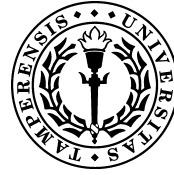# Clinical and Radiographic Outcome of Total Knee Arthroplasty

IRINA RINTA-KIIKKA

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Factors Related to Loosening

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■

CONTENTS

1. LIST OF ORIGINAL COMMUNICATIONS

This dissertation is based on the following original communications:

I   Rinta-Kiikka I, Savilahti S, Lindholm TS, Pajamäki J and Laippala P (1997): Measurement of lower limb alignment using short and long radiographs of the knee. *Ital J Orthop Traumatol 23(4): 497–504.*

II   Rinta-Kiikka I, Savilahti S, Lindholm TS and Pajamäki J (1996): Radiologic changes in alignment in the lower extremity after clinically successful total knee replacement. *Orthopaedics (International edition) 4(2): 101–107.*

III   Rinta-Kiikka I, Savilahti S, Pajamäki J and Lindholm TS (1996): A five to seven years follow-up of 102 cementless Synatomic knee arthroplasties. *Ann Chir Gyn 85(1): 77– 85.*

IV   Rinta-Kiikka I, Alberty A, Savilahti S, Pajamäki J, Lindholm TS and Tallroth K (1997): The clinical and radiological outcome of the rotating hinged knee prostheses in the long term. *Ann Chir Gyn 86(4): 349–356.*

V   Rinta-Kiikka I, Savilahti S, Pajamäki J, and Lindholm TS (1999): Intermediate-term clinical and radiographic results of Synatomic and AGC knee prostheses. *Orthopedics 22(3): 295–299.*

2. ABBREVIATIONS

AP   Anteroposterior
BMI   Body mass index
CSR   Cumulative survival rate
DJD   Degenerative joint disease
FFC   Fixed flexion contracture
MCL   Medial collateral ligament
OA   Osteoarthritis
PCL   Posterior cruciate ligament
PMMA   Polymethylmethacrylate
RA   Rheumatoid arthritis
ROM   Range of motion
SD   Standard deviation
TAA   Tibiofemoral angle measured in knee radiographs taken supine using distal femoral and proximal tibial anatomical axes
TAB   Tibiofemoral angle measured in knee radiographs taken weight-bearing using distal femoral and proximal tibial anatomical axes
TAC   Tibiofemoral angle measured in whole lower extremity radiographs taken weight-bearing using tibial and femoral mechanical axes
TAD   Tibiofemoral angle measured in whole lower extremity radiographs taken weight-bearing using tibial and femoral anatomical axes
TFA   Tibiofemoral angle
TKA   Total knee arthroplasty
UHMWP   Ultra-high molecular weight polyethylene

3. INTRODUCTION

In the early 1970s, a considerable variety of prosthetic designs were available, ranging from rigidly constrained metal-to-metal hinges to totally unconstrained metal-to-plastic compartmental resurfacings. The first bicondylar total knee prostheses were Freeman- Swanson, introduced in 1970, and the Geometric knee in 1971 (Coventry et al. 1972, Freeman et al. 1973a). The development of less constrained devices proceeded by emulating the form and kinematics of the human knee and taking account of the low-friction principle first formulated by Charnley (1972) for hip arthroplasties. Preliminary reports on modern total knee prostheses of nonlinked design from the early 1970s indicated that long-lasting results might be achieved (Coventry et al. 1972, Marmor 1973, Ranawat and Shine 1973).

For many of the designs evolved, however, longer-term follow-up revealed a high rate of loosening requiring reoperation (Bryan and Peterson 1979). Many of these early designs have since been abandoned, and in more recent decades total knee prostheses have gradually evolved to a tricompartmental design in which the components physically simulate, to a greater or lesser degree, the normal anatomy of the bones they resurface. Patellar resurfacing was introduced as a possible solution for patellofemoral symptoms, but early enthusiasm was tempered by concerns about implant loosening, patellar fracture, avascular necrosis and patellar dislocation (Insall et al. 1982, Scott 1982).

Although the incidence of early failure due to loosening seems to have been considerably reduced by means of modern designs, there continues to be concern over the long-term survival of the endoprosthesis-knee. Since this system may be affected by a variety of factors related to the patient, the operation or the design of the prosthesis, a closer examination of these background components is clearly of relevance. The aim of this study was to clarify the relationship between clinical symptoms and prosthesis outcome. Special emphasis was placed on a clarification of the possibilities and, on the other hand, the limitations of radiographic assessment.

4. REVIEW OF THE LITERATURE

4.1. General background

The modern principles of knee joint replacement were formulated by Gluck as early as 1890. At that time, no suitable biomaterials were available for further development. Subsequently, in 1951, Walldius introduced his hinged knee prosthesis, which was a metal-to-metal hinged joint fixed without bone cement (Walldius 1960). With this prosthesis knee replacement became a viable alternative in cases of a severely destroyed knee, particularly in patients with advanced rheumatoid arthritis. Walldius's prosthesis, however, failed to attain widespread acceptance by reason of its high complication rate, especially deep infections and prosthetic loosening. In most cases, moreover, remaining bone substance was insufficient for alternative procedures if these prostheses failed to function. In any case, Walldius made the first move toward a new generation of knee arthroplasties. After this first knee prosthesis model, several other designs were evolved (Marmor, St Georg, Walldius, Shiers, GUEPAR), constituting an intermediate phase in the overall progress in the field.

In designing newer prostheses, attempts have been made to imitate more closely the normal biomechanics of the knee joint, and to take into consideration the patellofemoral joint. At the same time, investigation of alternative implant fixation methods has achieved considerable advances. Improvement in the design of components and in surgical and fixation techniques have reduced the number of failures due to loosening.

4.2. Failure mechanisms

4.2.1. Aseptic loosening

In the case of the earlier implant designs, tibial component loosening was frequently the most common cause of failure with cemented fixation (Scuderi et al. 1989, Windsor et al. 1989). The magnitude of this problem has been greatly reduced by modification of the tibial component to incorporate metal backing and improved coverage of the tibial surface by the implant (Bartel et al. 1982, Windsor et al. 1989). Lewis (1991) introduced two main hypotheses, mechanical and biological to explain the loosening of cemented components.

Mechanical loosening may ensue from the degradation of the mechanical properties of polymethylmethacrylate (PMMA) or possible third- body wear from PMMA debris and deterioration of the bone-cement interface (Kraay et al. 1991). According to Hungerford and Kenna (1983), among others (Freeman et al 1985), methylmethacrylate is brittle and prone to fatigue fracture and is a poor transmitter of tensile stresses (Hungerford and Kenna 1983). Biologically, the bone-cement interface is always populated with macrophages (Kapandji 1970), and these cells, possibly activated by motion or unacceptable stress leading to cell death, may initiate osteoclastic activity and destroy precisely the bone to which the implant is bonded (Lewis 1991).

The various modes of tibial component loosening may, according to Cameron and McNeice (1981), be divided into five mechanical groups. The most common type in practice is the first tibial loosening mode: tilt and sink. Matthews et al. (1985) and Shimagaki et al. (1990) established that abnormal stresses secondary to disengaged polyethylene on the metal tray were linked to anterior and posterior lift-off and/or sinking. Too little stress on the trabecular bone supporting a prosthetic component, due either to disuse or to stress shielding, leads to trabecular atrophy, weakening of prosthetic support, and subsequent failure (Matthews et al.1985). On the other hand, an excessive load may also simply fracture the supporting trabeculae. Pugh et al. (1973) and Radin et al. (1973) demonstrated that cyclic loading of the bone can cause fatigue failure of trabecular bone.

Windsor et al. (1989), analysing the predisposing factors underlying failure by tibial loosening, found tibial component durability to be diminished above all by postoperative varus tibial alignment, varus component positioning and excessive tibial bone resection. Shift of the tibial component in varus or valgus direction or of the femoral component anteriorly or posteriorly, can be identified by comparison of sequential radiographs. Also subsidence of the tibial component may occur, but is difficult to determine radiographically (Schneider et al. 1982a). Other modes of tibial component failure, described by Cameron and McNeice (1981), are torsion and toggle, both uncommon and somewhat difficult to determine radiographically.

4.2.2. Component wear and osteolysis

Host response to particulate debris is known to be a key factor in the genesis of osteolytic lesions. Initially identified as a possible cause of late aseptic failure of cemented hip arthroplasties (Howie et al. 1988), it has been documented with increased frequency in well-fixed cemented implants (Anthony et al. 1990, Robinson et al. 1995) and more recently in cementless implants (Drown and Ring 1985, Maloney et al. 1990). Wear and breakage of polyethylene components have been documented as long-term problems since the early 1980s; polyethylene wear debris has rapidly emerged as the major culprit (Drown and Ring 1985, Anthony et al. 1990, Maloney et al. 1990).

Contact between metal and polyethylene components in total knee arthroplasty (TKA) results in a complex stress distribution on the surface and within the polyethylene (Bartel et al. 1986). A correlation between inadequate implant alignment and polyethylene failure has been ascertained (Engh 1988, Wallace et al. 1998). Shearing and distortion of the polyethylene occur upon indentation of the metal femoral component on the tibial surface. Such stresses on the polyethylene cause pitting and delamination of the articular surface, with resultant debris (Wimmer et al. 1998). The biologic response in the surrounding tissues, induced by particles of polyethylene, may induce histiolytic endosteal bone resorption and deterioration of the bone-implant interface (Wright and Bartel 1986, Wright et al. 1988). Debris from damage to the articular surface of polyethylene components in TKAs has been shown to contribute to long-term problems such as loosening and infection (Howie et al. 1988, Wright et al. 1992, Robinson et al. 1995). Younger, overweight patients with OA appear to run an increased risk of osteolysis and implant failure (Bartel et al. 1986, Robinson et al. 1995).

Many more recent studies of osteolytic reactions around total knee components have focused primarily on cementless implants (Gross and Lennox 1992, Peters Jr et al. 1992). Wear is dependent on a variety of factors, these including contact area, load, material properties, thickness of the polyethylene inlay and the length of time the component has been implanted (Bartel et al. 1986, Engh et al. 1992). Wright et al. (1988) and Hood et al. (1983) have classified the modes of surface damage occurring on polyethylene joint components and identify three important factors controlling the stresses associated with these damage modes: 1) the conformity between the metallic and polyethylene articulating surfaces, 2) the thickness of the polyethylene, and 3) the elastic modulus of the polyethylene material.

The incidence of polyethylene wear and subsequent osteolysis varies in the literature. Discrepancies may be due to differences in the definition of wear and the difficulty in detecting osteolytic changes on radiographs. Radiographs tend to underestimate the lytic defects, most of which may be radiographically imperceptible (Robinson et al. 1995).

4.2.3. Tibiofemoral instability

The incidence given for tibiofemoral instability has varied in different studies. In one series of 137 revision TKAs ten per cent were revised for instability (Friedman et al. 1990). Goldberg et al. (1988b) studied 65 revision TKAs and noted that the main reason for initial failure was prosthetic loosening and instability, and in a series reported by Rööser et al. (1987), 20 per cent of 76 revision TKAs were revised for instability.

Wang and Wang (1997) identified two patterns of sagittal plane instability: one with posterior translation of the tibia, occurring mainly in the postoperative period and usually resulting from a trauma, the other with anterior translation of the tibia, occurring 6 months to 7 years postoperatively without preceding trauma.

Angular errors can lead to chronic attritional incompetence of the supporting ligamentous structures. Instability may result from surgical errors in bony resection, overresection of the posterior femoral condyles possibly leading to difficult matching of flexion extension gaps and subsequent posterior instability. An excessive posterior slope of the tibia may also lead to a similar instability pattern (Fehring and Valadie 1994).

In a series of four cases of posterior subluxation of the tibia, two were associated with severe preoperative valgus deformities (Insall et al. 1979a). Galinat et al. (1988) and Sharkey et al. (1992) confirm the finding. Improper design of implants may likewise cause instability (Galinat et al. 1988, Gebhard and Kilgus 1990). Related to angular alignment of the extremity and implant design, incompetence of major ligamentous structures (most commonly MCL and PCL) and a deficient extensor mechanism can lead to functional anteroposterior instability (Cross and Powell 1984, Fehring and Valadie 1994). Merkow et al. (1985) and Sharkey et al. (1992) also noted that patellar instability, either subluxation or dislocation, was the primary problem accounting for most cases of tibiofemoral dislocation.

4.2.4. Fractures

Fracture following a total knee arthroplasty is a complication almost invariably necessitating revision (Torisu and Morita 1986). In a report on stress fracture of the tibia in 15 patients after geometric and polycentric TKAs, Rand and Coventry (1980) attributed the stress fracture mainly to axial malalignment and component orientation at the time of operation. On the femoral side, the most common fracture type associated with a knee endoprosthesis is the supracondylar fracture, with an incidence varying from 0.6% to 2.5 % (Convery et al. 1980, Delport et al. 1982, Webster and Murray 1985, Rutledge et al. 1986). All the reported fractures were traumatic and none of the patients had notching of the anterior cortex of the femur, though Merkel and Johnson (1986) are of the opinion that excessive anterior notching of the distal femur predisposes it to fracture. In the above-mentioned series reported by Rutledge et al. (1986), all patients had rheumatoid arthritis and 90 degrees motion before the femur fractured.

Fracture may equally well occur in endoprosthetic components, fracture of tibial components being formerly common (Ranawat et al. 1986, Moreland 1988, Morrey and Chao 1988). Also fracture of the femoral component has on occasion been reported in unicompartmental replacements (Moreland 1986, Cameron and Welsh 1990). One prominent factor influencing the rate of femoral component fractures is component size, smaller implants being found to fracture much more often than larger ones (Whiteside et al. 1993).

4.2.5. Patella-resurface or not?

Although the success of knee arthroplasty has improved dramatically over recent years (Merkow et al. 1985), patellar articulation remains a frequent source of complications (Abraham et al. 1988, Doolittle and Turner 1988). The need to resurface the patella as a part of a total knee arthroplasty remains controversial.

In TKAs without patellar resurfacing postoperative patellar or retropatellar pain has been reported to occur in 26% of cases as compared to 8% in arthroplasties with patellar resurfacing (Moreland et al. 1979). On the basis of this observation, patellar resurfacing was recommended. Likewise Sheehan (1978) reported that patellofemoral replacement would be indicated in every case, in view of the unpredictability of anterior knee pain. Figgie et al. (1986) give as high a proportion as 40% of patients in their series with posterior stabilized condylar knee prosthesis with patellar resurfacing as experiencing anterior or retropatellar pain. Without patellar resurfacing residual patellofemoral symptoms have been reported in between 16% and 30% of patients (Gunston and MacKenzie 1976, Sledge et al. 1978, Ranawat 1986). Elsewhere, in contrast, no difference has been found comparing resurfaced and non-resurfaced TKA knees (Partio and Wirta 1995).

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Some authors recommend routine resurfacing (Enis et al. 1990) some routine no-resurfacing (Smith et al. 1989, Levitsky et al. 1993). In addition, many have recommended resurfacing of patellae in selected cases. Picetti et al. (1990), Boyd et al. (1993), Rand (1994) and Kajino et al. (1997) recommend patellar resurfacing for patients with RA, Picetti et al. (1990) resurfacing of patellae in OA patients more than 160 cm tall and more than 65 kg in weight. Levitsky et al. (1993) suggest patellar resurfacing for younger, active patients.

4.2.6. Patellar fractures

Patellar fractures after TKA are uncommon (Insall et al. 1982, Insall et al. 1983), although one study documents an incidence of 21% (Cameron and Fedorkow 1982). Goldberg et al. (1988a) observed that 80% of patellar fractures occur within the first two years after operation.

Causative factors here include vascular compromise resulting from surgery, especially after a medial parapatellar arthrotomy, fat pad excision and lateral release, mechanical compromise consequent upon bone removal for resurfacing, peg fixation and cementation, and thermal damage from polymethylmethacrylate and improper patellar tracking (Hozack et al. 1988). Ranawat (1986) holds that improper femoral component size causes increased tension in the quadriceps mechanism and constitutes an etiologic factor in patellar fractures.

In selecting the patellar component, fixation lugs are of importance. If a central fixation lug is used, a smaller lug reduces the risk of postoperative patellar stress fracture (Clayton and Thirupathi 1982, Scott et al. 1982). The surgeon should remove no more than the amount of bone which is to be replaced by the patellar implant in order to avoid complications (Ranawat 1986).

Patellar fractures have been found to be more common in an older patient group, suggesting that they are more likely to occur in osteoporotic patellae (Brick and Scott 1988). However, patellar complications in general are on average more common in younger and heavier patients (Rosenberg et al. 1988). Brick and Scott (1988) compared patients with rheumatoid and osteoarthritis and found no statistically significant differences between these groups in the incidence of patellar fractures. Histologic examination of bone from fractured patellae has shown evidence of osteonecrosis (Scott et al. 1982).

4.2.7. Patellar instability

Patellar subluxation or dislocation has been related to inadequate soft tissue balance or a rotational malalignment of the tibial or femoral components (Bryan and Rand

1982, Merkow et al. 1985, Goldberg et al. 1988b). Quadriceps imbalance is seen to be as the second most common cause of patellar instability after rotational malalignment of the tibial and femoral components. A major function of the vastus medialis is to stabilize the patella against the lateral pull of the vastus lateralis (Kettelkamp and DeRosa 1976). Relative weakness of the vastus medialis or hypertrophy of the vastus lateralis will thus tend to sublux the patella laterally (Insall 1986). This is a frequent problem especially in knees with long-standing valgus deformity greater than 20 degrees, or previous patellar dislocation.

Symptomatic patellar instability after TKA has been reported in from less than 1% to nearly 50% of cases (Moreland et al. 1979, Buchanan et al. 1982, Cameron and Fedorkow 1982, Clayton and Thirupathi 1982). Nonetheless, the need for surgical treatment of patellar instability is uncommon, according to Grace and Rand (1988) 0.4%.

4.2.8. Infections

Deep infection must always be suspected in the presence of prosthetic loosening, especially if the loosening is gross and the knee has undergone previous surgery (Bryan and Rand 1982). Once a joint infection has occurred, it may present a major clinical problem (Hagemann et al. 1978). The two major categories are early (acute) and late sepsis, the latter being subdivided into two further categories, those with draining sinuses and those without.

An elevated erythrocyte sedimentation rate and pain may be the only clues to deep infection. Aspiration of the knee for culture is useful when positive, but a negative culture does not exclude infection (Bryan and Rand 1982, Schneider et al. 1982b).

In the radiograph, the progression of a radiolucent line and absence of a radiodense line surrounding the radiolucency may be a sign of deep infection (Schneider and Soudry 1986).

The various infection rates given in the literature are shown in Table 1.

Table 1.

Series	No. of knees	No. of prim/ rev	Follow- up time	Infection rate %
Rutledge et al.1986	245	245/0	over 2 years	2.0
Rand and Bryan 1988	50	0/50	4.8 years	0
Windsor et al. 1989	1430	1430/0	3- 12 years	0.63
Wilson et al. 1990	4171	both	3-17 years	1.6
Gill and Mills 1991	1000	1000/0	51 months	0.7
Hohl et al. 1991	61	6/29	6.1 years	5.7

Some authors have noted the oversized components and diagnosis of RA to be risk factors involved in cases of deep infection (Bryan and Rand 1982, Bengtson and Knutson 1991). In RA, the correlation with infections may be due to a greater tendency toward delayed wound healing (Garner et al. 1973) or to the use of steroids (Nelson 1987).

Previous operations on the knee have been associated with an increased risk of infection immediately postoperatively. Goldberg et al. (1988b) report that the infection rate in their revision study was 4.5% higher than in primary surgery. Wilson et al. (1990) confirmed this risk, but only in knees with a diagnosis of OA. Hartman et al. (1991) found no statistically significant relationship between success and failure in respect of age, gender, length of intravenous antibiotic therapy, previous surgery, preoperative diagnosis or time from clinical symptoms to debridement. Taking into account such variable success rates for the treatment options, attention should clearly also be focused on prophylactic measures.

4.3. Determining the clinical outcome

4.3.1. Survival analysis

With increasing numbers of total hip and knee arthroplasties now being undertaken, a need for an accurate follow-up parameter has arisen. Formerly, results were often reported as percentages, but the figures given were not comparable by reason of differences in the length of follow-up (Dobbs 1980). Armitage (1971) described a method of survival analysis which is used to calculate the probability of a certain event such as failure of a prosthesis as a function of time elapsed since operation. Survival analysis is a means of analysing data which can be applied for patients with different lengths of follow-up, allowing cases to enter and be withdrawn from a trial at any stage and for whatever reason. Considering the varying duration of follow-up, this constitutes a powerful tool in comparing results with different prostheses (Dobbs 1980, Nelissen et al. 1992).

In attempts to evaluate accurately the longevity of TKA results, two modes of survival analysis can be applied to follow-up data. So-called actuarial survival analysis or life-table analysis evaluates survival rates using a series of artificial time intervals; usually the number of failures is determined each year after the operation (Tew and Waugh 1985). The product-limit or Kaplan-Meier method differs from this latter in that it performs survival calculations at the exact times failures occur (Kaplan and Meier 1958).

There are advantages and disadvantages to both methods. The life-table method also allows confidence limits to be more readily determined and displayed. In consequence of the frequent recalculations, however, no table can be constructed,

and such a table would be advantageous in that it can include details of the number of joints followed, the number of failures and the number lost to follow-up (Murray et al. 1993).

Lettin et al. (1991) and Nelissen et al. (1992) have criticized survival analysis in general, because it can be affected by the size of the population of patients and the way the outcome is defined; the smaller the group, the wider the confidence intervals and thus the greater the uncertainty as to the probability of survival (Nelissen et al. 1992). A number of authors hold that 95 % confidence limits should be plotted in order to demonstrate the reliability of the survival curve (Nelissen et al. 1992). Survival analysis without confidence intervals is of little clinical significance (Lettin et al. 1991, Murray et al. 1993).

The theoretical advantages of the product-limit method, again, are that the arbitrary choice of time intervals is avoided, and that it is more accurate since the survival rate can change during the intervals. For joint replacements, however, these assets are in fact negligible, since patients are commonly reviewed annually. The life-table method is thus recommended with presentation of both the survival curve and the life table (Murray et al. 1993).

Revision of arthroplasty is the most widely used definition of failure. However, revision may be delayed or even postponed because of many extraneous factors, and in such cases early failures will be classified as continuing successes. One solution to this is to use more than one definition for failure (Murray et al. 1993). Nonetheless, it will remain difficult to compare survival analyses until a consensus is reached as to the outcome measures which should be assessed.

4.3.2. Scoring systems

Results after knee arthroplasty operations have been evaluated in many ways. Several scoring systems have been created in the search for an objective means of assessing patients postoperatively, and in addition, comparing the results obtained with different prosthetic designs. In Table 2. some of the most frequently used scoring systems are shown.

The Hospital for Special Surgery (HSS) knee score is perhaps that most widely used (Insall et al. 1989). It has its limitations, in that it incorporates a functional component, and the score tends to deteriorate as patients age, although the knee remains unchanged (Insall et al. 1989). Also other systems which take into account the functional status have the same problem, for example the Kettelkamp scale (Rutledge et al. 1986). In addition, patients with general infirmity or polyarticular arthritis may have received poorer scores for a comparable knee (Hohl et al. 1991).

Insall et al. (1989) proposed a new rating system (The Knee Society clinical rating system) in which the rating is divided into separate knee and patient function

scores. Konig et al. (1997) used this evaluation system, and concluded that systems adding up knee and functional rating to an overall result should not be used. Generally, it has been found that although an operation may be considered successful in terms of prosthetic function, improvement with regard to patient activity is less satisfactory; this would imply the advisability of separating other clinical factors from the lower extremity function.

Table 2.

Scoring system	Pain	Alignment	Deformity	Flexion contracture	Walking	ROM	Other
HSS Rating system	X	X	X	X	X	X	Climbing stairs
Callihan and Halley (1985)	X				X		
Freeman et al. (1973)b	X				X	X	
Kettelkamp scale (1975)							
Brigham knee score (1984)	X	X	X		X	X	
Mayo Clinic Rating scale	X		X	X	X	X	Stability, Effusion
The British Orthop Assoc.	X	X	X	X	X	X	Climbing stairs
Hungerford and Kenna (1983)	X		X	X	X	X	Synovia, activity
The Knee Society rating system	X	X	X	X	X	X	Climbing stairs
Weinfeld evaluation system (1969)	X	X	X	X	X	X	Quadric. function

4.4. Clinical symptoms and factors related to loosening

4.4.1. Pain

It has been estimated that 80% of individuals over 55 years of age have degenerative arthritis of the knee and that 10% have pain which limits activity (Kellgren and Lawrence 1958). It is not clear why some have more pain than others. Pain is a subjective sensation, the severity of which may not relate directly to the apparent cause. This variable response to pain is multifactorial. Neurogenic inflammation, measured in serum and joint fluid, has been postulated as one reason why some degenerative joints hurt and others do not (Marshall et al. 1990).

Preoperatively, patients with varus alignment usually complain of pain, whereas those with valgus or patellofemoral disease describe the knee as weak, unstable or deformed. Because pain is the most compelling reason for seeking medical intervention, patients with varus may seek evaluation earlier in the course of their disease (Barrett et al. 1990).

Postoperatively, pain has been associated with infections, loosening, reflex sympathetic dystrophy and occasionally litigation. Ritter (1997) found no correlation between these abnormalities and pain. In the case of total knee replacement, pain of patellar origin is usually held as a distinct pain type, described as retropatellar or anterior knee pain.

4.4.2. Range of motion (ROM)

In general, although the principal movements of the knee are flexion and extension, significant rotation and lateral movement also occur (Swanson 1980). In the normal knee some posterior rollback of the femur occurs as the knee flexes, and the instantaneous center moves back and forward some millimetres (Swanson 1980). Brantigan and Voshell (1941) observed that both menisci slide backward with flexion, the medial meniscus moving only a few millimetres, the lateral at least one centimetre. When measuring the load against the knee joint the tibial contact points on the medial side have been anterior in extension, and moved to the center in flexion, to remain there for further flexion. On the lateral side, the contact point is initially central and moves steadily posteriorly with flexion (Nilsson et al. 1990, Walker and Garg 1991).

One of the primary goals of TKA is the restoration of a painless, functional range of motion (Parsley et al. 1992). After arthroplasty, the range of motion can be adequate for good function yet not the same as normal. Up to 113 degrees of knee motion is needed for healthy adults to rise from a chair, and some activities such as the lifting of an object from the floor may require 117 degrees (Laubenthal

et al. 1972). Hungerford and Krackow (1985) give that an arc of 5 to 70-80 degrees as that usually providing normal gait, including stair walking. Others are of the opinion that flexion beyond 90 degrees is desirable to facilitate rising from a chair, and this is especially important for patients with bilateral knee disease (Friedman et al. 1990) or for patients having solid knee arthrodesis on the opposite side (Kaufer and Matthews 1979).

The most important determinant of postoperative ROM is the range prevailing before arthroplasty (Ranawat et al. 1976, Insall et al 1983, Rorabeck et al. 1988). Patients with preoperative flexion less than 75 degrees have shown an improvement and those with preoperative flexion greater that 95 degrees a decrease in postoperative flexion (Parsley et al. 1992, Anouchi et al. 1996).

A correlation has been ascertained between diagnosis and postoperative ROM (Parsley et al. 1992, Harvey et al. 1993). A positive correlation was found between pre- and postoperative flexion with stronger predictability in an inflammatory patient group (Parsley et al. 1992, Harvey et al. 1993). Dennis et al. (1992) found, in contrast, no statistically significant differences between OA and RA in a comparison of the pre- and postoperative flexion.

In clinical follow-up studies of TKA, the average range of motion is usually between 80 and 120 flexion, depending on the type of prosthesis and the patient population. There is usually considerable variation between different series (Townley 1985, Ranawat and Boachie-Adjei 1988, Ewald et al. 1991). No correlation has been found between flexion and the age or gender of the patient (Ritter and Stringer 1979).

Prosthetic component alignment affects the ROM. If the femoral component is positioned in anterior tilt, cruciate ligament tension is reduced and flexion increased (Kaufer and Matthews 1979, Walker and Garg 1991). Tilting the tibial component in the sagittal plane likewise affects flexion; a 10 degree posterior tilt gives 30 degrees of extra flexion, and an anterior tilt the opposite effect (Walker and Garg 1991). There is no consensus on the matter of patellar resurfacing, but Murray (1985) established that flexion is increased between 5 and 10 degrees following patellar resurfacing.

4.4.3. Flexion deformity

Fixed flexion contracture (FFC) is among the most challenging of total knee arthroplasty situations. Underlying FFC is a complex combination of ligamentous, capsular and bony deformity. Flexion contracture reduces the femorotibial weight-bearing surfaces and concentrates stress posteriorly. It also increases stresses in the patellofemoral joint (Maquet 1980).

Knees with a minor degree of flexion contracture are usually corrected by ligamentous and capsular release. Fixed flexion greater that 30 degrees usually

requires collateral ligament release and release of the peripheral posterior capsular margin of the concave side of the deformity (Hood et al. 1981, Firestone et al. 1992).

Satisfactory results have been reported with patients suffering preoperatively from severe deformity and restricted ROM (Bradley et al. 1987, Tew and Forster 1987, Aglietti et al. 1989). Interestingly, Tew and Forster (1987) also state that even though flexion deformity more often and more seriously affects rheumatoid than osteoarthritic knees, arthroplasty was nevertheless more successful in correcting the deformity in the former.

Greater flexion deformity has been shown to have an adverse effect on knee function by reason of the increase in quadriceps energy expenditure and joint reaction forces during weight-bearing (Perry et al. 1975). A correlation has also been found between pain and residual flexion contracture after total knee arthroplasty (Ritter and Campbell 1987).

4.4.4. Lower extremity alignment

Logical surgery of the arthritic knee must aim at restoring an equilibrium between the mechanical stresses in the knee joint and the resistance of the tissues. Correction can be accomplished by adequate soft-tissue release and precise insertion of the prosthetic components. An exact correction of varus or valgus deformity would restore the anatomic shape and also the mechanical conditions which caused the disease to appear and to develop (Maquet 1980).

Hungerford and Krackow (1985) hold that error in the valgus direction is better tolerated than varus deformity. A series reported by Gibbs et al. (1979) and Bargren et al. (1983) demonstrated that varus alignment was associated with a 67% failure rate, neutral alignment with 29% and valgus alignment with 6%. In ideal lower limb alignment, both sides of the joint are loaded equally. With knee misalignment, force transmission to the tibia has been found to be the same whether the misalignment was produced by femoral or tibial component misplacement (Hsu et al. 1989).

Ewald et al. (1984) noted that the knees which had a preoperative varus deformity also tended to remain in varus. Residual varus, primarily of the tibial component, accounted for the overall varus alignment of the limb. This may be a contributing factor underlying the overall lower scores among varus deformity patients (Teeny et al. 1991).

4.4.5. Demographic factors

The difference in outcomes in different age groups is thought to be involved in, among other things, activity level. In studies of knee biomechanics no correlation has been found between the knee-alignment angles and age (Hsu et al. 1990). However, younger patients with an unsuccessful TKA result, have had OA more frequently than RA (Stern et al. 1990).

Barrett et al. (1990) noted differences in degenerative joint disease (DJD) between the sexes. Whereas the numbers of men and women with DJD varus were about equal, women with DJD valgus knees were twice as common as men, and primary patellofemoral arthrosis was seven times more frequent in women (Barrett et al. 1990). The explanation here lies in anatomical differences, namely the increased Q-angle in women (Barrett et al. 1990). Also patellar complications have been seen to occur more commonly in young, heavy, male patients (Rosenberg et al. 1988). However, three multi-centre studies report that neither sex nor weight had any effect on the durability of TKAs (Knutson et al. 1986, Scuderi et al. 1989, Rand and Ilstrup 1991).

There are varying opinions on patients' weight in the context of knee arthroplasty outcome. Leach et al. (1973) found that 83% of women and 35% of men with OA of the knee were overweight. An obese patient may generate stresses exceeding tolerable prosthetic limits. The interface areas for the obese are not much larger than those for normal patients, and the resultant contact stresses can easily reach dangerous levels (Matthews et al. 1985). Ahlberg and Lundén (1981) found a positive correlation between increased failure rate and overweight, Landon et al. (1985), for their part, exercise great caution in offering TKA to patients who weigh more that 100 kg, and Stern and Insall (1990) concluded that seriously overweight patients experienced significantly more patella-related problems.

However, other authors have found no statistically significant correlation between failures and overweight (Townley 1985, Windsor et al. 1989, Marcacci et al. 1997).

4.5. Radiographic factors related to loosening

4.5.1. Radiographic alignment

It is generally agreed that the best way to evaluate the lower leg alignment is to obtain a whole-leg anteroposterior radiograph with the subject in standing position (Jessup et al. 1997). Anatomic and mechanical axes of the femur and tibia can be drawn from the radiograph and alignment of the lower extremity measured (Maquet 1984, Moreland et al. 1987). The mechanical axis of the lower extremity is

determined as the line between the center of the femoral head and the center of the talus. The course of this line is determined at the level of the knee joint, and the neutral course is determined slightly medial of the center of the knee joint (Kennedy and White 1987). The mechanical axis of the femur is thus the line between the center of the femoral head and the center of the knee joint, and the mechanical axis of the tibia is the line between the center of the knee joint and the center of the ankle.

Two means of defining the anatomical axis of the femur can be used. First, it can be defined as the line in the mid-shaft medial-to-lateral width of the femur to the center of the knee. The second approach is to begin the shaft center line ten centimeters above the surface of the knee joint, midway between the medial and lateral surfaces (Moreland et al. 1987).

There are, however, differences in the results of tibiofemoral angles measurement by different authors. Moreland et al (1987) described a physiological tibiofemoral angle of 4 degrees valgus with an anatomical axis running through the center of the knee, i.e., an angle of 6 degrees valgus with a femoral anatomical axis defined by the midpoints of the femoral shaft and thus lying somewhat off the center of the knee. Definitions of these axes differ and it remains open whether these differences lead to different numerical results. Kapandji (1970) and Maquet (1976) give 6 degrees valgus as the physiological angle between anatomical and mechanical axes. In both of the studies in question, the axes were defined based on the center of the knee located in the intercondylar notch of the femur.

Postoperatively, prosthetic component alignments are measured from radiographs as recommended by Hood et al. (1981). They used the distal anatomical axis of the femur and the proximal anatomical axis of the tibia with respect to the horizontal lines of the prostheses components. In addition, Mont et al. (1996) measured tibial and femoral component displacement on anteroposterior and lateral films and recorded it in millimeters and displacements >3 mm medially or laterally were considered abnormal. Displacements >3 mm anteriorly or >10 mm posteriorly were considered abnormal.

When the patella is subluxated laterally to a significant degree, this is obvious on the radiograph without measurement. If however there is a minor degree of subluxation, it is more difficult to estimate. Merchant et al (1974) proposed a measurement to evaluate the degree of congruence of the patellofemoral joint, namely the congruence angle. Laurin et al. (1978) also developed a method for the evaluation of patellar subluxation this being based on what they termed the lateral patellofemoral angle. Both of these approaches are still in use depending on the radiographic technique. In addition, newer methods have been developed, for example that of Grelsamer et al. (1993), using the radiographic technique of Merchant.

Several other aspects of the patella can be measured from plain lateral knee radiographs. Gomes et al. (1988) introduced patellar radiographic measurements including measurement of patellar height, patellar length and lenght of articulating

surface, and distance from the tibial tubercle to the joint line. Patellar thickness can be measured from plain radiographs, as pointed out by Hofmann and Hagena (1987), who showed that the measurement differed very little from direct measurement after dissection.

The ratio between the length of the patella ligament and that of the patella itself (Insall and Salvati 1971) has been the most commonly used measurement of patellar height in the assessment of abnormal conditions such as osteoarthritis, recurrent dislocation of the patella and chondromalacia (Insall et al. 1972, Ahlbäck and Mattson 1978). Grelsamer and Meadows (1992) described a modified Insall-Salvati ratio, which also takes into account unusual patellar shapes. Abraham et al. (1988) measured patellar altitude as the distance from the joint line to the inferior edge of the patellar articular surface.

4.5.2. Radiolucent lines

The incidence of visualization of radiolucent lines at the cement-bone interface after TKA varies with different reported series and with different prostheses from 18% to 96% of patients (Insall et al. 1979a, Ritter et al. 1981, Ewald et al. 1984, Tibreval et al. 1984).

A number of theories have been put forward to explain the presence of radiolucency; among factors envisaged are poor cement packing, design of the prosthesis, motion of the prosthesis before the cement is fixed, interposition of blood between cement and bone, foreign body reaction to the cement with histocytic resorption, osteonecrosis due to the exothermic reaction of the cement, and development of a subchondral bone plate with a surface of connective tissue at the cement-bone interface due to stress (Reckling et al. 1977, Insall et al. 1979b, Tibreval et al. 1984, Ecker et al. 1987, Ritter et al. 1994). The size of the radiolucent lines, however, has been correlated to substantial and progressive migration (Ryd et al. 1987, Ryd et al. 1990). On the other hand, Ritter and Meding (1986) found no correlation between radiolucencies and anterior instability.

Many authors have noted that the lucent lines are most frequently located under both aspects of the tibial component (Reckling et al. 1977, Schneider and Soudry 1986, Rand and Coventry 1988). The higher incidence of a radiolucent zone on the side of the resin tibial rather than the metallic femoral component may suggest that generation of heat by bone cement plays a role in the development of a radiolucent zone (Torisu and Morita 1986). In contrast, Ritter et al. (1981) observed that more femoral components evinced a radiolucent zone than did tibial components, making the thermal hypothesis seem implausible.

Improper alignment after TKA has been shown to lead to the emergence of radiolucent lines (Ewald et al. 1984). Especially a connection between radiolucencies and varus-alignment has been noted (Ecker et al. 1987, Rand and

Coventry 1988, Patel et al. 1991). Some authors (Kim 1987, Hsu et al. 1989, Kobs and Lachiewicz 1993) have nonetheless found no correlation between radiolucencies and either varus or valgus alignment of the knee. Bargren et al. (1983) and Hsu et al. (1989) report that more medial tibial radiolucent lines were produced at the extremes of the alignment.

It is generally agreed that the relationship of radiolucent lines to loosening rates is dependent on their width and extent (Dennis et al. 1992). In asymptomatic patients the lines are usually thin, 1 mm or less in width (Schneider and Soudry 1986). Radiolucent lines wider than 2 mm at the cement-bone interface should be considered radiographic evidence of loosening (Schneider et al. 1982a). For example, Ecker et al. (1987) reported a 7% occurrence of thicker (>2 mm) radiolucencies located at the central peg and under both tibial plateaus of the total condylar prosthesis; these were associated with poor results. On the other hand, the incidence of loosening as a mode of clinical failure has consistently been found to be much lower than that of radiolucent lines (Reckling et al. 1977). Another important factor in determining radiolucencies is their progression. The significance of the nonprogressive type of line remains obscure. If progression occurs, infectious or mechanical loosening must be suspected (Schneider and Soudry 1986).

The data on radiolucencies and their significance are based mainly on studies with cemented total knee prostheses. Some radiologic findings pertinent to the evaluation of bone-cement and bone-component interfaces may have different implications. In cementless prostheses an osteoblastic reaction is developed for months allowing bone ingrowth which fixes the components (Ordonez-Parra et al. 1992). Partly, the discrepancies in results obtained concerning the significance of radiolucencies are due to the Mach effect, that is, to the presence of an apparent, but not real, lucency at the interface of two materials of greatly differing radiographic density (Lane et al. 1976).

Cook et al. (1989) studied histologically retrieved implants and found that radiolucencies were invariably associated with fibrous ingrowth, whereas sclerotic lines were associated with both fibrous and bony ingrowth. Insall et al. (1983) confirmed the finding that this fibrous membrane is seen in cementless prostheses as a radiolucent line even in knees with an excellent clinical result. In view of this observation, it is clearly difficult to determine the adequacy of component fixation based on radiolucencies.

5. AIMS OF THE PRESENT STUDY

The studies in this series were undertaken in order to clarify the various problem groups associated with TKA. Special emphasis was placed on an analysis of the possibilities of radiographic assessment.
The overall aims of the study were to ascertain:

1) The accuracy of long cassette, whole lower extremity radiographs compared with short knee radiographs in determining lower extremity alignment.

2) Whether clinically successful prostheses migrate during postoperative follow-up.

3) Whether there is any pre- or postoperative, clinical or radiographic factor which would indicate aseptic loosening in the case of a cementless knee prosthesis.

4) Whether a rotating hinged knee-prostheses can ensure acceptable results in the case of preoperatively severely unstable knees.

5) How the design of the femoral component effects tibio- and patellofemoral outcome. Is there a difference between anatomic and non-anatomic prosthesis design?

6. PATIENTS AND METHODS

6.1. Preoperative measurement of lower limb alignment (I)

A total of 103 arthrotic knees (63 patients) awaiting an osteotomy or endoprosthesis operation were radiologically evaluated prior to surgery. The group comprised 52 females and 11 males with a mean age of 70.1 years (range 45.7 to 82.4 years).

The study group was collected retrospectively. First, a long cassette (film size 30cm x 120cm) radiograph was taken of all 103 arthrotic knees, whereafter the patients were subdivided into two groups according to short radiographs taken at the same time as the long cassette: Group 1 consisted of 68 short knee radiographs taken in supine position (film size 24cm x 30cm) and group 2 of 35 short radiographs taken weight-bearing (film size 35cm x 35cm). In some cases imaging failed and preoperative assessment was made of 100 knees. Arthrosis stage was determined radiologically using the method described by Ahlbäck (1968). Most knees were classified as grade 1 (53/100) or 2 (27/100) arthrosis, located mainly in the medial or mediopatellar compartment of the joint.

The tibiofemoral angles were measured on every AP radiograph. In the short radiographs the angle was determined as the medial angle between distal femoral and proximal tibial anatomical axes. The anatomical axis of the distal femur was defined as the axis between the upper point midway on the femoral cortex, as proximal as possible, and the lower point between the tibial spines. The tibial anatomical axis was drawn correspondingly using the center of the tibial spines as the knee center reference point. The center of the femoral head, the knee and the ankle were determined as outlined in studies by Moreland et al. (1987).

The tibiofemoral angle thus measured was termed TAA in supine short radiographs and TAB in weight-bearing short radiographs (Fig 1a).

In long radiographs, correspondingly, the femoral anatomical axis was defined as a line between the tips of the tibial spines to midway between the femoral cortexes at the middle level on the greater trochanter. The tibial anatomical axis was defined as a line between the center of the tibial spines and the center of the talus. This angle was designated TAD (Fig 1b). From the long radiographs it was also possible to measure the tibiofemoral angle using the mechanical axes of the femur and tibia. The femoral mechanical axis was defined as a line drawn from the center of the tibial spines to the center of the femoral head. The mechanical axis of the tibia corresponded in practice to the tibial anatomical axis, and was thus not differentiated from it. The angle on the medial side of the femoral and

tibial mechanical axes was designated angle TAC (Fig 1b). In addition, a whole lower extremity mechanical axis was drawn between the femoral head and the center of the talus. The distance from this axis to midway on the tibial spines at knee-joint level was measured.
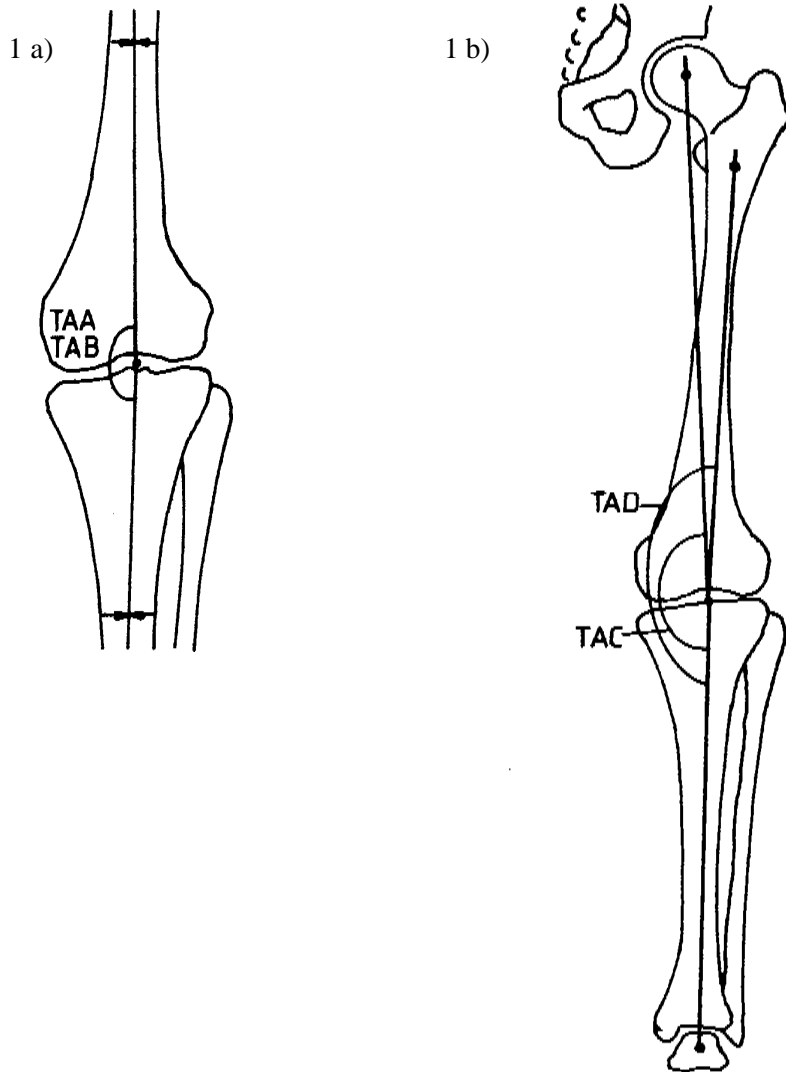

Figure 1. a) The tibiofemoral angles (TFAs) measured from short knee radiographs TAA in non- weightbearing and TAB in weightbearing radiographs, b) TFAs measured in long radiograph TAC using femoral mechanical and TAD using femoral anatomical axes (published by permission of J Italian Orthop Trauma)

6.2. Radiographic changes in postoperative alignment (II)

The study group consisted of 38 knee-prosthesis patients (52 knees) chosen retrospectively. The indication for TKA had been osteoarthritis in all cases. All these endoprosthesis knees were retrospectively regarded as clinically successful. On the Weinfeld (1969) evaluation system a clinically successful endoprosthesis knee was defined as a painless joint both at rest and in moderate exertion, without need for walking aids, range of motion well over 80 degrees and no instability.

The study group fulfilled these criteria, having a Weinfeld point range from 0 to 2.

The group comprised 28 females and 10 males of mean age 72.9 years (range 48.6 to 84.9 years). In addition to age, also height and weight were taken into account by body mass index (BMI). This was determined as the quotient between the square of the patient's height in meters and weight in kilograms. The mean follow-up time was 31.1 months (range 22 to 66 months). Two prosthesis types had been used; cementless Synatomic prosthesis in 29 and a cementless PCA Modular in 23 knees.

Radiographic assessment began with preoperative staging of arthrosis by the method described by Ahlbäck in 1968. Lower extremity alignment was measured preoperatively in a long cassette radiograph (film size 30cm x 120cm) using the anatomical axes of femur and tibia. The femoral anatomical axis was defined as the line drawn through the center of the tips of the tibial spines and a point midway between the femoral cortexes at the medial level of the greater trochanter. Correspondingly, the tibial anatomical axis was defined as the line drawn through the center of the tibial spines to the center of the talus. The tibiofemoral angle was determined as that measured from the medial side. Values less than 180 represent varus and values greater than 180 valgus alignment. The axes were drawn and the angles measured once by the same author. Long-cassette radiographs were taken from legs, making pre- and postoperative comparison between both lower extremities alignments possible.

Postoperative assessment was performed immediately, after 3 months, after 6 months, after one year and thereafter annually, and comprised clinical and radiological evaluation of the overall outcome. The axial alignment of the extremity was measured by the same method as preoperatively, using short (film size 35cm x 35cm) weight-bearing radiographs. The position of prosthesis components was measured using the method of Hood et al. (1981). In addition, radiolucencies and densities were determined using the guidelines described in the Knee Society scoring system (Ewald 1989).

6.3. Clinical and radiographic outcome of nonconstrained cementless TKAs (III)

A series of 102 consecutive uncemented Synatomic arthroplasties involving the tibiofemoral joint was reviewed. No patients were lost to follow- up, but eight died prior to the five-year follow-up of causes not related to the knee prosthesis. The data on these patients was included in this study. The mean follow-up time was 64 months. Table 3. shows basic clinical data on the patients.

Table 3. Basic clinical data of 97 patients in the Synatomic series

Total number of patients	97
Men	22
Women	75
Mean age in years	67
OA	74
RA	16
Other diagnoses	7

Overall survival was estimated by the Kaplan-Meier method. The decision to revise was used as end point. The clinical evaluation and assessment of clinical results was made using the knee joint and function scoring systems of Insall et al. (1989). In addition, patient-related factors, such as age, gender, preoperative diagnosis and body structure in terms of body mass index (BMI) were taken into account. The size of the prosthetic components were noted.

Preoperatively long cassette (film size 30cm x 120cm) lower-extremity radiographs were taken for measurement of alignment with the patient standing. Knees with preoperative gross (over 12 degrees) varus or valgus were grouped separately in order to ascertain whether any correlation prevails between preoperative alignment and overall survival. The grouping gave 14 knees in preoperative valgus and 27 in varus.

In addition to the full-length lower-extremity radiographs, supine anteroposterior and lateral views (film sizes 24cm x 30cm) were taken together with a skyline view of the patella in order to determine the preoperative stage of arthrosis, using Ahlbäck's method (1968).

In postoperative assessment, anteroposterior and lateral view radiographs were taken using the same method as preoperatively. Possible loosening of the prosthesis

was identified by the method used by The Knee Society (Ewald 1989). The overall extremity alignment was determined as the tibiofemoral angle between the distal femoral and proximal tibial anatomical axes. Prosthesis component position measurements were made using the method of Hood et al. (1981).

The study group involved no patellar replacements, and thus skyline views were not taken routinely but only if there was a suspicion of patellar subluxation or if the patient had anterior knee pain. The patella was assessed mainly using a routine lateral radiograph of the knee joint. From this view patellar thickness was measured in order to estimate possible patellar erosion.

Heterotopic bone formation was estimated by inspection and graded into four classes: 0= absence of heterotopic bone, 1= mild, 2= moderate, and 3= severe heterotopic bone formation.

6.4. Clinical and radiographic outcome of constrained cemented TKAs (IV)

Between August 1982 and December 1990, 48 rotating hinged knee prostheses were implanted in the Hospital of the Invalid Foundation. Two different prosthesis types were used; 18 Kinematic Hinge - and 30 Link Endomodel prostheses. As no statistically significant differences were noted in clinical scores between patients receiving the respective prosthesis types, we separated primary operations from revisions, since the operation has an influence on the outcome.

The study group comprised 22 primary operated and 26 revised knees. Seven of the patients were men and 38 women, average age at the time of the knee operation being 68.5 years (range 36.1 to 84.9 years).

The majority of the knees were operated because of ligamentous instability (52.1%); secondly, instability together with aseptic loosening (25%), thirdly, instability with bone loss (18.8%), and fourthly aseptic loosening with bone loss (4.2%).

The mean follow-up time was 66.3 months. Eleven patients died prior to the most recent review, of causes not related to the knee prosthesis. The data on these patients are included in the study.

In clinical examination we used the knee joint and knee function scores introduced by Insall et al. (1989). Range of motion, extension lag and both anteroposterior and mediolateral stability, walking ability in general and possible limp were estimated. The patients were asked about pain, assistive devices and climbing stairs. In addition, at every review standard AP and lateral knee radiographs were taken.

Radiographic assessment was made by two authors in consensus, using all the parameters described by The Knee Society (Ewald 1989). In addition, attention was paid to the incorporation of the graft in the host bone, cortical hypertrophy around the components, stress shielding and heterotopic bone formation. The

tibiofemoral angle was estimated by measuring the medial angle between the distal femoral and proximal tibial anatomical axes in order to follow the alignment of the lower extremity.

6.5. Comparison of anatomic and non-anatomic TKAs (V)

6.5.1. Patients

The study group comprised two cementless knee prosthesis types, Synatomic and AGC 2000. The models differ from each other mainly in the design of the patellofemoral articulation.

The Synatomic (DePuy) is an anatomically designed knee endoprosthesis with cobalt- chromium femoral, tibial and patellar components. The bearing surface is contoured in both frontal and sagittal sections. The type used was the short-stemmed (25 mm) Synatomic VF prosthesis, which features flanges to control rotation. The Synatomic series contains individual components for right and left knees. In the patellofemoral joint function is ensured with joint resurfacing, the main idea in this being to provide uninterrupted patellar articulation.

The other prosthesis type used, AGC 2000 (Biomet, Inc.) also contains cobalt-chromium femoral and tibial components; the patellar component is available both in UHMWPE construction or metal-reinforced UHMWPE. The anterior flange of the femoral components is angled at 3 degrees anteriorly. The tibial components in this study were a modular series, which have a keeled surface engaging cancellous bone to resist rotation. The trochlear path in the patellofemoral articulation is recessed.

All the patients in this study underwent a tibiofemoral endoprothesis operation, none of the patellae were resurfaced.

The basic information on the study group is given in Table 4.

	Synatomic	AGC 2000
Patients (knees)	71 (75)	68 (79)
Female/ Male	58/ 13	54/ 14
Average age (range)	67.2 (35- 82)	69.4 (56- 80)
Preoper. dg OA/RA/other	61/ 8/ 2	57/ 11/ 0
Follow-up time months (range)	63 (4- 108)	50 (12- 96)

6.5.2. Clinical assessment

Survival was determined using the life-table method. A survival was defined as a patient alive and not requiring reoperation. Death or decision to reoperate were thus used as end points.

Clinical assessment was made preoperatively, one year after the operation and at the latest review. Clinical outcome was staged using the scoring system described by Insall et al. (1989). Knee joint points (50 for pain, and 25 range of motion and stability, respectively) were thus separated from functional points (50 points for walking and climbing stairs, respectively) and deductions were made in the knee joint score for flexion contracture, extension lag and alignment errors and in the knee function score for the use of assistive devices. In addition limp was noted in order to estimate walking capacity more precisely.

6.5.3. Radiographic assessment

Preoperatively, long cassette (30cm x 120cm), weight-bearing radiographs were taken in order to determine lower extremity alignment. First, the stages of radiographic findings were compared in Synatomic and AGC 2000 knees by the methods of Ahlbäck (1968) in OA and Larsen (1977) in RA.

Postoperative radiological assessment was performed from weight-bearing anteroposterior and supine lateral radiographs taken at every review. The assessment included all the parameters described by the Knee Society (Ewald 1989). Absence or presence of radiolucencies was noted and their possible progressivity taken into account. Tibiofemoral alignment was measured as the medial angle between the distal femoral and proximal tibial anatomical axes.

Heterotopic bone formation was determined by inspection and further subdivided into the following four classes: 0 absence of heterotopic bone, 1 mild, 2 moderate and 3 severe heterotopic bone formation. Patellofemoral articulation was examined, the location of the patella in both vertical and sagittal plane was noted. Thickness of patella was determined in order to detect possible retropatellar erosions.

6.6. Statistical methods

In survival analysis we used the life-table method recommended by Murray et al. (1993). The product limit method described by Kaplan and Meier (1958) was used when confidence intervals were not needed. The effective number at risk was obtained as recommended by Murray et al. (1993). This figure is the reciprocal of

the average of the reciprocal of the numbers at risk in the year in question and each preceding year.

The descriptive values of variables are expressed as means, range or percentages. Analysis of variance was used to compare categorial variables (with three classes) with normally distributed variables. If a categorial variable had more than three classes, regression analysis was used. Comparison of two categorials was by chi- square test. Two-tailed t-test was used when one variable was continuous and the other categorical with two classes. Significance levels of $p < 0.05$ or $p < 0.001$ were used depending on the mode of calculation. Computation in all studies was with CSS Statistica software.

7. RESULTS

7.1. Results of the comparative study of short and long cassette radiographs (I)

7.1.1. Group 1 (Short radiographs taken supine)

The mean tibiofemoral angle (TAA) measured from 68 standard supine knee radiographs was 181.9 degrees, with a range from 166 to 204 degrees. Measured from a full-length radiograph the angle was 182.7 degrees, with a range from 150 to 221 degrees using femoral anatomical axis (TAD) and 177.5 degrees with a range from 144 to 217 degrees using the femoral mechanical axis (TAC).

Thus the mean difference between tibiofemoral angles using the femoral anatomical axis in the full-length radiograph was 0.9 degrees (p= 0.37) and using the femoral mechanical axis in the full-length radiograph 4.3 degrees (p< 0.001).

7.1.2. Group 2 (Short radiographs taken weight-bearing)

The mean tibiofemoral angle (TAB) measured from 35 weight-bearing knee radiographs was 181.1 degrees, with a range from 161 to 206 degrees. The angle measured from a full-length radiograph was 182.5 degrees, range 158.5 to 199.5 degrees using femoral anatomical axis (TAD) and 176.7 degrees, range 153 to 196.5 degrees using the femoral mechanical axis (TAC).

Thus the mean difference between tibiofemoral angles using the femoral anatomical axis in the full-length radiograph was 1.3 degrees (p= 0.14) and using the femoral mechanical axis in the full-length radiograph 4.5 degrees (p< 0.001).

7.2. Radiographic changes in postoperative alignment (II)

7.2.1. Preoperatively

Most knees awaiting an osteotomy or endoprosthesis operation were grade 1– 3 arthrosis. None fulfilled the criteria for stage 5.

The mean tibiofemoral angle in operated knee was 178.1 degrees, with a range from 150 to 222 degrees. No correlation was found between the alignments of the operated and opposite limb. Nor was there any correlation between preoperative alignment and BMI, even though the mean BMI was 28.1, implying that 62 per cent of the studied patients were to be regarded as obese.

7.2.2. Postoperatively

The ideal few (3–7) degrees alignment was obtained in only one-half (26/52) of the patients. Immediately postoperatively the mean tibiofemoral angle (TFA) was 184.2 degrees, with a range from 173 to 190 degrees. At the latest review mean TFA was 181.8 degrees, range 169 to 192 degrees. A shift toward varus was noted with a mean of 2.4 degrees. In the case of the femoral component a mean shift of 0.9 degrees toward varus was noted in anteroposterior view (p< 0.001).

No correlation was found between preoperative and final alignment or between BMI and final alignment. Radiolucent lines were discerned in 38 per cent of femoral components, located most usually in the anterior flange. In 67 per cent of tibial components radiolucencies were in most cases limited to the interface beneath the medial or lateral tibial plateau. None of these lucencies was more than 2 mm wide. No radiographic signs of loosening were found.

7.3. Clinical and radiographic outcome of Synatomic TKAs (III)

The overall survival rate was 88.6 per cent, with a mean follow-up of 64 months. Six patients developed a superficial wound infection immediately postoperatively; all were cured successfully with antibiotic therapy and local treatment. Four revisions were needed in the study group due to symptomatic aseptic loosening of components. In addition, one knee failed due to traumatic rupture of the patellar tendon. In addition, two patients suffered from anterior knee pain and patellar arthroplasty was performed. In the clinically successful group the mean age was 68.6 and in the failure group 60.1 years, a difference which was statistically significant (p<0.05).

7.3.1. Clinical results

Pain was clearly alleviated by the endoprosthesis operation. Ninety-three knees had preoperatively caused moderate to intolerable pain on weight-bearing; at the

latest review, seven knees caused moderate and one severe pain. Of these eight knees, three were revised for aseptic tibial component loosening. The other five patients suffering discomfort had other reasons for the lower extremity pain.

Preoperatively the mean range of motion measured as active flexion was 95.9 degrees and at the latest review postoperatively 96.8 degrees. The improvement in ROM was not statistically significant.

Extension deficit measured at the latest review was significantly ($p<0.05$) higher in the unsuccessful group; 16.3 degrees, differing from that measured in the clinically successful group, 7.0 degrees. No correlation was found between clinical outcome and patient's sex, preoperative diagnosis, BMI or arthrosis stage. Prosthesis component size or preoperative function did not affect the clinical outcome.

7.3.2. Radiographic results

Preoperatively the mean tibiofemoral angle was 178.5 degrees, with a range from 150 to 218.5 degrees; immediately postoperatively it was 183.4 degrees (range 173 to 192) and at the latest review, 182.3 (range 172 to 190). As no correlation was observed between postoperative tibiofemoral angles and clinical outcome, correlation was expressed as between clinical outcome and preoperative tibiofemoral angle. The mean tibiofemoral angle preoperatively in the clinically successful group was 175.7, in the unsuccessful group 187.6 degrees. In comparing knees with preoperative gross (over 12 degrees, respectively) valgus or varus, a statistically significant correlation was found between clinical failure and marked correction of preoperative gross valgus. No correlation emerged in the varus group. No correlation prevailed between the tibiofemoral angle attained in the endoprosthesis operation and the shift in alignment during the follow- up.

The mean thickness of the patella measured from lateral radiographs was 22.8 mm, with a range from 16 to 30 mm. During the follow-up, the patella thinned on average 0.9 mm (range 0 to 5mm). No correlation was found between patellar thinning and other factors.

Partial radiolucencies were common, in most cases in the anterior flange of the femoral component or limited to the interface beneath the medial or lateral tibial plateau in the tibial component. Even though the great majority of the lucencies were interpreted as progressive they were extremely uncommon surrounding the fixation pegs.

7.4. Results of constrained cemented TKAs (IV)

At the latest review, 35 patients (38 knees) had satisfactory and 10 (10 knees) unsatisfactory results demanding reoperation. Immediately postoperatively complications occurred in 20.8 per cent of the patients, most of these, 16.6 per cent, having wound infection. Four patients developed immediate postoperative wound infection which persisted in spite of continuous antibiotic and local therapy. Two of them died of causes not related to the infection, and two were treated with antibiotics and arthrodesis. In addition, two patients suffered from late chronic infection and fistulae.

Aseptic loosening of the femoral component occurred in two patients and were reoperated. Two required patellar revision because of anterior knee pain and radiological findings in patellofemoral articulation.

7.4.1. Knee joint score

In the primary operated group, all knees had a poor preoperatively score (<60 points). All the patients concerned had good to excellent results at the latest review. In the revision group 25 knees had preoperatively poor (<60) and one fair (60–69) points. At the latest review, one knee still scored low and one only fair; all other 24 knees had good to excellent scores.

Pain was markedly alleviated by the endoprosthesis operation. Preoperatively 95.8 per cent of the knees had caused moderate to severe pain on weight-bearing. At the latest review, only five patients complained of moderate pain; none suffered severe or intolerable pain.

Extension lag was reduced in the primary operated knees from a mean of 6.6 to 2.0 degrees and increased in the revised knees from a mean of 1.7 to 5.4 degrees.

Preoperatively, 75 per cent of the knees were grossly and 25 per cent slightly unstable in anteroposterior (AP) direction. In lateral direction, the figures were preoperatively 81.3 and 18.7 per cent, respectively. At the latest review all were naturally stable in AP direction by merit of the constrained design of the implant. In 12.5 per cent a slight instability was noted in the lateral direction.

7.4.2. Knee function score

Knee function scores did not improve as clearly as joint scores; some improvement in function was recorded. One year after the operation none of the patients was unable to walk. In the primary group 50 per cent and in the revision group 65 per

cent were able to walk a distance of one kilometer at most. At the latest review, three revised patients were housebound, all of them with similar problems with deep wound infection and chronic fistulae. All of them had also been housebound preoperatively. Their general health was so poor that they were treated conservatively.

Twenty-six of the patients were preoperatively able to climb up stairs, but were unable to descend. At the latest review, there were no patients unable to climb stairs in the primary group. In the revision group, two were unable to climb stairs. Most (47 out of 48) used a cane or crutches for walking at the latest review, and one revised patient had to use a wheelchair.

7.4.3. Radiographic results

Preoperatively, most knees were in gross (over 20 degrees) deformity, varus (21/ 47) or valgus (17/ 47). Postoperatively, most (44/47) were in slight (0–9 degrees) valgus, due to the prosthetic design. Cortex hypertrophy was estimated in one femur and one tibia, and in addition, one patient had cortex hypertrophy in both femur and tibia. None of these prostheses was loose. Neither was there correlation between stress shielding and prosthetic loosening, even though stress shielding was noted in 13.5 per cent of the femoral and 15.6 per cent of the tibial components.

Three knees showed radiographic signs of component loosening estimated as a progressive radiolucency or a shift in component position. In one patient with deep wound infection there were radiographic signs of infection, and in another there was a granulomatous process surrounding the femoral component, while in one knee the tibial component was radiographically loose. In addition, one patella showed an ununited old fracture of the upper pole. No fresh fractures were found, and no heterotopic bone formation was evinced. Loose beads were noted in four tibiofemoral joint spaces.

7.5. Comparison of anatomic and non-anatomic prostheses (V)

7.5.1. Synatomic

The overall survival rate was 90.7 per cent, with a mean follow-up of 63 months. Five patients died during the follow-up due to factors not related to their knee prosthesis. There were four immediate postoperative complications; two superficial wound infections, one wound necrosis and one case with knee mobilisation problems.

Knee joint scores are shown in Table 5. Pain was significantly alleviated in the endoprosthesis operation. This is shown in Table 6. At the latest review two patients in the Synatomic-group suffered anterior knee pain and patellar arthroplasty was performed.

The knee function scores are shown in Table 7. The improvement in function score was not as marked as that in knee joint score. Two patients were not able to walk at the latest review; both had very poor general health which compromised their walking ability. Preoperatively, only one patient could climb stairs without problems. This was still possible for 21 per cent in the Synatomic group at the latest review.

Table 5. Knee joint scores preoperatively, at one year postoperatively and at the latest follow-up

Scores	Synatomic No of pat.			AGC No of pat.		
	Pre	At 1 y.	Latest	Pre	At 1 y.	Latest
Excellent 85-100	1	48	43	0	69	53
Good 70-84	21	22	26	17	8	18
Fair 60-69	26	4	3	21	1	4
Poor <60	27	0	2	41	1	3

Table 6. Pain preoperatively, at one year postoperatively and at the latest follow-up

Stage	Synatomic No of pat.			AGC No of pat.		
	Pre	At 1 y.	Latest	Pre	At 1 y.	Latest
0	0	59	46	0	67	39
1	5	13	21	3	9	28
2	54	2	6	48	2	9
3	13	0	1	26	0	0
4	2	0	0	2	0	2
Missing	0	1	1	0	1	1

Table 7. Knee function scores preoperatively, at one year postoperatively and at the latest follow-up

Score	Synatomic No of pat.			AGC No of pat.		
	Pre	At 1 y.	Latest	Pre	At 1 y.	Latest
Excellent 85-100	0	16	12	0	26	20
Good 70-84	4	29	21	0	21	17
Fair 60-69	12	13	17	6	15	16
Poor <60	59	16	24	73	16	25

7.5.2. AGC 2000

The overall survival rate was 92.4 per cent, with a mean follow-up of 50 months. Ten patients died during the follow-up for reasons not related to the knee endoprosthesis. There was one immediate postoperative complication; a deep wound infection. This did not affect the overall outcome.

Although knee joint scores were improved in the case of the Synatomic group, there was no statistically significant difference between the subgroups. Also in the AGC group pain was clearly alleviated after the operation. At the latest review two patients in this latter group suffered from anterior knee pain, requiring patellar arthroplasty. In addition, three suffered from slight anterior knee pain thought to be of patellar origin. They were treated conservatively.

Eleven knees were slightly unstable at the latest review. This instability was mainly of mediolateral type. As in the Synatomic group, functional abilities did not improve as clearly as knee joint scores; knee function scores are shown in Table 5. There were no statistically significant differences between the subgroups.

7.5.3. Radiographic results

The ideal, 3–7 degrees valgus in tibiofemoral alignment was attained only 45.3 per cent of the knees in the Synatomic and in 32.9 per cent in the AGC group. Two patellae in the Synatomic and five in the AGC group were regarded as patella alta. Patellar height did not affect the clinical outcome.

Radiolucencies were most common surrounding the tibial plateau. In the Synatomic group 1.3 per cent and in the AGC group 3.8 per cent were regarded as progressive in the femoral, 24.0 and 25.3 per cent in the tibial component,

respectively. Radiologically there were three failures. Two knees evinced progressive radiolucency around tibial components and clinically symptomatous tibial component loosenings, and were revised. In addition, in one knee there was radiologically a suspicion of a chronic infection because of a granulomatous process seen in the radiograph, and the knee was reoperated. The infection was confirmed surgically.

8. DISCUSSION

8.1. Measurement of alignment using short and long radiographs (I)

Total knee arthroplasty is the ultimate surgical procedure for the treatment of incapacitating pain and loss of motion in patients with joint-destroying arthritis. Prosthetic alignment depends almost entirely on the quality of the surgical preparation of femur and tibia during the operation. Aligning the bone cuts of the distal femur and proximal tibia along the plane of the original preoperative joint line, in anatomical relationship to the mechanical axis, will not only correct the deformity but also, in most cases, preserve or reconstitute ligamentous stability (Scott and Volatile 1986, Hofmann and Hagena 1987, Hofmann et al. 1991). This requires a reliable preoperative assessment of varus or valgus deformity of the affected limb and an adaptable instrumentation system allowing the surgeon to perform the necessary adjustments with high precision in keeping with the preoperative plan.

Our results concerning the difference in TFAs measured from short and long radiographs are largely comparable to those obtained in earlier studies. The mean difference between tibiofemoral angles using the femoral anatomical axis in the long radiographs compared to supine short radiographs was 0.9 degrees, and 1.3 in weight-bearing short radiographs. The mean difference between the tibiofemoral angles using the femoral mechanical axis in the long radiographs compared to supine short radiographs was 4.3 degrees, and 4.5 in weight-bearing short radiographs. Petersen and Engh (1988) give the mean difference between the tibiofemoral angles measured from long and short radiographs as 1.4 degrees (using femoral anatomical axis), Patel et al. (1991) 1.6 degrees (using femoral anatomical axis) and Boegård et al. (1984) 6 degrees (using femoral mechanical axis).

The major discrepancies prevail in the mode of determining joint characteristics. Krackow (1983) used mathematical calculation and found normal axial alignment to be 6 degrees valgus. Similarly Kapandji (1970) and Maquet (1976) give 6 degrees valgus as the physiological angle between anatomical and mechanical axes. Both of these investigators determined the center of the knee to be located in the intercondylar notch. Likewise Oswald et al. (1993) chose the deepest point of the intercondylar notch as the origin of all femoral axes. A number of other authors have advocated this point in view of its importance as a surgical landmark and its

easy discernibility on radiographs and in the operating room (Krackow 1983, Laskin 1984, Hsu et al. 1990).

The significance of a proper radiographic technique must also be emphasized. In the present study, in taking long cassette radiographs, the patellae were used as a guide to neutral rotation. However, such an assumption does not hold if the patella is subluxated or dislocated (Jiang and Insall 1989). Hsu et al. (1990) and Chao et al. (1994) used the tibial tubercle as the positioning reference instead of the patella, and the technique was found to be reliable and repeatable. The extension is extremely important, because if the knee is slightly flexed, external rotation will make the knee appear to be in more varus angulation, and internal rotation will accentuate the degree of valgus angulation (Moreland et al. 1987). Jeffery et al. (1991) holds that an error of rotation in the limb up to 20 degrees during radiography introduces a projectional error of less than 2 degrees in the tibiofemoral angle, provided that the knee is fully extended. In addition, a combination of rotation and knee flexion may introduce much larger errors. When the patient is carefully positioned and the knee is in full extension, long-cassette standing radiographs can be used to measure tibiofemoral angles to within 2 degrees (Jeffery et al. 1991) while short-arm goniometers (Tew and Waugh 1985) and short radiographs (Bonnici and Allen 1991) are accurate only to within 5 degrees.

8.2. Change in radiographic alignment in clinically successful knees (II)

Proper component positioning and restoration of neutral lower extremity alignment are the most important factors countering prosthetic loosening (Windsor et al. 1989, Anouchi et al. 1993). Continuous prosthesis component migration is taken as a sign of aseptic loosening of the component. However, both laboratory studies (Walker et al. 1976) and animal models (Stulberg et al. 1991) have shown that motion occurs at the implant-bone interface. This relative displacement between tibia and the component has been observed one to two years after successful arthroplasty, in other words, in the early period (Toksvig-Larsen et al. 1994).

In order to measure this acceptable change in tibiofemoral alignment, 38 patients with clinically successfully operated 52 cementless TKAs were retrospectively chosen for the study group.

The mean valgus alignment was 4.2 degrees immediately postoperatively. The overall alignment was altered to a mean 1.8 degrees valgus measured at the latest review. Thus the average migration toward varus was 2.4 degrees. A similar decrease in the valgus- angulation obtained at the time of replacement has also been noted by Okamoto and Koshino (1991).

In the present study, one of the authors measured the alignment angles once. Odenbring et al. (1993) studied the reliability of knee alignment measurements. In

their opinion, assessment of the hip-knee-ankle angle showed a variability of at most 2 degrees. This is highly significant for reliable preoperative planning (Odenbring et al. 1993). Jeffery et al. (1991) found the standard deviation for the measurement of the same angle on different films of the same patient to be 0.8 degrees. Wright et al. (1991) give the mean inter-observer difference as 1.4 degrees (SD 1.1) and the mean intra-observer difference 0.7 degrees (SD 0.9). Derek et al. (1999) gained good interreader reliability (kappa=0.92) in their radiographic grading including alignment angle measurements.

8.3. Cementless Synatomic knee prostheses (III)

The problem of mechanical loosening of TKA components is multifactorial. Its occurrence can often be ascribed to poor angular or rotational positioning of the prosthesis components. In addition, prosthesis design, fixation system and demographic factors may influence the entity.

In the present study, the multiple clinical and radiographic symptoms and factors pertaining to TKA were studied in order to find a marker of failure. The cumulative survival rate (CSR) was calculated for the 102 cementless tibiofemoral Synatomic knee prostheses. The overall clinical survival rate was 88.6 per cent, which is highly comparable to the results in a multicentre study by Rand and Ilstrup (1991) and the studies of Moran et al. (1991). The survival rates in these cementless knee prosthesis series were 93 and 84 per cent, respectively. Nielsen et al. (1992) reported CSR for 103 cementless AGC knees after 3 years' follow-up to be 97 per cent when revision as end point and 91 per cent when pain and radiographic findings were taken into account.

Preoperatively, 14 knees were in gross (over 12 degrees) valgus and 27 knees in gross (over 12 degrees) varus. These were further grouped separately to establish, whether preoperative tibiofemoral alignment is linked to overall clinical survival. All the clinical factors from the Knee Society rating scale (Insall et al. 1989) and radiographic factors from the Knee Society scoring system (Ewald 1989) were taken into account.

In the present study the absence of pain and extension deficit correlated with good clinical survival. A correlation was also noted between clinical survival and patient's age. The mean age in the clinically successful group was 68.6 years, against 60.1 years in the failure group. Ritter et al. (1994) have reported similarly better clinical outcome with older patients. Here this was thought to be a reflection of the patient's physical activity. No correlation between survival and diagnosis or body mass index was established.

Jeffery et al. (1991) noted that knees with preoperative varus were more likely to loosen than valgus knees. In the present case, the result was the opposite. A statistically significant correlation was observed between marked improvement

from preoperative valgus and clinical failure. However, our study group with strong valgus angulation was small. In Jeffery's series (1991) 46 knees were in preoperative varus angulation and eight of these eventually failed.

We also compared the shift in tibiofemoral alignment with other factors. Similarly to Boegård et al. (1984) at least three degrees migration of prosthesis components was used as criterion for radiological failure. Pain was correlated with significant shift in alignment.

8.4. Rotating hinged knee prostheses (IV)

Reconstruction by total joint prosthesis of a severely instable knee with extensive loss of bone is a difficult operation. The indications previously given for hinged implants were extensive destruction of the joint, severe ligamentous instability, severe tibiofemoral malalignment, loss of bone and revision of a failed total knee arthroplasty (Bargar et al. 1980, Walldius 1960). In the present study, these same indications resulted in selection of the hinged prothesis type. A retrospective review was made of all the rotating hinged type knee prostheses implanted at our hospital. Thus the study group consisted of 45 patients having either Kinematic Hinge (37.5 %) or Link Endomodel (62.5 %) prostheses. Twenty-two of the operations were primary and twenty-six revisions.

At the latest review, with a mean follow-up time of 66.3 months, 79.2 % of the patients were regarded as having satisfactory and 20.8 % unsatisfactory results. This is comparable to figures from earlier studies, Rand et al. (1987) gave a 72 % and Walker et al. (1982) a 77 % success rate in their series with Kinematic Hinge prostheses.

In the present study the number of immediate complications was high, 20.8 per cent; 16.7 per cent had wound infection, one primary operated and seven revised knees. The infection rate has varied considerably in different studies made of hinged knee arthroplasties. Hui and Fitzgerald (1978) achieved 11.7 %, Rand et al. (1987) 16 %, Rand and Bryan (1988) 1.5 % and Cameron et al. (1997) 13% infection rates. In every case the infection rate is too high compared with the incidence reported with the surface replacement type of TKA. It has been pointed out that many of these patients have had multiple previous operations on the knee, with the resultant scarred and poorly vascularized tissue which appears to predispose to infection (Goldberg et al. 1988b). This conception was confirmed here.

Kim (1987) investigated failed total knee arthroplasties. All patients in his series had retro- and peripatellar pain attributable to bone destruction and lateral subluxation of the patella. Also Scott (1982) observed virtually 100 % of the roentgenograms of hinge knee patients to show flattening and erosion of the patellar bone. In this present series, half of the patients had patella constantly laterally dislocated. A wide lateral release was performed in eight cases, medial release in

two and a release on both sides in two. Postoperatively, only three patients suffered from patellar dislocation problems, one primary and two revised knees. All of them already had their patellar problems at the first review two months after the operation.

8.5. The comparison of anatomic and non-anatomic prosthesis designs in patellofemoral joint

Patellar articulation has remained a frequent source of complications after TKA (Merkow et al. 1985). When the patella is resurfaced, problems such as patellar fracture, disruption and loosening may occur (Clayton and Thirupathi 1982). Most particularly, however, patellar subluxation still occurs in up to 25 per cent of cases (Ranawat 1986). Several predisposing causes of patellar subluxation have been postulated: absence of a patellar groove in the early designs (Moreland et al. 1979), excessive preoperative valgus deformity, insufficient length or height of the lateral femoral facet or a short femoral flange (Merkow et al. 1985).

This study was undertaken in order 1) to determine the results without patellar replacement and 2) to compare the anatomic prosthesis design with the non-anatomic. The study group comprised 75 Synatomic and 79 AGC 2000 knee prostheses. Synatomic (DePuy, Warsaw, Ind) is an anatomically designed knee endoprosthesis which contains individual components for both knees. AGC 2000 (Biomet Inc, Warsaw, Ind) is a non-anatomic prosthesis type with a recessed trochlear path in patellofemoral articulation. With a mean follow-up time of 63 months in Synatomic and 50 months in AGC, the overall survivals were 90.7 and 92.4 per cent, respectively.

In this study, none of the patients complained of anterior knee pain after one year postoperatively. At the latest review, two patients in the Synatomic group and two in the AGC 2000 group suffered severe anterior knee pain, and patellar resurfacing was undertaken. In addition, three patients in the AGC 2000 group suffered slight anterior knee pain and were treated conservatively.

Fern et al. (1992) evaluated postoperative anterior knee pain in 138 knees with rheumatoid arthritis treated by total knee replacement with Mark I Insall-Burstein prostheses. None of the patellae were primarily resurfaced. The mean follow-up time was 63.9 months. Anterior knee pain was rated as mild in 13.5 per cent and moderate to severe in 13.5 per cent. Partio and Wirta (1995) compared PFC knees both with and without patellar resurfacing. In their study, pain was observed significantly more often in the non-resurfaced group, but in every case the pain was slight. In their opinion, the results in the two subgroups were equally good, as assessed on the Knee Society scoring scale (Ewald 1989).

Engh et al. (1992) studied retrieved cementless tibial components. In their series of 43 retrieved Synatomic tibial components with a mean follow-up time of 39.5

months, over half of the Synatomic knees were revised because of patellar polyethylene wear and subsequent separation from the metal backing. In our series no polyethylene wear was encountered, possibly due to relatively short follow- up times.

Soudry et al. (1986) showed 65 per cent of non-resurfaced patellae to have progressive joint erosion, not, however, correlating with anterior knee pain.

Figgie et al. (1986) related postoperative anterior knee pain to three variables: the position of the prosthetic joint line, the height of the patella, and the anteroposterior location of the tibial prosthesis on the tibial plateau. Also Grace and Rand (1988) and Merkow et al. (1985) reported a higher incidence of patellar instability in patients with pre-existing varus alignment. In the present study with Synatomic and AGC 2000 prostheses the result was different; retrospectively no correlation was found between preoperative alignment and anterior knee pain. The results were thus similar to those of Kirk et al. (1992).

9. CONCLUSIONS

Using the complex entity of knee joint resurfacing arthroplasty as a starting-point to this study, preoperative radiographs were studied for their accuracy in preoperative planning in alignment deformity corrections. In addition, demographic, clinical and radiographic factors influencing the survival and clinical outcome of total knee prostheses were examined. On the basis of the findings, the following conclusions could be drawn:

1) Preoperative planning is, in addition to clinical examination and patients' symptoms, based on radiographs. Full- lenght lower extremity radiographs are more accurate than short knee radiographs.

2) In clinically successful cementless endoprosthesis knees a mean shift of 2.4 degrees toward varus was noted without clinical or radiographic signs of component loosening.

3) Pain, extension deficit and young age at the time of operation were the factors related to failure in a series of contemporary cementless prostheses.

4) In totally unstable revision knees, the rotating hinged knee prosthesis type can give acceptable results.

5) No differences in either tibiofemoral or patellofemoral results were noted in a study comparing anatomic and non-anatomic cementless knee prostheses clinically and radiographically.

10. SUMMARY

The main purpose in the present study was to clarify a number of distinct problems associated with TKA.

Preoperatively, demographic factors were taken into account in order to find risk patients. In addition to clinical assessment, radiographs play a crucial role in deciding whom to operate and how. Prior to TKA, the degree of bone destruction and angular deformity are estimated from radiographs. In the first series here, 68 patients (103 knees) with long cassette, whole lower extremity radiographs were compared to supine (68 knees) and weight-bearing (35 knees) short knee radiographs in a search for the most suitable radiograhic technique for operation planning. Differences in tibiofemoral alignments were measured using both femoral mechanical and anatomical axes. Short radiographs taken in supine position showed a mean difference of 4.3 degrees compared to long cassette radiographs using the femoral mechanical axis and 0.9 degrees if the femoral anatomical axis was used. The short radiographs taken weight-bearing showed corresponding differences of 4.5 and 1.3 degrees. The long cassette radiograph was recommended if precisely executed.

In the second study postoperative alignment was determined in a clinically successful group in order to establish acceptable migration and at the same time criteria for radiographic failure in cementless TKAs. In a group of 52 retrospectively chosen clinically successful knees the mean follow-up time was 31.1 months. Tibiofemoral alignment was measured using distal femoral and proximal tibial anatomical axes. At the latest review a slight 2.4 degrees decrease in valgus-angulation without clinical symptoms was noted. Thus the shift in tibiofemoral alignment must be over 2.4 degrees to signify in radiographic assessment.

In the third study, clinical or radiographic symptoms or factors indicating failure were sought. The contemporary cementless prosthesis type was used. A total number of 102 Synatomic knees were evaluated. The overall survival was 88.6%. Pain, extension deficit and young age at the time of operation were related to failure. Also a correlation was found between gross (over 12 degrees) preoperative valgus angulation and failure.

A study group consisting of rotating hinged knee prostheses (Kinematic Hinge and Link Endomodel) was evaluated in order to estimate results gained with a constrained, cemented prosthesis design. Twenty-two of the operations were

primary and twenty-six revisions. With a mean follow- up time of 66.3 months satisfactory results were gained in 79.2% and unsatisfactory results in 20.8% of the patients. The incidence of postoperative wound infections was 16.6%. The rotating hinged prothesis designs are recommended for severely unstable salvage knee operations.

The last problem pertaining to TKA dealt with in this study, was that with patellofemoral articulation. We studied this aspect by comparing two contemporary cementless tibiofemoral prosthesis types, differing mainly in the design of the patellofemoral compartment. The study group comprised 75 Synatomic and 79 AGC knees without patellar resurfacing. The overall survival rate for Synatomic was 90.7%, 92.4% for AGC. Clinical assessments were made using the knee joint and function scores described by Insall et al. (1989) and radiographic assessments by the Knee Society scoring system (Ewald 1989). No significant differences emerged.

11. ACKNOWLEDGEMENTS

12. REFERENCES

Abraham W, Buchanan JR, Daubert, Greer RB 3rd and Keefer J (1988): Should the patella be resurfaced in total knee arthroplasty? Efficacy of patellar resurfacing. Clin Orthop 236: 128– 134.

Aglietti P, Windsor R, Buzzi R and Insall J (1989): Arthroplasty for the stiff or ankylosed knee. J Arthroplasty 4: 1–5.

Ahlberg Å and Lunden A (1981): Secondary operations after knee joint replacement. Clin Orthop 156: 170–174.

Ahlbäck S (1968): Osteoarthrosis of the knee. A radiographic investigation. Acta Radiol Suppl No 277.

Ahlbäck S and Mattson S (1978): Patella alta and gonarthrosis. Acta Radiol Diagnosis 19: 578–584.

Anouchi YS, McShane M, Kelly Jr F, Elting J and Stiehl J (1996): Range of motion in total knee replacement. Clin Orthop 331: 87– 92.

Anouchi YS, Whiteside LA, Kaiser AD, Milliano MT (1993): The effects of axial rotational alignment of the femoral component on knee stability and patellar tracking in total knee arthroplasty demonstrated on autopsy specimens. Clin Orthop 287: 170–177.

Anthony PP, Gie GA, Howie CR and Ling RS (1990): Localised endosteal bone lysis in relation to the femoral components of cemented total hip arthroplasties. J Bone Joint Surg Br 72: 971– 979.

Armitage P (1971): Statistical methods in medical research. Blackwell, Oxford, pp. 408– 414.

Bargar WL, Cracchiolo A and Amstutz HC (1980): Results with the constrained total knee prosthesis in treating severely disabled patients and patients with failed total knee replacements. J Bone Joint Surg Am 62: 504–511.

Bargren JH, Blaha JD and Freeman MAR (1983): Alignment in total knee arthroplasty. Correlated biomechanical and clinical observations. Clin Orthop 173: 178– 183.

Bartel DL, Bicknell VL and Wright TM (1986): The effect of conformity, thickness, and material on stresses in ultra- high molecular weight components for total joint replacement. J Bone Joint Surg Am 68: 1041–1051.

Bartel DL, Burstein AH, Santavicca EA and Insall JN (1982): Performance of the tibial component in total knee replacement. J Bone Joint Surg Am 65: 1026–1033.

Barrett JP, Rashkoff E, Sirna EC and Wilson A (1990): Correlation of roentgenographic patterns and clinical manifestations of symptomatic idiopathic osteoarthritis of the knee. Clin Orthop 253: 179–183.

Bengtson S and Knutson K (1991): The infected knee arthroplasty. A 6- year follow- up of 357 cases. Acta Orthop Scand 62: 301–311.

Boegård T, Brattström H and Lidgren L (1984): Seventy- four Attenborough knee replacement for rheumatoid arthritis. A clinical and radiographic study. Acta Orthop Scand 55: 166– 171.

Bonnici AV and Allen PR (1991): Comparison of long leg and simple knee radiographs in assessment of knees prior to surgery. J Bone Joint Surg Br 73 (Suppl): 75–78.

Boyd AD Jr, Ewald FC, Thomas WH, Poss R and Sledge CB (1993): Long- term complications after total knee arthroplasty with or without resurfacing of the patella. J Bone Joint Surg Am 75: 674–681.

Bradley GW, Freeman MAR and Albrektsson BEJ (1987): Total prosthetic replacement of ankylosed knees. J Arthroplasty 2: 179–183.

Brantigan OC and Voshell AF (1941): The mechanics of the ligaments and menisci of the knee joint. J Bone Joint Surg 23: 44–48.

Brick GW and Scott RD (1988): The patellofemoral component of total knee arthroplasty. Clin Orthop 231: 163–178.

Bryan RS and Peterson LF (1979): Polycentric total knee arthroplasty: A prognostic assessment. Clin Orthop 145: 23– 28.

Bryan RS and Rand JA (1982): Revision total knee arthroplasty. Clin Orthop 170: 116–122.

Buchanan JR, Greer RB 3rd, Bowman LS, Shearer A and Gallaher K (1982): Clinical experience with the variable axis total knee replacement. J Bone Joint Surg Am 64: 337–346.

Callihan SM and Halley DK (1985): Prospective analusis of Sheehan total knee arthroplasty. Clin Orthop 192: 124– 131.

Cameron HU and Fedorkow DM (1982): The patella in total knee arthroplasty. Clin Orthop 165: 197– 199.

Cameron HU, Hui C and Vyamont D (1997): Hinge total knee replacement revisited. Can J Surg 4: 278– 283.

Cameron HU and McNeice GM (1981): Mechanical failure modes in total knee replacement. Arch Orthop Trauma Surg 98: 135–138.

Cameron HU and Welsh RP (1990): Fracture of the femoral component in unicompartmental total knee arthroplasty. J Arthroplasty 5: 315–317.

Charnley J (1972): The long- term results of low- friction arthroplasty of the hip performed as a primary intervention. J Bone Joint Surg Br 54: 61–76.

Convery FR, Minteer- Convery M and Malcolm LL (1980): The spherocentric knee: A re- evaluation and modification. J Bone Joint Surg Am 62: 320–327.

Cook SD, Barreck RL, Thomas KA and Haddad RJ (1989): Quantitative histologic analysis of tissue growth into porous total knee components. J Arthroplasty 4 (Suppl): 33-–43.

Coventry MB, Finerman GAM, Riley LH, Turner RH and Upshaw JE (1972): A new geometric knee for total knee arthroplasty. Clin Orthop 83: 157–164.

Cross MJ and Powell JF (1984): Long- term follow- up of posterior cruciate ligament rupture: A study of 116 cases. Am J Sports Med 12: 292–297.

Delport PH, Van Audekerck R, Martens M and Mulier JC (1982): Conservative treatment of ipsilateral supracondylar femoral fracture after total knee arthroplasty. J Trauma 24: 864–869.

Dennis DA, Clayton ML, O'Donnell S, Mack RP and Stringer EA (1992): Posterior cruciate condylar total knee arthroplasty. Average 11- year follow- up evaluation. Clin Orthop 281: 168– 176.

Dobbs HS (1980): Survivorship of total hip replacements. J Bone Joint Surg Br 62: 168–173.

Doolittle KH II and Turner RH (1988): Patellofemoral problems following total knee arthroplasty. Orthop Rev 17: 696–702.

Drown IW and Ring PA (1985): Osteolytic changes in the upper femoral shaft following porous coated hip replacement. J Bone Joint Surg Br 67: 218–221.

Ecker ML, Lotke PA, Windsor RE and Cella JP (1987): Long- term results after total condylar knee arthroplasty. Significance of radiolucent lines. Clin Orthop 216: 151–158.

Engh GA (1988): Failure of the polyethylene bearing surface of a total knee replacement within four years. A case report. J Bone Joint Surg Am 70: 1093– 1096.

Engh GA, Dwyer KA and Hanes CK (1992): Polyethylene wear of metal- backed tibial components in total and unicompartmental knee prosthesis. J Bone Joint Surg Br 74: 9– 17.

Enis JE, Gardner R, Robledo MA, Latta L and Smith R (1990): Comparison of patellar resurfacing versus nonresurfacing in bilateral total knee arthroplasty. Clin Orthop 260: 38–42.

Ewald FC (1989): The Knee Society total knee arthroplasty roentgenographic evaluation and scoring system. Clin Orthop 248: 9–12.

Ewald FC, Jacobs MA, Miegel RE, Walker PS, Poss R and Sledge CB (1984): Kinematic total knee replacement. J Bone Joint Surg Am 66: 1032–1040.

Ewald FC, Wright RJ, Walker PS, Poss R, Sledge CB, Thomas WH and Reilly DT (1991): Long- term results of posterior cruciate- preserving total knee arthroplasty. J Bone Joint Surg (in press)

Fehring TK and Valadie AL (1994): Knee instability after total knee arthroplasty. Clin Orthop 299: 157–162.

Fern ED, Winson IG and Getty CJM (1992): Anterior knee pain in rheumatoid patients after total knee replacement. J Bone Joint Surg Br 74: 745–748.

Figgie III HE, Goldberg VM, Heiple KG, Moller HS and Gordon NH (1986): The influence of tibial- patellofemoral location on function of the knee in patients with the posterior stabilized condylar knee prosthesis. J Bone Joint Surg Am 68: 1035–1040.

Firestone TP, Krackow KA, Davis JD IV, Teene SM and Hungerford DS (1992): The management of fixed flexion contractures during total knee arthroplasty. Clin Orthop 284: 221–227.

Freeman MAR, Samuelson KM and Bertin KC (1985): Freeman- Samuelson total arthroplasty of the knee. Clin Orthop 192: 46–58.

Freeman MAR, Swanson SAV and Todd RC (1973a): Total replacement of the knee using Freeman- Swanson knee prosthesis. Clin Orthop 94: 153–162.

Freeman MAR, Swanson SAV and Todd RC (1973b): Total replacement of the knee design considerations and early clinical results. Acta Orthop Belg 39: 181– 202.

Friedman RJ, Hirst P, Poss R, Kelley K and Sledge CB (1990): Results of revision total knee arthroplasty performed for aseptic loosening. Clin Orthop 255: 235– 241.

Galinat BJ, Vernace JV, Booth RE Jr and Rothman RH (1988): Dislocation of the posterior stabilized total knee arthroplasty: A report of two cases. J Arthroplasty 3: 363–367.

Garner RW, Mowat AG and Hazleman BL (1973): Wound healing after operations on patients with rheumatoid arhritis. J Bone Joint Surg 55: 134–144.

Gebhard JS and Kilgus DJ (1990): Dislocation of a posterior stabilized total knee prosthesis: A report of two cases. Clin Orthop 254: 225–228.

Gibbs A, Green G and Taylor J (1979): A comparison of the Freeman/ Swanson (ICLH) and Walldius prosthesis in total knee replacement. J Bone Joint Surg Br 61: 358–361.

Gill GS and Mills DM (1991): Long- term follow- up evaluation of 1000 consecutive cemented total knee arthroplasties. Clin Orthop 273: 66–76.

Goldberg VM, Figgie MP, Figgie HM III, Heiple KG and Sobel M (1988a): Use of a total condylar knee prosthesis for treatment of osteoarthritis and rheumatoid arthritis. J Bone Joint Surg Am 70: 802–811.

Goldberg VM, Figgie MP, Figgie HM III and Sobel M (1988b): The results of revision total knee arthroplasty. Clin Orthop 226: 86–92.

Gomes LSM, Bechtold JE and Gustilo RB (1988): Patellar prosthesis positioning in total knee arthroplasty: a roentgenographic study. Clin Orthop 236: 72–81.

Grace JN and Rand JA (1988): Patellar instability after total knee arthroplasty. Clin Orthop 237: 184–189.

Grelsamer RP, Bazos AN and Proctor CS (1993): Radiographic analysis of patellar tilt. J Bone Joint Surg Br 75: 822-–824.

Grelsamer RP and Meadows S (1992): The modified Insall- Salvati ratio for assessment of patellar height. Clin Orthop 282: 170–176.

Gross TP and Lennox DW (1992): Osteolytic cyst like area associated with polyethylene and metallic debris after total knee replacement with a vitallium prosthesis. A case report. J Bone Joint Surg Am 74: 1096–1101.

Gunston FH and McKenzie RI (1976): Complications of polycentric knee arthroplasty. Clin Orthop 120: 11–17.

Hagemann WF, Woods GW and Tullos HS (1978): Arthrodesis in failed total knee replacement. J Bone Joint Surg Am 60: 790–794.

Hartman MB, Fehring TK, Jordan L and Norton HJ (1991): Periprosthetic knee sepsis. The role of irrigation and debridement. Clin Orthop 273: 113–118.

Harvey IA, Barry K, Kirby SPJ, Johnson R and Elloy MA (1993): Factors affecting the range of movement of total knee arthroplasty. J Bone Joint Surg Br 75: 950–955.

Hofmann AA, Bachus KN and Wyatt RWB (1991): Effect of the tibial cut on subsidence following total knee arthroplasty. Clin Orthop 269: 63–69.

Hofmann GO and Hagena FW (1987): Pathomechanics of the femoropatellar joint following total knee arthroplasty. Clin Orthop 224: 251–259.

Hohl WM, Crawfurd E, Zelicof SB and Ewald FC (1991): The total condylar III prosthesis in complex knee reconstruction. Clin Orthop 273: 91–97.

Hood RW, Vanni M and Insall JN (1981): The correction of knee alignment in 225 consecutive total condylar knee replacements. Clin Orthop 160: 94–105.

Hood RW, Wright TM and Burstein AH (1983): Retrieval analysis of total knee prosthesis. A method and its application to forty- eight total condylar prosthesis. J Biomed Mater Res 17: 829–842.

Howie DW, Vernon- Roberts B, Oakeshott R, Monthey B (1988): A rat model of bone at the cement- bone interface in the presence of polyethylene wear particles. J Bone Joint Surg Am 70: 257–297.

Hozack WJ, Goll SR, Lotke PA, Rothman RA and Booth RE Jr (1988): The treatment of patellar fractures after total knee arthroplasty. Clin Orthop 236: 123–127.

Hsu HP, Garg A, Walker PS, Spector M and Ewald FC (1989): Effect of knee component alignment on tibial load distribution with clinical correlation. Clin Orthop 248: 135–144.

Hsu RWW, Himeno S, Coventry MB and Chao EYS (1990): Normal axial alignment of the lower extremity and load- bearing distribution at the knee. Clin Orthop 255: 215–227.

Hui FC and Fitzgerald RH (1978): Hinged total knee arthroplasty. Orthop Trans 2: 195–199.

Hungerford DS and Kenna RV (1983): Preliminary experience with a total knee prosthesis with porous coating used without cement. Clin Orthop 176: 95–107.

Hungerford DS and Krackow KA (1985): Total joint arthroplasty of the knee. Clin Orthop 192: 23–33.

Insall JN (1986): Instructional course lectures. St Louis, C. V. Mosby p. 319.

Insall JN, Dorr LD, Scott RD and Scott WN (1989): Rationale of the knee society clinical rating system. Clin Orthop 248: 13–14.

Insall J, Goldberg V and Salvati E (1972): Recurrent dislocating and the high-riding patella. Clin Orthop 88: 67–69.

Insall JN, Hood RW, Flawn LB and Sullivan DJ (1983): The total condylar knee prosthesis in gonarthrosis- A five to nine year follow- up of the first one hundred consecutive replacements. J Bone Joint Surg Am 65: 619–628.

Insall JN, Lachiewicz PF and Burstein AH (1982): The posterior stabilized condylar prosthesis: A modification of the total condylar design. J Bone Joint Surg Am 64: 1317–1323.

Insall J and Salvati E (1971): Patella position in the normal knee joint. Radiology 101: 101–104.

Insall JN, Scott WN and Ranawat CS (1979a): The total condylar knee prosthesis. A report of two hundred and twenty cases. J Bone Joint Surg Am 61: 173–180.

Insall JN, Tria AJ and Scott WN (1979b): The total condylar knee prosthesis. The first five years. Clin Orthop 145: 68–77.

Jeffery RS, Morris RW and Denham RA (1991): Coronal alignment after total knee replacement. J Bone Joint Surg Br 73: 709–714.

Jessup DE, Worland RL, Clelland C and Arredondo J (1997): Restoration of limb alignment in total knee arthroplasty: evaluation and methods. J South Orthop Assoc 1: 37–47.

Jiang CC and Insall JN (1989): Effect of rotation on the axial alignment of the femur. Pitfalls in the use of femoral intramedullary guides in total knee arthroplasty. Clin Orthop 248: 50–56.

Kajino A, Yoshino S, Kameyama S, Kohda M and Nagashima S (1997): Comparison of the results of bilateral total knee arthroplasty with and without patellar replacement for rheumatoid arthritis. A follow- up note. J Bone Joint Surg Am 79: 570–574.

Kapandji IA (1970): The physiology of the joints. Vol 2. Lower Limb, Edinburgh, Churchill Livingstone

Kaplan EL and Meier R (1958): Nonparametric estimation from incomplete observations. J Am Stat Assoc 53: 457–481.

Kaufer H and Matthews LS (1979): Spherocentric knee arthroplasty. Clin Orthop 145: 110–116.

Kellgren JH and Lawrence JS (1958): Osteoarthrosis and disk degeneration in an urban population. Ann Rheum Dis 17: 388–397.

Kennedy WR and White RP (1987): Unicompartmental arthroplasty of the knee. Postoperative alignment and its influence on overall results. Clin Orthop 221: 278–285.

Kettelkamp DB and DeRosa GP (1976): Surgery of the patellofemoral joint. Part 1. Biomechanics and functional role of the patellofemoral joint. In AAOS Instructional course lectures vol 25. St Loius, C:V: Mosby p. 27.

Kettelkamp DB and Thompson C (1975): Development of a knee scoring scale. Clin Orthop 107: 93–99.

Kim YH (1987): Salvage of failed hinge knee arthroplasty with a total condylar III type prosthesis. Clin Orthop 221: 272–277.

Kirk PG, Rorabeck CH and Bourne RB et al. (1992): Management of recurrent dislocation of patella following total knee arthroplasty. J Arthroplasty 7: 229–233.

Knutson K, Lindstrand A and Lindgren L (1986): Survival of knee arthroplasties. A nation- wide multicentre investigation of 8000 cases. J Bone Joint Surg Br 68: 795–803.

Kobs JK and Lachiewicz PF (1993): Hybrid total knee arthroplasty. Two- to five- year results using the Miller- Galante prosthesis. Clin Orthop 286: 78–87.

Konig A, Scheidler M, Rader C and Eulert J (1997): The need for a dual rating system in total knee arthroplasty. Clin Orthop 345: 161– 167.

Kraay MJ, Meyers SA, Goldberg VM, Figgie III and Conroy PA (1991): ”Hybrid” total knee arthroplasty with the Miller- Galante prosthesis. A prospective clinical and roentgenographic evaluation. Clin Orthop 273: 32–41.

Krackow KA (1983): Approaches to planning lower extremity alignment for total knee arthroplasty and osteotomy about the knee. Adv Orthop Surg: 69–73.

Landon GC, Galante JO and Casini J (1985): Essay on total knee arthroplasty. Clin Orthop 192: 69–74.

Lane EJ, Proto AV and Phillips TW (1976): Mach bands and density perception. Radiology 121: 9–17.

Laskin R (1984): Alignment of total knee components. Orthopedics 7: 62–72.

Laubenthal KN, Smidt GL and Kettelkamp DB (1972): A quantitative analysis of knee motion during activities of daily living. Physical therapy 52: 34–43.

Laurin CA, Levesque HP, Dussault R, Labelle H and Peides JP (1978): The abnormal lateral patellofemoral angle. J Bone Joint Surg Am 60: 55–60.

Leach RE, Baumgard S and Broom J (1973): Obesity: its relationship to osteoarthritis of the knee. Clin Orthop 93: 271–273.

Lettin AWF, Ware HS and Morris RW (1991): Survivorship analysis and confidence intervals: an assessment with reference to the Stanmore total knee replacements. J Bone Joint Surg Br 73: 729–731.

Levitsky KA, Harris WJ, McManus J and Scott RD (1993): Total knee arthroplasty without patellar resurfacing: clinical outcomes and long- term follow- up evaluation. Clin Orthop 286: 116–121.

Lewis JL (1991): Cement in total knee replacements. In: Controversies of total knee arthroplasty, pp. 89–93. Ed. VM Goldberg, Raven Press, New York.

Maloney WJ, Jasty M, Harris W et al. (1990): Endosteal erosion in association with stable uncemented femoral components. J Bone Joint Surg Am 72: 1025–1034.

Maquet P (1976): Biomechanics of the knee. Springer- Verlag, Berlin.

Maquet P (1980): The biomechanics of the knee and surgical possibilities of healing osteoarthritic knee joints. Clin Orthop 146: 102–110.

Maquet PGJ (1984): Biomechanics of the knee, ed. 2. New York, Springer- Verlag.

Marcacci M, Iacono F, Zaffagnini S, Visani A, Loreti I, Petitto A, Neri MP and Kon E (1997): Total knee arthroplasty without patellar resurfacing in active and overweight patients. Knee Surg Sports Traumatol Arthrosc. 4: 258–261.

Marmor L (1973): The modular knee. Clin Orthop 94: 242–248.

Marshall KW, Chiu B and Inman RD (1990): Substance P and arthritis: analysis of plasma and synovial fluid levels. Arthritis Rheum 33: 87–90.

Matthews LS, Goldstein SA and Kaufer H (1985): Experiences with three distinct types of total knee joint arthroplasty. Clin Orthop 192: 97–107.

Merchant AC, Mercer RL, Jacobsen RH and Cool CR (1974): Roentgenographic analysis of patellofemoral congruence. J Bone Joint Surg Am 7: 1391–1396.

Merkel KD and Johnson EW (1986): Supracondylar fracture of the femur after total knee arthroplasty. J Bone Joint Surg Am 68: 29–43.

Merkow RL, Soudry M and Insall JN (1985): Patellar dislocation following total knee replacement. J Bone Joint Surg Am 67: 1321–1327.

Mont MA, Fairbank AC, Yammamoto V, Krackow KA and Hungerford DS (1996): Radiographic characterization of aseptically loosened cementless total knee replacement. Clin Orthop 321: 73–78.

Moran CG, Pinder IM, Lees TA and Midwinter MJ (1991): Survivorship analysis of the uncemented porous coated anatomic knee replacement. J Bone Joint Surg Am 73: 848–857.

Moreland JR (1986): Fracture of a unicompartmental knee replacement femoral component. Clin Orthop 206: 166–168.

Moreland JR (1988): Mechanisms of failure in total knee arthroplasty. Clin Orthop 226: 49–64.

Moreland JR, Bassett LW and Hanker GJ (1987): Radiographic analysis of the axial alignment of the lower extremity. J Bone Joint Surg Am 69: 745–749.

Moreland JR, Thomas RJ and Freeman MAR (1979): ICLH replacement of the knee: 1977 and 1978. Clin Orthop 145: 47–59.

Morrey BF and Chao EYS (1988): Fracture of the porous- coated metal tray of a biologically fixed knee prosthesis: Report of a case. Clin Orthop 228: 182–189.

Mose K (1964): Legg- Calve- Perthes disease. Thesis. Copenhagen, Universitetforlaget.

Murray DG (1985): Total knee arthroplasty. Clin Orthop 192: 59–68.

Murray DW, Carr AJ and Bulstrode C (1993): Survival analysis of joint replacements. J Bone Joint Surg Br 75: 697–704.

Nelissen RGHH, Brand R and Rozing PM (1992): Survivorship analysis in total condylar knee arthroplasty. J Bone Joint Surg Am 74: 383–389.

Nelson CL (1987): Prevention of sepsis. Clin Orthop 222: 66–72.

Nielsen PT, Hansen EB and Rechnagel K (1992): Cementless total knee arthroplasty in unselected cases of osteoarthritis and rheumatoid arthritis. A 3- year follow- up study of 103 cases. J Arthroplasty 7: 137–143.

Nilsson KG, Kärrholm J and Ekelund L (1990): Knee motion in total knee arthroplasty. A roentgen stereophotogrammetric analysis of the kinematics of the Tricon- M knee prosthesis. Clin orthop 256: 147–161.

Odenbring S, Berggren AM and Peil L (1993): Roentgenographic assessment of the hip- knee- ankle axis in medial gonarthrosis. A study of reproducibility. Clin Orthop 289: 195–196.

Okamoto R and Koshino T (1991): Yearly changes of limb alignment toward varus as measured by the femorotibial angle after total knee arthroplasty. Bullet Hosp J Dis Orthop Ins 2: 230–235.

Ordonez- Parra JM, Fernandez- Baillo N, Bello S, Coya J, Marin D and Munuera L (1992): Scintimetric study of the bone response around noncemented knee prosthesis. Preliminary results. Clin Orthop 283: 106–115.

Oswald MH, Jacob RP, Schneider E and Hoogewoud HM (1993): Radiological analysis of normal axial alignment of femur and tibia in view of total knee arthroplasty. J Arthroplasty 4: 419–426.

Parsley BS, Engh GA and Dwyer KA (1992): Preoperative flexion. Does it influence postoperative flexion after posterior- cruciate- retaining total knee arthroplasty? Clin Orthop 275: 204–210.

Partio E and Wirta J (1995): Comparison of patellar resurfacing and nonresurfacing in total knee arthroplasty: a prospective randomized study. J Orthop Rheum 8: 69–74.

Patel DV, Aichroth PM and Wand JS (1991): Posteriorly stabilised (Insall- Burstein) total condylar knee arthroplasty. A follow- up study of 157 knees. Int Orthop 15: 211–218.

Perry J, Antonelli D and Ford W (1975): Analysis of knee- joint forces during flexed- knee stance. J Bone Joint Surg Am 57: 961–967.

Petersen TL and Engh GA (1988): Radiographic assessment of knee alignment after total knee arthroplasty. J Arthroplasty 3: 67–72.

Picetti GD III, McGann WA and Welch RB (1990): The patellofemoral joint after total knee arthroplasty without patellar resurfacing. J Bone Joint Surg Am 72: 1379–1382.

Pugh JW, Rose RM and Radin EL (1973): A structural model for the mechanical behaviour of trabecular bone. J Biomech 6: 657–670.

Radin EL, Parker HG, Pugh JW, Steinberg RS, Paul IL and Rose RM (1973): Response of joint to impact loading. J Biomech 6: 51–57.

Ranawat CS (1986): The patellofemoral joint in total condylar knee arthroplasty: Pros and cons based on five- to ten- year follow- up observations. Clin Orthop 205: 93–99.

Ranawat CS and Boachie- Adjei O (1988): Survivorship analysis and results of total condylar knee arthroplasty. Eight- to 11- year follow- up period. Clin Orthop 226: 6–13.

Ranawat CS, Insall J and Shine J (1976): Duocondylar knee arthroplasty. Clin Orthop 120: 76–82.

Ranawat CS, Johanson NA, Rimnac CM, Wright TM and Schwartz RE (1986): Retrieval analysis of porous- coated components for total knee arthroplasty. A report of two cases. Clin Orthop 209: 244–248.

Ranawat CS and Shine JJ (1973): Duo- condylar total knee arthroplasty. Clin Orthop 94: 185–195.

Rand JA (1994): The patellofemoral joint in total knee arthroplasty. J Bone Joint Surg Am 76: 612–620.

Rand JA and Bryan RS (1988): Results of revision total knee arthroplasty using condylar prostheses. A review of fifty knees. J Bone Joint Surg Am 70: 738–745.

Rand JA, Bryan RS, Chao EYS and Ilstrup DM (1987): A comparison of cemented versus cementless Porous Coated Anatomic total knee arthroplasty. In Rand JA and Dorr LD (eds.): Total arthroplasty of the knee. Proceedings of the knee society 1985–1986. Rockville, Maryland, Aspen, pp. 195–212.

Rand JA and Coventry MB (1980): Stress fractures after total knee arthroplasty. J Bone Joint Surg Am 62: 226–233.

Rand JA and Coventry MB (1988): Ten- year evaluation of geometric total knee arthroplasty. Clin Orthop 232: 168–173.

Rand JA and Ilstrup DA (1991): Survivorship analysis of total knee arthroplasty: cumulative rates of survival of 9200 total knee arthroplasties. J Bone Joint Surg Am 73: 397–409.

Reckling FW, Asher MA and Dillon WL (1977): A longitudinal study of the radiolucent line at the bone- cement interface following total joint- replacement procedures. J Bone Joint Surg Am 59: 355–358.

Ritter MA (1997): Postoperative pain after total knee arthroplasty. J Arthroplasty 3: 337–339.

Ritter MA and Campbell ED (1987): Effect of range of motion on the success of a total knee arthroplasty. J Arthroplasty 2: 95–97.

Ritter MA, Faris PM, Keating EM and Meding JB (1994): Postoperative alignment of total knee replacement . Its effect on survival. Clin Orthop 299: 153–156.

Ritter MA, Gioe TJ and Stringer EA (1981): Radiolucency surrounding the posterior cruciate condylar total knee prosthetic components. Clin Orthop 160: 149–152.

Ritter MA and Meding JB (1986): Anterior displacement. Its effects on instability and radiolucency in total knee replacements. Clin Orthop 208: 259–265.

Ritter MA and Stringer EA (1979): Predictive range of motion after total knee replacement. Clin Orthop 143: 115–119.

Robinson EJ, Mulliken BD, Bourne RB, Rorabeck CH and Alvarez C (1995): Catastrophic osteolysis in total knee replacement. A report of 17 cases. Clin Orthop 321: 98–105.

Rorabeck CH, Bourne RB and Nott L (1988): The cemented Kinematic-II and the noncemented porous coated anatomic prosthesis for the total knee replacement. J Bone Joint Surg Am 70: 483–490.

Rosenberg AG, Andriacchi TP, Barden R and Galante JO (1988): Patellar component failure in cementless total knee arthroplasty. Clin Orthop 236: 106–114.

Rutledge R, Webster DA and Murray DG (1986): Experience with the variable axis knee prosthesis. Clin Orthop 205: 146–152.

Ryd L, Lindstrand A, Rosenquist R and Selvik G (1987): Micromotion of conventionally cemented all- polyethylene tibial components in total knee replacements. Arch Orthop Trauma Surg 106: 82–88.

Ryd L, Lindstrand A, Stenström A and Selvik G (1990): Porous coated anatomic tricompartmental tibial components. The relationship between prosthetic position and micromotion. Clin Orthop 251: 189–197.

Rööser B, Boegård T, Knutson K, Rydholm U and Lidgren L (1987): Revision knee arthroplasty in rheumatoid arthritis. Clin Orthop 219: 169–172.

Schneider R, Freiberger RH, Ghelman B and Ranawat CS (1982): Radiologic evaluation of painful joint prostheses. Clin Orthop 170: 156–167.

Schneider R, Hood RW and Ranawat CS (1982): Radiologic evaluation of knee arthroplasty. Orthop Clin North Am 13: 1, pp 225–244.

Schneider R and Soudry M (1986): Radiographic and scintigraphic evaluation of total knee arthroplasty. Clin Orthop 205: 108–120.

Scott RD (1982): Duopatellar total knee replacement: The Brigham experience. Orthop Clin North Am 13: 89–102.

Scott RD, Turoff N and Ewald FC (1982): Stress fracture of the patella following duopatellar total knee arthroplasty with patellar resurfacing. Clin Orthop 170: 147–151.

Scott RD and Volatile TB (1986): Twelve years' experience with posterior cruciate-retaining total knee arthroplasty. Clin Orthop 205: 100–107

Scuderi GR, Insall JN, Windsor RE and Moran MC (1989): Survivorship of cemented knee replacements. J Bone Joint Surg Br 71: 798–803.

Sharkey PF, Hozack WJ, Booth RE Jr, Balderston RA, Rothman RH (1992): Posterior dislocation of total knee arthroplasty. Clin Orthop 278: 128–133.

Sheehan JM (1978): Arthroplasty of the knee. J Bone Joint Surg Br 60: 333–338.

Shimagaki H, Bechtold JE, Sherman RE and Gustilo RB (1990): Stability of initial fixation of the tibial component in cementless total knee arthroplasty. J Orthop Res 8: 64–71.

Sledge CB, Stern PJ and Thomas WH (1978): Two year follow- up of the duocondylar total knee replacement. Orthop Trans 2: 193–197.

Smith SR, Yoshino S and Kajino A (1989): Non- resurfaced patella in total knee arthroplasty. J Arthroplasty Suppl 4: 81–86.

Soudry M, Mestriner LA, Binazzi R and Insall JN (1986): Total knee arthroplasty without patellar resurfacing. Clin Orthop 205: 166–170.

Stern SH, Bowen MK, Insall JN and Scuderi GR (1990): Cemented total knee arthroplasty for gonarthrosis in patients 55 years old or younger. Clin Orthop 260: 124–129.

Stern SH and Insall JN (1990): Total knee arthroplasty in obese patients. J Bone Joint Surg Am 72: 1400–1404.

Stulberg BN, Watson JT, Stulberg SD, Bauer TW and Manley MT (1991): A new model to assess tibial fixation. II. Concurrent histologic and biomechanical observations. Clin Orthop 263: 303– 309.

Swanson SAV (1980): Biomechanics. In Freeman MAR (ed): Arthritis of the knee. New York, Springer- Verlag.

Teeny SM, Krackow KA, Hungerford DS and JonesM (1991): Primary total knee arthroplasty in patients with severe varus deformity. A comparative study. Clin Orthop 273: 19–31.

Tew M and Forster IW (1987): Effect of knee replacement on flexion deformity. J Bone Joint Surg Br 69: 395–399.

Tew M and Waugh W (1985): Tibiofemoral alignment and the results of knee replacement. J Bone Joint Surg Am 4: 551–556.

Tibreval SB, Grant KA and Goodfellow JW (1984): The radiolucent line beneath the tibial components of the Oxford meniscal knee. J Bone Joint Surg Br 66: 523–528.

Toksvig- Larsen S, Ryd L and Lindstrand A (1994): Effect of cooled saw blade on prosthesis fixation. Randomized radiostereometry of 33 knee cases. Acta Orthop Scand 65: 533–537.

Torisu T and Morita H (1986): Roentgenographic evaluation of geometric total knee arthroplasty with a six- year average follow- up period. Clin Orthop 202: 125–134.

Townley CO (1985): The anatomic total knee resurfacing arthroplasty. Clin Orthop 192: 82–96.

Walker PS, Emerson R, Potter T, Scott RD, Scheller AD, Murray W and Walker P (1982): The Kinematic rotating hinge: Preliminary clinical experience. Orthop Trans 6: 370–374.

Walker PS and Garg A (1991): Range of motion in total knee arthroplasty. A computer analysis. Clin Orthop 262: 227–235.

Walker PS, Ranawat C and Insall J (1976): Fixation of the tibial components of condylar replacement knee prostheses. J Biomech 9: 269–276.

Walldius B (1960): Arthroplasty of the knee using an endoprosthesis. 8 years' experience. Acta Orthop Scand 30: 137–148.

Wang CJ and Wang HE (1997): Dislocation of total knee arthroplasty. A report of 6 cases with 2 patterns of instability. Acta Orthop Scand 3: 282–285.

Webster DA and Murray DG (1985): Complications of variable axis total knee arthroplasty. Clin Orthop 193: 160–167.

Weinfeld MS (1969): Proposed rating system for evaluation of knee arthroplasties. Surg Clin North Am 49: 947–950.

Whiteside LA, Fosco DR and Brooks JG (1993): Fracture of the femoral component in cementless total knee arthroplasty. Clin Orthop 286: 71–77.

Wilson MG, Kelly K and Thornhill TS (1990): Infection as a complication of total knee replacement arthroplasty. Risk factors and treatment in 67 cases. J Bone Joint Surg 72: 878–883.

Wimmer MA, Andriacchi TP, Natarajan RN, Loos J, Karlhuber M, Petermann J, Schneider E and Rosenberg AG (1998): A striate pattern of wear in UHMW polyethylene components of Miller- Galante total knee arthroplasty. J Arthroplasty 1: 8–16.

Windsor RE, Scuderi GR, Moran MC and Insall JN (1989): Mechanisms of failure of the femoral and tibial components in total knee arthroplasty. Clin Orthop 248: 15–20.

Wright JG, Treble N and Feinstein AR (1991): Measurement of lower limb alignment using long radiographs. J Bone Joint Surg Br 73: 721–723.

Wright TM, Astion DJ, Bansal M, Rimnac CM, Green T, Insall JN and Robinson RP (1988): Failure of carbon fiber- reinforced polyethylene total knee-raplacement components. J Bone Joint Surg Am 70: 926–932.

Wright TM and Bartel DL (1986): The problem of surface damage in polyethylene total knee components. Clin Orthop 205: 67–74.

Wright TM, Rimnac CM, Stulberg SD, Mintz L, Tsao AK, Klein RW and McCrae C (1992): Wear of polyethylene in total joint replacements. Observations from retrieved PCA knee implants. Clin Orthop 276: 126–134.

13. ORIGINAL COMMUNICATIONS