<0.001) than high-risk occupation (p=0.7). Unilateral OA tended to be more common in building workers than in the other occupational groups (RR: 3.2, CI: 0.96–11, p=0.06). A corresponding analysis comparing all high risk groups (14/102) with low risk groups (13/145) did not reach statistical significance (RR: 1.5, CI: 0.76–3.0, p=0.2).

**Study 5 – Medial and lateral osteoarthritis of the knee is related to variations of hip and pelvic anatomy**

*Intra-interobserver variability.* 17 radiographic examinations of the pelvis were used. Intraobserver variability for the neck shaft angle was 1.7° (SD), and for the femoral neck length and head–shaft distance 4.2 and 3.1 mm, respectively. The interobserver error (mean (1 SD)) for neck shaft angle, femoral neck length and head–shaft distance was −0.3 (2.4°), 1.1 (4.5) mm and 1.6 (2.2) mm.

The intraobserver variability for Ac-Ac distance and midpelvis–shaft distance was 1.8 and 3.2 mm. The interobserver error (mean (1 SD)) for the same distances was −1.0 (6.6) and −0.2 (3.5) mm.

Left vs. right side (Table 8). The femoral neck length was 4 mm longer (p=0.03) and the head–shaft distance was 3 mm longer (p=0.03) on the right side in patients with lateral OA and the head–shaft distance 1 mm longer in medial OA (p=0.03). Therefore, further comparisons between patients with medial and lateral OA were restricted to the right side.

**OA of the hip.** In the first series of patients, operated during 1985–1994, those with lateral OA had been operated more often with hip arthroplasty (13 of 25) than those with medial OA (13 of 217) (p<0.001).

**Hip angles and distances** (Table 9). Patients with medial knee OA (without hip OA) revealed a greater offset than controls (+11.4 mm; p=0.005), but there was no difference in pelvis width. The femoral neck in patients with medial OA was also longer (64 vs. 55 mm; p=0.001).

Patients with lateral knee OA (without hip OA)
Table 8. Anatomic hip angles and distances. Comparison between right and left side.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Right side</th>
<th>Left side</th>
<th>p-value *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medial OA of the knee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck–shaft angle</td>
<td>10</td>
<td>130</td>
<td>133</td>
</tr>
<tr>
<td>Femoral neck length</td>
<td>10</td>
<td>62.5</td>
<td>61</td>
</tr>
<tr>
<td>Head–shaft distance</td>
<td>10</td>
<td>46</td>
<td>45</td>
</tr>
<tr>
<td>Lateral OA of the knee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neck–shaft angle</td>
<td>7</td>
<td>134.5</td>
<td>134.5</td>
</tr>
<tr>
<td>Femoral neck length</td>
<td>7</td>
<td>61</td>
<td>57</td>
</tr>
<tr>
<td>Head–shaft distance</td>
<td>7</td>
<td>44</td>
<td>41</td>
</tr>
</tbody>
</table>

* Wilcoxon signed rank test

Table 9. Pelvis and hip distances and angles. Lateral and medial arthrosis of the knee with and without coxarthrosis versus controls. Hip values on the right side (missing observations are due to discarded radiographs)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>No coxarthrosis</th>
<th>With coxarthrosis</th>
<th>No coxarthrosis</th>
<th>With coxarthrosis</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ac–ac distance</td>
<td>12</td>
<td>166 (10.3)</td>
<td>17</td>
<td>164 (6.8)</td>
<td>14</td>
</tr>
<tr>
<td>Neck–shaft angle</td>
<td>11</td>
<td>133.3 (4.4)</td>
<td>13</td>
<td>134.5 (6.8)</td>
<td>14</td>
</tr>
<tr>
<td>Head–shaft distance</td>
<td>10</td>
<td>42.7 (4.6)</td>
<td>8</td>
<td>40.9 (8.1)</td>
<td>10</td>
</tr>
<tr>
<td>Femoral neck length</td>
<td>10</td>
<td>59 (4.1)</td>
<td>8</td>
<td>57 (7.9)</td>
<td>10</td>
</tr>
<tr>
<td>Midpelvis–caput distance</td>
<td>9</td>
<td>118 (5.0)</td>
<td>7</td>
<td>122.5 (8.9)</td>
<td>8</td>
</tr>
<tr>
<td>Midpelvis–shaft distance</td>
<td>9</td>
<td>161.3 (7.8)</td>
<td>7</td>
<td>162.8 (8.3)</td>
<td>8</td>
</tr>
<tr>
<td>Lever arm</td>
<td>9</td>
<td>0.37 (0.03)</td>
<td>7</td>
<td>0.33 (0.08)</td>
<td>8</td>
</tr>
</tbody>
</table>

P-values (T-test)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>LNC mean (SD)</th>
<th>LWC mean (SD)</th>
<th>MNC mean (SD)</th>
<th>MWC mean (SD)</th>
<th>NC mean (SD)</th>
<th>WC mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ac–ac distance</td>
<td>0.001</td>
<td>0.009</td>
<td>0.68</td>
<td>0.18</td>
<td>0.009</td>
<td>0.15</td>
</tr>
<tr>
<td>Neck–shaft angle</td>
<td>0.53</td>
<td>0.93</td>
<td>0.07</td>
<td>0.007</td>
<td>0.14</td>
<td>0.008</td>
</tr>
<tr>
<td>Head–shaft distance</td>
<td>0.14</td>
<td>0.46</td>
<td>0.005</td>
<td>0.001</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>Femoral neck length</td>
<td>0.04</td>
<td>0.26</td>
<td>0.001</td>
<td>0.001</td>
<td>0.02</td>
<td>0.055</td>
</tr>
<tr>
<td>Midpelvis–caput distance</td>
<td>0.06</td>
<td>0.036</td>
<td>0.98</td>
<td>0.58</td>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>Midpelvis–shaft distance</td>
<td>0.02</td>
<td>0.18</td>
<td>0.01</td>
<td>0.003</td>
<td>0.73</td>
<td>0.68</td>
</tr>
<tr>
<td>Lever arm</td>
<td>0.28</td>
<td>0.92</td>
<td>0.006</td>
<td>0.002</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

There were no significant differences between coxarthrosis or not, within medial and lateral arthrosis.

The wider pelvis in lateral knee OA was compensated by shorter offset on the AP radiographs resulting in about equal shaft-to-shaft distances (midpelvis–shaft distance) in the two groups (lateral vs. medial OA of the knee: -1.6 mm, p=0.7) (Figure 8).

The influence of hip OA. With hip OA, the difference in offset between the medial and lateral
knee OA groups increased to 12.2 mm (p=0.01), and the difference in pelvic width (Ac–Ac distance) decreased to 6.3 mm (p=0.15; medial OA: +3.9 mm, lateral OA: -2.0 mm).

Compared to cases without hip OA, the femoral neck angle decreases in the medial knee OA group with 2.2° and increased in lateral OA group with 1.2°. Comparison between the 2 groups revealed a difference of 7.8° (p=0.008).

In lateral knee OA the calculated lever arm (offset/midpelvis–caput distance) was 19% smaller in patient without and 30% smaller in patients with OA of the hip compared with medial knee OA (p=0.02 and 0.02). No differences were found compared to controls (p>0.3).

**Study 6 – Hip and knee joint rotations differ between patients with medial and lateral knee osteoarthritis. Gait analysis of 30 patients and 15 controls**

Walking speed and stride length (Table 10). There was a tendency to reduced speed in the two patient groups (p=0.03). The stride length was shorter in medial OA (p=0.001) and lateral OA (p=0.02) than in controls. These parameters did not differ between the two patient groups (p=0.8/0.7).

Flexion/extension – hip (Tables –3). Both patient groups had smaller maximum hip extension angle than controls. In the group with medial OA it was reduced with 5° (p=0.0) and in the lateral OA group with 11° (p=0.008). The flexion angles did not differ (p=0.8).

In the early swing phase the peak flexion moment was higher in controls than in patients

| Table 10. Demographic data (Study 6), values are median (range) |
|-------------------|-------------------|-------------------|-------------------|
|                   | Controls (n=15)   | Medial OA (n=15)  | Lateral OA (n=15) |
| Age (year)        | 69 (60–86)        | 70 (47–79)        | 70 (61–83)        |
| Height (cm)       | 163 (150–180)     | 164 (148–166)     | 166 (151–178)     |
| Weight (kg)       | 70.5 (49.8–76.9)  | 77.8 (51–99.8)    | 89 (47.3–101)     |
| BMI (kg/m²)       | 26.5 (21–30.1)    | 29.6 (20.2–40.5)  | 37.4 (19.4–35.2)  |
| Cadence (stride/min) | 111 (87–140)   | 102 (56–124)      | 102 (33–123)      |
| Speed (m/s)       | 1.10 (0.8–1.7)    | 0.9 (0.4–1.3)     | 0.8 (0.2–1.2)     |
| Stride length (m) | 1.2 (1.0–1.4)     | 1.1 (0.7–1.2)     | 1.1 (0.5–1.4)     |
| Ahlbäck (Grade)   | -                 | 3 (1–5)           | 1 (1–4)           |

*Kruskal-Wallis between three and Mann-Whitney between two groups*
with medial OA (p=0.004). A similar tendency was observed in cases with lateral OA (p=0.03).

**Flexion/extension – knee.** Decreased flexion was shown in lateral knee OA (5°; p=0.006), but not in medial knee OA (8°; p=0.03), but both groups walked with less maximum knee extension (4–5°; p=0.004) than controls. The knee extension moments were smaller in both patient groups (p<0.001), but their flexion moments did not differ from normal (p=1).

**Adduction/abduction – hip.** At midstance patients with lateral OA had 2° more adduction of their hip joints (p=0.02), and patients with medial OA 7° more abduction than controls (p<0.001), but at the end of the cycle (past 60%) the pattern became closer to normal (Figure 9).

Patients with OA walked with reduced abduc
Lateral osteoarthritis of the knee
Jonas Weidow

Maximal internal knee abduction moments throughout stance. The maximum values were reduced in medial OA by 13% (p=0.007) and lateral OA with 8% (p<0.001). The minimum values (adduction moments) did not differ.

Adduction / abduction – knee. In controls the maximum adduction angle reached 4° and the maximal abduction angle 3°. In medial OA the knee was in 8° more adduction (max value) through the gait cycle, and in lateral OA in 8° more abduction (max value) than in controls.

The maximum internal knee abduction

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Medial OA</th>
<th>Lateral OA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexion</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>Extension</td>
<td>0.014</td>
<td>0.023</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>0.1</td>
<td>0.8</td>
</tr>
<tr>
<td>External rotation</td>
<td>0.027</td>
<td>1.0</td>
</tr>
<tr>
<td>Adduction</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Maximum moment</td>
<td>0.014</td>
<td>0.004</td>
</tr>
<tr>
<td>Extension</td>
<td>0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Abduction</td>
<td>0.2</td>
<td>0.9</td>
</tr>
<tr>
<td>Abduction</td>
<td>0.014</td>
<td>0.007</td>
</tr>
<tr>
<td>Internal rotation</td>
<td>0.035</td>
<td>1.0</td>
</tr>
<tr>
<td>External rotation</td>
<td>1.0</td>
<td>0.9</td>
</tr>
</tbody>
</table>

* 40% of gait cycle (midstance)
Knee adduction/abduction moments (Nm/kg)

Figure 10. Mean value of knee or relative tibial adduction/abduction moments related to a standardized gait cycle in women with medial or lateral OA and in the controls. See also legend to Figure 1.

Hip internal/exterior rotation angles (degree)

Figure 11. Mean value of hip or relative femoral internal/external rotation angles related to a standardized gait cycle in women with medial or lateral OA and in the controls. See also legend to Figure 1.

Knee internal/exterior rotation angles (degree)

Figure 12. Mean value of knee or relative tibial internal/exterior rotation angles related to a standardized gait cycle in women with medial or lateral OA and in the controls. Rotation of tibia vs. femur. See also legend to Figure 1.

Moments were 52% higher in medial OA (p=0.009) and 63% less in lateral OA (p<0.001) than observed in the controls (Figure 0).

Rotations – hip. In patients with lateral OA the femur was positioned in about 7° more external rotation (maximum value, p=0.01) than in controls, but seemed to otherwise follow the variations observed in the normal hip during the gait cycle. Patients with medial OA did not differ from controls (p=0.8) (Figure 11).

The internal rotation moment in lateral OA was greater than in controls (p=0.021). The outward rotation moments were small without difference (-0.2 to 0.1 Nm/Kg; p≥0.04).

Rotations – knee. At midstance, cases with medial
Lateral osteoarthritis of the knee
Jonas Weidow

OA had 9° more external tibial rotation than controls and cases with lateral OA 6° less. These differences did not reach significance (p>0.06), but comparison between the OA groups revealed a significant difference (p=0.001) (Figure 12). The moments were small and did not differ (p≥0.08).

**Study 7 – Changes of knee joint kinematics caused by lateral osteoarthritis**

**Rotations.** At 45° of flexion the tibia had rotated inwards whether the knee had lateral OA or not. Both groups showed a tendency to valgus angulation during active extension compared to the supine reference position, without significant difference at 45° (p=0.3) (Figure 13). With increasing extension knees with lateral OA tended to rotate into slightly more valgus, whereas the normal knees showed slight varus angulation resulting in a mean / median difference of about 3 / 4.5° at 15° of flexion (p=0.001) (Table 14).

**Translations.** The centre of the tibial plateau had displaced slightly more than 1 cm posteriorly at 45°. This displacement decreased to slightly less than 2 mm at 15° still without any difference between the two groups.

At 45° the medial flexion facet centre had displaced 3–4 mm distally in both groups. It moved proximally and to about the same amount with proceeding extension (p>0.7).

In both groups the internal tibial rotation resulted in a relative anterior displacement of the medial condylar centre. At 45° and in knees with lateral OA the medial condyle had translated 7–8 mm forwards. The corresponding displacement in normal knees was about 4 mm smaller (p=0.03) (Figure 14). At 15° there was still a mean/median-anterior displacement in the OA group, whereas

---

**Table 14. Kinematic recordings at 15 and 45 degrees of knee flexion. Values are median (range)**

<table>
<thead>
<tr>
<th></th>
<th>15 degrees knee flexion</th>
<th>45 degrees knee flexion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lateral OA</td>
<td>Controls</td>
</tr>
<tr>
<td>Tibial rotations, degrees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>internal(+) / external(-)</td>
<td>4.8 (-3.3 to 6.5)</td>
<td>2.9 (-2.6 to 7.4)</td>
</tr>
<tr>
<td>varus(+) / valgus(-)</td>
<td>-2.1 (-4.9 to -0.7)</td>
<td>0.0 (-1.2 to 2.9)</td>
</tr>
<tr>
<td>Tibial translations, mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>anterior(-) / posterior(+)</td>
<td>-2.0 (-7.4 to -0.7)</td>
<td>-1.9 (-4.7 to -0.3)</td>
</tr>
<tr>
<td>Femoral translations, mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>– medial condyle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>proximal(+) / distal(-)</td>
<td>-1.9 (-4.5 to -0.1)</td>
<td>-2.6 (-3.9 to 0.2)</td>
</tr>
<tr>
<td>anterior(-) / posterior(+)</td>
<td>0.3 (-0.3 to 6.2)</td>
<td>-0.4 (-2.1 to 1.4)</td>
</tr>
<tr>
<td>– lateral condyle</td>
<td></td>
<td></td>
</tr>
<tr>
<td>proximal(+) / distal(-)</td>
<td>-4.0 (-6.0 to -2.2)</td>
<td>-0.8 (-3.1 to -0.2)</td>
</tr>
<tr>
<td>anterior(-) / posterior(+)</td>
<td>-4.2 (-6.3 to 3.2)</td>
<td>-4.2 (-7.2 to 0.8)</td>
</tr>
</tbody>
</table>

* Mann-Whitney test.
Figure 15. Proximal-distal translation of the lateral condylar flexion facet center. The lateral condyle had a more distal position and especially up to 20° probably because of loss of cartilage and bone. Numbers of observations are placed according to Figure 13. Mean and standard error of the mean (SE) are shown.

Figure 16. Anteroposterior translations of the lateral flexion facet center are illustrated. These motions were small without any substantial difference between the two groups. Numbers of observations are according to Figure 13. Mean and standard error of the mean (SE) are shown.

Figure 17. Reconstruction of the tibial plateau and the projections of the flexion facet centers between the reference position (x) and 45° (dot or square) are shown. The tibial plateau was reconstructed from CT data of a normal knee. In addition to data from control subjects and knees with lateral osteoarthritis (OA) the corresponding mean translations in 14 knees with medial OA (from Saari et al. 2005 are illustrated. As an effect of internal tibial rotation at 45° the medial femoral condylar center displaced anteriorly and the lateral one posteriorly (mean values) in control subjects and knees with lateral OA. In medial OA, the mean AP translations were small and in the opposite directions (posteriorly in medial compartment and anteriorly in the lateral one).

normal knees showed a corresponding minimum posterior displacement (p=0.05).

In both groups the lateral flexion facet centre had displaced distally at 45° (3–4 mm more in lateral OA than controls; p=0.05). In the group with lateral OA this distal displacement was 2–3 mm higher than observed on the medial side. In contrast, the control group was 2–3 mm smaller laterally than medially resulting in a difference of about 4–5 mm between the groups.

The lateral flexion facet centre translated in a proximal direction with proceeding extension in both groups (lateral OA/ controls; 1.2/ 0.6 mm), with a 3.2 mm more proximal position in lateral OA compared to controls at 15° of flexion (p=0.001) (Figure 15).

At 45° this centre had translated posteriorly mean / median -0.9 /-3.4 mm in the OA group and -4.5 / -2.7 mm in the controls (p=0.7). At 15° these positions had changed with about 1–2 mm, still without any differences (p=0.6) (Figures 16 and 17).
Discussion

The location of wear on the tibial joint surface may reflect the position of maximum load and the location of primary failure of the cartilage during the initiation of the disease. The locations of the wear in study 1 are consistent with our primary hypothesis with more anterior wear in medial OA and a more posterior wear in lateral OA. Findings of a stiffer bone in these regions also support these observations (Hvid and Hansen 1985). Vande Berg et al. (2002) used multidetector spiral CT arthrography to study lesions of the femoro-tibial cartilage in patients with knee pain but without OA changes on conventional radiographs. They used a detailed grid with 16 areas and the cartilage defects found on the tibial plateau were located posterior on the lateral side and in the bare area (without meniscus) on the medial side. We chose to divide each articular surface into only 6 parts, because we thought that a more detailed division would jeopardize the reproducibility of this procedure. Tibial plateaus are more or less different, not only in size but also regarding other anatomical features and particularly if there are degenerative changes. Division of the articular surface into 6 regions was recently used in the previously quoted study by Moschella et al. (2006), who compared degenerative changes in cases with and without old tears of the ACL.

Our observations may explain some of the difficulties to obtain an accurate diagnosis of OA and especially in cases with primary involvement of the lateral compartment. The degree of tension in the knee ligaments is probably important. When the tension of the ligament decreases the femoral condyle may more easily slip into the most worn part of the tibia. However, even if this often occurs it might be that the most worn part of the two joint surfaces does not contact because the instantaneous moment over the knee joint counteracts such a position. Unevenness of the surface or active avoidance of the patient to obtain such a position due to pain are further possible explanations. In study 2, the standing radiographs overestimated the joint space width, with an increased scatter in lateral OA, probably because the wear is often located in the posterior part on the femoral condyle (Boegård et al. 1997). This, together with a frequently occurring spherical wear on the tibial plateau implies that the most worn part is not visualized unless weight-bearing radiographs are exposed in a more flexed position than usually practiced. In these instances the so called tunnel view has been recommended (Resnick and Vint 1980). This is consistent with our own clinical experience that flexion up to 30–60° can sometimes be necessary to visualize the location of most pronounced wear. Our experimental setup allows precise positioning, but could not completely address the need for a more flexed position. Use of different pressures in our experimental model had little if any influence on the recorded joint space width indicating that this factor did not act as a confounder within the ranges of load used. The clinical implication of this study is that present routines do not fulfil the need for exact diagnosis in lateral OA.

The observations in studies 1-2 explains some of the problems with the Ahlbäck classification documented in study 3. Also a previous study has shown that the Ahlbäck classification has poor inter- and intra-observer reliability and is dependent on the experience of the individual observer (Galli et al. 2003). Contrary to these authors our intra-observer variability tended to be somewhat better than the inter-observer variation. Overall, we could confirm that the consistency of the Ahlbäck classification was poor.

When evaluating the radiographs we recognized 2 important problems. One was to determine if a visible joint space represents remaining cartilage. The other was to determine presence of bone attrition. In his Thesis, Ahlbäck (1968) was aware of cases with obvious bone attrition despite presence of a visible joint opening, but did not comment on this problem in this or a later publication (Ahlbäck and Rydberg 1980). During our study we tried to improve the definition of the radiographic changes, but failed prob-
ably because the information on the radiographs about the true extension of the disease is insufficient. Lack of improvement after repeated analyses of the same observer supports this hypothesis. Changes of the radiographic technique and if possible improved radiographic classification are probably necessary to improve the diagnostic accuracy. However, other methods than conventional radiography might be required to achieve this goal. Recently, several articles have indicated that detecting cartilage loss on MRI is more sensitive than conventional radiography (Cicuttini et al. 2001, 2003, Jones et al. 2004, Amin et al. 2005). Loss of cartilage may become visible on MRI when no radiographic changes are detectable.

In study 4 we found an increased risk to undergo surgical treatment for knee OA in subjects who worked in a farm. Interestingly, farmers who owned their farm had an increased risk but not those who were employed in a farming enterprise. The reason for this difference is not clear, but could be related to the length of exposure to one or more risk factors associated with farming. Those who own their farm have often lived and worked there since young age, whereas persons employed at a farm may have a more variable background in terms of living conditions and earlier employments. One could expect that farmers and building workers who also underwent more frequent surgical treatment, were operated at a lower age. Instead, their age was higher suggesting that the onset of the disease was similar to the other groups. It is possible that these patient groups seek medical attention later or that they have a slower progression of OA or increased tolerance to this disease. Unilateral disease was more common in men, probably indicating that men more often had a traumatic origin, which previously has been documented in knees (Davis et al. 1989) and hips (Heliövaara et al. 1993). Our study supports the theory that uni- and bilateral OA of the knee, at least to certain extent, has different origin.

Standardized pelvic positioning is a prerequisite for reproducible radiographic measurements. Anterior/posterior tilting will change the angles of the hip joint (Jacobsen et al. 2004, Lembeck et al. 2005), but not the medial/lateral distances, nor the angle and rotation of the proximal femur. Tilting from side to side (i.e. rotation of the trunk/pelvis), will change the pelvic width. An angular rotation of e.g. 10° can be expected to reduce the width with 1.5% (cos 10° = 0.985) but at the same time the magnification is greater as the pelvis is closer to the beam source. The ratio between the distance between the centre of the pelvis and the centre of the femoral head and the corresponding distance to the centre of the femur may be subjected to such errors even if the femur is not rotated. Probably, this error has a smaller influence than the error caused by femoral rotation, which changes the apparent length of the offset. In our study a small pillow was routinely placed under the knees to prevent such rotation. Studies based on CT are necessary to further elucidate this issue.

The controls consisted of patients with a contralateral femoral neck fracture, which is another source of possible methodological error. Based on previous observations (Faulkner et al. 1993, Duboeuf et al. 1997, Gnudi et al. 1999, Gnudi et al. 2004), it could be expected that these patients have a longer femoral neck than normal, even if it still remains uncertain if patients with unilateral femoral neck fracture have a longer neck on both sides. Nonetheless in both OA groups the femoral necks were still longer than in our “normal” hips, indicating that our observation is valid.

Our hypothesis that patients with lateral OA had coxa valga could not be confirmed in our study. The neck shaft angle showed equal values in lateral OA and controls. However, we found a coxa vara in patients with medial OA, who also had a manifest osteoarthritis of the hip.

We found a wider pelvis in patients with lateral OA, than in those with medial OA and controls. The width of the pelvis (the distance between the medial borders of the acetabulum) was more than 1 cm larger in cases with lateral OA, regardless presence of osteoarthritis of the hip. These patients had smaller functional offset, which decreased the shaft to shaft distance resulting in the same total width from the centre of the pelvis to the femoral canal. In medial OA a wide pelvis
was observed only in cases, which also had hip OA. Thus, it seems as that pelvic width could influence the location of the knee OA. Women, who have a short functional femoral neck, may have difficulties to maintain sufficient hip abductor strength due to a short lever arm. During gait the pelvic tilt might increase resulting in hip adduction and increased external abduction moment at the knee. This gait pattern might also predispose to development of hip OA resulting in further contracture of the hip adductors.

More than 20 years ago (Cooke 1983) proposed that the coexistence of knee disease in cases with hip OA was more common than the opposite. Almost half of his cases with hip OA had knee involvement, but only 1/10 with knee OA had hip involvement. The reason for this is not known, but our observations suggest that there could be biomechanical reasons.

In study 6 we found less maximum abduction moment over the hip in both medial (13 %) and lateral OA (8 %), than in controls. These findings can not be explained by the seemingly smaller lever arm in lateral OA as observed in the radiographic study (-19 % compared to medial knee OA, study 5). This reduced functional offset may be an effect of valgus position of the femoral neck. Our findings could also, at least partially, be an effect of increased outward rotation (7º) of the femur as observed in study 6. Reduced abductor moment at the hip may result in adduction of the hip joint and secondary displacement of the knee into valgus. Any increase of the activity of the hip abductors trying to compensate the small lever arm at the hip might also involve the tensor fascia lata muscle. This muscle may also influence the forces acting on the knee since its distal insertion is located on the tibia and passes the lateral side of the knee.

The outward rotation of the hip in lateral knee OA could result in changed pressure distribution in the hip joint (Genda et al. 2001). If so this could be a reason for the coexistence of hip and lateral knee OA in 50 % of the cases. In cases with medial knee OA only 5% of the patients had osteoarthritis in their ipsilateral hip joint. In those patients the rotational position of the femur did not differ from controls.

Our hypothesis that patients with lateral OA of the knee showed hip biomechanics different from those with medial OA could be verified in study 6. Both the hip and knee angles and moments differed between patients with medial and lateral OA of the knee during gait. In the knee the difference in abduction/adduction angles and moments were expected.

Walking speed and stride length may influence the gait parameters and especially the moments in the sagittal plane (Andriacchi et al. 1977, Vaughan et al. 1992, Holden et al. 1997, Lelas et al. 2003). The difference between patients and controls could partly be an effect of different walking speed. We think that the angular velocity has a higher influence on the hip than on the knee because of the difference in mass of the thigh and shank segment. Healthy adults raised their external rotational moment with ¼ in early stance and the hip internal rotation moment in late stance with increased speed (Draganich and Kuo 2004). In our study patients and controls walked with a self-selected speed which probably is influenced by various degrees of pain. Standardization of walking speed, if possible, may represent a walking pattern never used by the patient. Even if such an observation could have some interest, the clinical relevance could be questioned. In a recently performed study, self-selected normal walking speed explained only 9% of the variation in maximum knee adduction moment in patients with knee OA (Mazzuca et al. 2002). Patients with less-severe OA adapt a walking style that differs from that of patients with more-severe OA and controls. This walking style is associated with the potential to reduce the adduction moment when walking at slower speeds. However, the walking speed between the two OA groups was equal and we do not think that the observed difference could be explained by any demographic difference.

In our study the diverging pattern of femoral and tibial rotations about the longitudinal axis was not expected. Anatomical torsion of the tibia itself (between the distal and the proximal part) has been described with inward anatomical torsion of tibia in men (mean -5º) compared to women (+11º) (Yoshioka et al. 1989). In medial
OA the ankle region is further internally rotated (12° more than normal) with increasing values in severe OA (Yagi 1994). 5 degrees of increased outward tibial torsion has been described in the lateral compared to medial OA but any gender related differences were not accounted for (Takai et al. 1985). The rotation of the entire tibia relative to the thigh segment found in study 6 could to some extent explain these differences in tibial torsion. In our gait analysis we found 15° more internal tibial rotation in lateral OA than in medial OA (medial OA 9° more external tibial rotation; lateral OA 6° less external rotation than controls). With RSA, external tibial rotation relative to a fixed femur in medial OA has been confirmed (Saari et al. 2005a). This reduction of external rotation was mirrored by reduced posterior translation of the lateral femoral facet centre. Saari et al also described a small (1 mm) anterior movement of the medial facet centre up to 25° of flexion followed by a small posterior displacement in the more flexed positions. In normal knees the medial facet centre showed increasing anterior translation with flexion and 3 mm difference between 20° and 50° of flexion.

The tibial internal rotation found in lateral OA could be an effect of the external rotation of the hip where rotational malalignment of the femur may influence the position of the knee. The internal tibial rotation will neutralize the position of the lower leg and the foot. Because of this and compared to medial OA, the medial femoral condyle may contact the tibia more anteriorly or the lateral femoral condyle more posteriorly or both. This was partly evaluated in study 7, in which we chose to illustrate tibial rotations around the longitudinal axis computing anterior-posterior translations of the flexion facet centres. We found increased anterior translation of the medial facet centre which at 45° was 4–5 mm more than in the normal knees. With extension this condyle displaced posteriorly but remained more anteriorly displaced than normal up to at least 15° of flexion. Hereafter the number of observations became too few for relevant analysis. A small posterior dislocation on 1 mm of the lateral facet centre of the femoral condyle was found. These observations indicate that the centre of rotation is displaced laterally in cases with lateral OA.

Study 7 has limitations with a small patient group and the limited arc of flexion studied. Our hypothesis with a more posterior location of femur condyle could not be verified. Studies beyond 50° are necessary, especially since the location for maximum wear in lateral OA often is located posteriorly. In some cases it might be that these areas may not contact until flexion has passed this limit.

Future

Our studies have indicated that a more accurate diagnosis of lateral knee OA can be expected if the knee is examined in a more flexed position. Further studies including radiographic exposure at increasing degrees of flexion and dynamic RSA studies including more pronounced knee flexion are desirable.

Anatomical hip abnormalities may, to a certain extent, cause the development of knee OA. Our observations support that this is the case in lateral OA. Anatomical abnormalities of the pelvis and the hip may result in rotational malalignment and an increased external abduction moment over the knee. The changes of the hip anatomy also seem to be associated with development of hip OA, but these theories need documentation in future prospective studies. To evaluate the anteversion of the hip in lateral knee OA, more detailed measurements based on CT evaluations of patients with lateral as well as medial knee OA and age-matched controls are necessary. To evaluate whether or not the anatomical changes in our studies are primary or secondary would require a prospective radiographic study preferably including gait analysis starting in the second decade of life.

It is not clear whether the gait abnormalities observed in this thesis are secondary to wear/pain of the joint or are primary and causing degenerative changes and development of OA. We found that presence of lateral OA is associated with specific changes of the pattern of knee motion. We speculate that the abnormal rotation of the tibia with translation of the medial femoral condyle with flexion in an anterior position is
one reason for the development of wear.

One could speculate that the abnormal knee motion observed in cases with lateral and medial OA was already present to a greater or lesser extent before any degenerative changes had developed. The observation of changes in knee joint kinematics similar to those observed in medial OA after tear of the anterior cruciate ligament supports this theory. If so prediction and perhaps also prevention of degenerative knee disease would be facilitated.

We have shown altered kinetics of the knee as well as the hip in lateral knee OA, compared to medial knee OA. Further studies of the anatomy of knees with lateral knee OA, together with more comprehensive investigations of the kinetics and kinematics of the knee could open up for improvements of knee prosthesis design. Different configuration based on knee joint anatomy and function reflecting the primary location of the disease might be beneficial to optimize the clinical results.
Conclusions

**Study 1 – Different patterns of cartilage wear in medial and lateral gonarthrosis**

The hypothesis of more anterior wear in medial knee OA and more posterior wear in lateral knee OA could be verified. In both groups, the central part of the tibial plateau showed the most pronounced wear, followed by the anterior part in medial OA and the posterior part in lateral OA.

**Study 2 – Standing radiographs underestimate joint width: comparison before and after resection of the joint in 34 total knee arthroplasties**

In medial OA standing radiographs underestimated joint width, but the observed difference between the 2 methods was small and acceptable. The more pronounced discrepancy in lateral OA motivates the use of other diagnostic measurements. In lateral OA there was no consistent underestimation, but larger scatter suggesting less precise determination, which motivates development of improved diagnostics.

**Study 3 – Ahlbäck grading of knee osteoarthritis. Reproducibility and validity based on visual inspection of the joint.**

The reproducibility and validity of Ahlbäck classification was poor. When the same observer classified the radiographs according to Ahlbäck twice, the repeatability was fair in both medial and lateral OA, but between different observers it was poor. Comparison between the radiographic classification and classification based on visual inspection of the bone pieces removed during arthroplasty revealed an acceptable sensitivity in both medial and lateral OA but the specificity was low.

The main problem with the Ahlbäck classification is that the joint space can often be seen on radiographs despite the presence of bone attrition as observed on the preparations. According to our study conventional radiographs do not give sufficient information for correct grading.

**Study 4 – Working conditions resulting in increased need for surgical treatment of knee OA**

Our study supports the theory that individuals expected to have had high physical demands on their knees during work, such as farmers and building workers, run increased risk to undergo surgical treatment because of OA of the knee. Increased incidence of unilateral disease in men and building workers suggests that this joint disease more commonly originates from previous trauma and supports the hypothesis that primary knee OA is a bilateral disease.

**Study 5 – Medial and lateral osteoarthritis of the knee is related to variations of hip and pelvic anatomy**

The hypothesis that patients with lateral OA of the knee had reduced lever arm in the hip compared to those with medial OA could be verified. In presence of hip OA this was an effect of coxa valga in cases with lateral knee OA and coxa vara in those with medial knee OA. In the subgroups without hip OA the Femoral Neck length was shorter in presence of lateral than in presence of medial OA of the knee. Our findings suggest that occurrence of medial or lateral OA has a biomechanical background originating from pelvis and hip anatomy.

**Study 6 – Hip and knee joint rotations differ between patients with medial and lateral knee osteoarthritis. Gait analysis of 30 patients and 15 controls**

According to our hypothesis we found an association between presence of lateral OA of the knee and changed biomechanics of the hip joint with the femur positioned in more external
rotation, compared to medial OA and controls. Patients with medial OA had more and those with lateral OA less external tibial rotation than the controls had. If the changed biomechanics of the hip joint is a reason for or a result of lateral OA is still unclear.

**Study 7 – Changes of knee joint kinematics caused by lateral osteoarthritis**

The hypothesis that the lateral femoral condyle would occupy a more posterior position in knees with lateral knee OA could not be verified. Instead and compared to controls, the medial femoral condyle occupied a more anterior position consistent with a more internally rotated tibial position as observed during the gait analysis (study 6).
I avhandlingen studeras om patienter med latent knäledsartros (förlovning i den yttre delen av knäleden) företer speciella karaktäriska beträffande anatomi, kinematik/kinetik (rörelser och moment) av höft- och knäled som skulle kunna ha samband med sjukdomens uppkomst.

**Studie 1.** För att utvärdera om det finns systematiska skillnader av slitage mönsteret vid medial respektive lateral artros undersöktes tibia- och femurplatån på preparat från 4 patienter som genomgått knäproteskirurgi. Slitaget definierades efter en 5-gradig skala och noterades i ett rutmönster. Maximalt slitage observerades i mitten av tibiaplatån oberoende av artrosens primära lokalisation. Vid medial artros var slitage mer uttalat i den främre (p=0.0) medan knäleder med lateral artros uppvisade ett större slitage i den bakre 1/3-delen (p=0.00). Det olika slitage mönstret talar för att knäleden rör sig på olika sätt beroende på artrosens primära lokalisering.

**Studie 2.** För att utvärdera validiteten av konventionell röntgenundersökning av knäledsartros under belastning bedömdes 34 undersökningar som jämfördes med motsvarande röntgenundersökning av de skelettdelar avlägsnade vid operation med totalprotes. Dessutom graderades brosk och benslitagens omfattning visuellt. Benpreparaten monterades och belastades under kontinuerligt tryck och röntgades i en apparat som konstruerats för detta projekt. Vi använde röntgendifil med hög densitet för optimal bildkvalité. De preoperativa röntgenundersökningarna visade en vidare ledspringa jämfört med preparatbilder. Vid medial respektive lateral artros var skillnaderna 0,3 mm (median; p=0,05; 0–0,5 mm) samt 0,2 mm (median; p=0,04; 0,1–1,2 mm). Den större spridningen vid lateral artros beror sannolikt på att patientens knäled vid klinisk undersökning inte ledar mot platsen för maximalt slitage, som vid lateral artros ofta finns långt bak på femurkondylen.

**Studie 3.** För att utvärdera reproducerbarhet vid gradering av knäledsartros enligt Ahlbäck bedömdes 48 belastade röntgenundersökningar av knäleden 2 gånger av 4 observatörer. Grad av artros (medial; n=30, lateral: n=18) bedömdes enligt Ahlbäck. Jämförelse mellan röntgenbilder och visuell gradering av benpreparat visade en acceptabel sensitivitet vid medial (67–95%) och lateral (43–86%) artros, men låg specificitet särskilt vid den mediala varianten (medial: 11–67%; lateral: 25–75%). Reproducerbarheten mellan observatörer var låg (kappa: 0,1) men inom samma observatör bättre (medial: kappa = 0,15–0,65; lateral: kappa = 0.59–0,76).

**Studie 4.** För att undersöka om socioekonomisk tillhörighet och typ av arbete påverkade uppkomsten av knäledsartros studerades 990 patienter som opererats med knäledsprotes och proximal tibiaosteotomi. För varje patient identificerade 3 ålders- och könsmatchade kontroller. Med hjälp av folkboksdatal inkry och sociala förhållanden under 1970 fann vi att jordbrukare hade en 70% ökad risk (p<0,0005) och byggnadsarbetare en 40% ökad risk (p=0,047). Personer med kontorsarbete visade en riskreduktion med 30% (p=0,00). Personer med kontorsarbete visade en riskreduktion med 30% (p=0,001). I en undergrupp (n=451) kunde vi visa att ensidig förslitning var 3,7 gånger vanligare hos män än hos kvinnor och hos byggnadsarbetare 3,2 gånger vanligare än hos andra yrkesgrupper. Detta kan tolkas så att tidigare knäledskada är en viktig orsak till utveckling av ensidig knäledsartros även om bevis saknas.

**Studie 5.** För att undersöka om biomekaniska faktorer relaterade till bälken och höftregionen kan spela roll för utveckling av medial respektive lateral knäledsartros studerades röntgenbilder av bälkenet på 29 kvinnor med lateral och jämförs med 27 kvinnor med medial knäledsartros. Patienter med lateral knäledsartros hade ett 13,7 mm bredare (p=0,001) häcken än kontroller och de med medial knäledsartros 11,4 mm längre (p=0,005) avstånd från acetabulum till femur (offset). Hos patienter utan höftartros
(lateral/medial = 12/9) hade de med lateral knäartros ett bredare bäcken \( p=0.009 \), kortare femurbäckenlängd \( p=0.02 \) och offset \( p=0.04 \) än medial artros. I gruppen med höftartros (lateral/medial: 17/18) fann vi ökad femurbäckenrotation \( p=0.008 \), medan skillnaden i bäckenvidden försvann \( p=0.15 \). Vi fann en kortare havarm över höften vid lateral jämfört med medial knäledsartros \( p=0.02 \), men inte jämfört med kontroller. Denna studie visade att bäcken och höftanatomin skiljer sig fast på olika sätt från det normala beroende på förekomst av medial eller lateral knäledsartros.

**Studie 6.** För att undersöka om rörelser och moment över höft och knä skiljer sig mellan medial och lateral knäledsartros undersöktes 5 patienter ur vardera gruppen och 5 kontroller med rörelseanalyser där ledvinklar och ledmoment uppmättes vid gång. vårt hypothesis var att förutom förväntade skillnader av knäledskinetik och kinematik mellan grupperna, skulle det även finnas skillnader av motsvarande parametrar i höftleden. Patienter med lateral knäledsartros hade mer höftadduktion \( (2^\circ, p=0.015) \) och 7 graders ökad utåtroteration \( p=0.001 \) jämfört med kontroller. Patienter med medial knäledsartros hade 7 grader ökad höftabduktion \( p<0.001 \). Det maximala abducerande momentet över knäen var 52% högre vid medial OA \( p=0.005 \) och 63% lägre vid lateral artros \( p<0.001 \). Tibia utåtroterades mer vid medial artros och inåtroterades mer vid lateral artros.

**Studie 7.** Dynamisk radiostereometri användes för att studera knäledens detaljerade rörelse- mönster (kinematik) på 5 patienter med lateral knäledsartros. Vid undersökningen utförde patienterna en aktiv sträckning av leden när de steg upp på en plattform. Data jämfördes mot 11 friska kontroller. Vid lateral artros noterades att den mediala femurkondylen förflyttades längre fram än hos kontroller. Vid jämförelse med tidigare studier av patienter med medial artros förelåg ökad inåtroteration av tibia, vilket kan relateras till nedsatt rörlighet av framför allt den mediala femurkondylen hos patienter med medial artros.
Acknowledgements

I want to express my gratitude to those who with their work, influence, patience, and enthusiasm guided and supported me through this work. I want to thank:

Johan Kärholm, my tutor, for your enormous patience with this work, as well as your patience with me. Thank you for your humble attitude to science and humans.
Eva Fermén, for all your professional help as secretary, acting as an important link between me and my tutor and most of all for your personal help and guidance during these years.
Tuuli Saari, for all support, collaboration and patience when reading manuscripts and with all my questions.
Roy Tranberg, for all discussions about kinetics and kinematics, lasting for hours.
Lennart Jonsson and his colleagues at Medical Technical Department at Halmstad hospital, for technical knowledge and support.

Andy McPherson for language correction.
Anders Holmén, FoU Halmstad, for strenuous support regarding statistics, references, computer programs. You always solved the problems.
Marie Hultgren for your invaluable help with patient administration.
My colleagues at the Department of Orthopaedics and the personal at the Department of Surgery, Halmstad Hospital during the collection of specimens from knee arthroplasty surgery.
My colleagues Ingvar Mars, Claes-Göran Cederglund and Björn Flodmark at the Radiographic Department, Halmstad Hospital for your practical help and discussions.
The Department of Radiology, Halmstad Hospital for use of radiographic laboratories.
Vetenskapliga rådet, Hallands county, for economic support.
References


Vaughan CL, Davis BL, O’Connor JC. Dynamics of Human Gait. Second ed. Western Cape, South Africa: Kiboho Publisher; 1999.


