COMPARISON OF FIXED-BEARING AND MOBILE BEARING TOTAL KNEE ARTHOPLASTY

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Certificate

This is to certify that the dissertation entitled ***COMPARISON OF FIXED BEARING AND MOBILE BEARING TOTAL KNEE ARTHROPLASTY*** is a bonafide work of Dr. James C George in partial fulfillment of the requirements for the M.S. Orthopaedics (Branch II) Examination of the Tamilnadu Dr. M.G.R. Medical University, to be held in 2007.

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Table – 1

AMERICAN KNEE SOCIETY SCORE

Patient category

A. Unilateral or bilateral (opposite knee successfully replaced)
B. Unilateral, other knee symptomatic
C. Multiple arthritis or medical infirmity

Pain	Points
None	50
Mild or occasional	45
Stairs only	40
Walking and stairs	30
Moderate	
Occasional	20
Continual	10
Severe	0

Range of Motion

(**5º** = 1 point)

Stability (maximal movement in any position)

Anteroposterior	
<5 mm	10
5-10 mm	5
10 mm	0
Mediolateral	
<5°	15
6° – 9°	10
10° – 14°	5
15°	0
Subtotal	

Deductions (minus)

Flexion Contracture	
5° – 10°	2
10° – 15°	5
16° – 20°	10
>20°	15
Extension lag	
<10°	5
10° – 20°	10
>20°	15
Alignment	
5° – 10°	0
0° – 4°	3 points each degree
11° – 15°	3 points each degree
other	20
Total deductions	

Knee score

Function

Walking	50
Unlimited	40
>10 blocks	30
5-10 blocks	20
<5 blocks	10
Housebound	0
Unable	
Stairs	
Normal up and down	50
Normal up; down with rail	40
Up and down with rail	30
Up with rail: unable down	15
Unable	0
Subtotal	

Deduction (minus)

Cane	5
Two Canes	10
Crutches or walker	20
Total deduction	
Function score	

TABLE 2

OXFORD KNEE SOCIETY SCORE

Item	scoring categories	
During the past four weeks		
1.How would you describe the pain you usually have from your knee?	1.	None
	2.	Very mild
	3.	Mild
	4.	Moderate
	5.	Severe
2. Have you had any trouble with washing and drying yourself because of your knee?	1.	No trouble at all
	2.	Very little trouble
	3.	Moderate trouble
	4.	Extreme difficulty
	5.	Impossible to do
3.Have you had any trouble in getting out of a car or public transport because of your knee?	1.	No trouble at all
	2	Very little trouble
	3.	Moderate trouble
	4.	Extreme difficulty
	5.	Impossible to do
4.For how long have you been able to walk before the pain from your knee becomes severe?	1.	No pain/>30 min
	2.	60 min to 30 min
	3.	5 min to 15 min
	4.	Around the house
	5.	Not at all – severe on walking
5.After a meal how painful has it been for you to stand up from a chair because of your knee?	1.	Not at all painful
	2.	Slightly painful
	3.	Moderately painful
	4.	Very painful
	5.	Unbearable
6. Have you been limping when walking, because of your knee?	1.	Rarely/Never
	2.	Sometimes
	3.	Often
	4.	Most of the time
	5.	All of the time
7.Could you kneel down and getup again afterwards?	1.	Easily
	2.	With little difficulty
	3.	With Moderate difficulty
	4.	With extreme difficulty
	5	No impossible
8. Have you been troubled by pain from your knee in bed at night?	1.	No nights
	2.	Only one or two nights
	3.	Some nights
	4.	Most nights
	5.	Every night
9. How much has pain from your knee interfere with your usual work?	1.	Not at all
	2.	Little bit
	3.	Moderately
	4.	Greatly
	5.	Totally
10. Have you felt your knee might suddenly “give way” or let you down?	1.	Rarely/Never
	2.	Sometimes
	3.	Often
	4.	Most of the time
	5.	All of the time
11.Could you do household shopping on your own?	1.	Easily
	2.	With little difficulty
	3.	With Moderate difficulty
	4.	With extreme difficulty
	5	No impossible
12.Could you walk down a flight of stairs?	1.	Easily
	2.	With little difficulty
	3.	With Moderate difficulty
	4.	With extreme difficulty
	5	No impossible

Table 4: Patient Demographic Data		
Variables	LCS	PFC
Number of patients	30	21
Number of knees	47	26
Male / Female	11/19	11/10
Mean age (in years)	57.7	60.46
Diagnosis (no. of patients)		
Osteoarthritis	25	20
Rheumatoid arthritis	5	1
Mean duration of follow up (in years)	3.76	2.37

Table 5

Range of flexion (mean)	LCS	PFC
Pre operative	94.68° (20° – 130°)	111.53° (70°– 140°)
Post operative	98.29° (50°-140°)	113.26° (90°–140°)

INTRODUCTION

Total knee arthroplasty has become a highly successful joint reconstruction procedure. Surgical outcome, patient satisfaction, and implant survival have improved steadily since its inception and the operation has become widely accepted to afford relief of pain, restoration of range of motion and function [1-4] . In the earlier years of total knee arthroplasty, the operation was offered usually to an older age group whose activity level was relatively sedentary[5]. It has now been shown that total knee arthroplasty is effective and durable in the younger, more active patient[6, 7], as well as the elderly population.

As early as 1861 Fergusson reported resection arthroplasty of the knee for arthritis. Vermeil generally is credited with performing the first interposition arthroplasty of the knee in 1863, when he inserted a flap of joint capsule between the resected tibia and femur to prevent them from growing together. Mold hemiarthroplasty of the knee was attempted by Campbell and Boyd in 1940 and by Smith-Peterson in 1942. Tibial hemiarthroplasty also was attempted in the Mckeever and Macintosh tibial plateau prostheses. These prostheses, like their femoral counterparts, were subject to painful early loosening and failed to replace both surfaces of the arthritic knee joint, so the unaltered joint surface remained a source of persistent pain.

The prime indications for total knee arthroplasty still are severe pain and functional disability. Relative indications include deformity, instability, and loss of motion. Other sources of knee and leg pain, radicular pain from spinal disease, referred pain from the ipsilateral hip, peripheral vascular disease, meniscal pathology and bursitis of the knee should be excluded.

Before surgery is considered, conservative treatment measures should be exhausted, including anti-inflammatory medications, activity modifications, and the use of a cane for ambulation. Even though knee replacement is generally indicated in older patients with more sedentary lifestyles, it is also clearly indicated in younger patients who have limited function because of systemic arthritis with multiple joint involvements. Severe pain from chondrocalcinosis and pseudogout in an elderly patient is an occasional indication for arthroplasty in the absence of complete cartilage loss. Deformity can become the principal indication for arthroplasty in patients with moderate arthritis and variable levels of pain when the progression of deformity begins to threaten the expected outcome of an anticipated arthroplasty. Rarely, severe patellofemoral arthritis in an elderly patient may justify arthroplasty because the expected outcome of arthroplasty is better than that of patellectomy in these patients.

Recent and active sepsis remains an absolute contraindication to total knee arthroplasty. Other absolute contraindication includes inadequate soft tissue coverage of the knee joint with or without associated poor vascularity. Those patients with poor limb perfusion and severe peripheral vascular disease are also not candidates for joint arthroplasty. Relative contraindications are neuropathic arthropathy and arthrodesed knee.

AIMS AND OBJECTIVES

The aim of the study was to compare between mobile bearing total knee arthroplasty and posterior stabilized fixed bearing total knee arthroplasty. The following factors were analysed:

1. Range of movement
2. Short term functional outcome
3. Joint line

The objectives of this study were to answer the following questions:

1. Is there a significant difference in the post operative flexion range between mobile and fixed-bearing total knee arthroplasty?

2. What is the short term functional outcome in our population undergoing total knee replacement?

3. How does the change in joint line affect the function in the mobile and fixed bearing total knee systems?

ANATOMY, BIOMECHANICS AND PROSTHETIC DESIGN

Knee motion during normal gait has been studied by many investigators who have found it to be much more complex than simple flexion and extension. Knee motion occurs in flexion and extension, abduction and adduction, and rotation about the axis of the limb. Kettlekamp[15] found that normal gait requires 67 degrees of flexion for stair climbing, 90 degrees for descending stairs and 93 degrees to rise from a chair.

Mechanical axis of lower limb extends from center of femoral head to centre of ankle joint and passes near or through the center of the knee. Anatomical axis of femur is 6^{o} valgus from mechanical axis of lower limb while anatomical axis of tibia is parallel to the mechanical axis. In a normal knee, the tibial articular surface is 3° of varus with respect to the mechanical axis and the femoral articular surface is in a corresponding 9° of valgus. Since the aim of surgery is to reproduce near normal anatomy and biomechanics, the tibial component generally is implanted perpendicular to the mechanical axis of tibia in coronal plane, with varying amount of posterior tilt in sagittal plane, depending on the articular design of the component to be implanted. The femoral component usually is implanted in 5 to 6° of valgus, the amount necessary to re-establish a neutral mechanical axis of the limb, and 3^{o} external rotation relative to the posterior condylar axis[16, 17].

Femoral rollback is defined as posterior shift of tibio-femoral contact areas (fig. 1). It has been argued that the phenomenon of rollback of the femur on the tibia during flexion prevents the impingement of the femur on the posterior border of the tibia with flexion[18]. Normal rollback is dependent on the intact functioning of anterior and posterior cruciate ligaments. This produces a polycentric inverted “J” shaped center of rotation (fig. 2). Even

in the absence of anterior cruciate ligament, the posterior cruciate ligament can produce femoral rollback, but at the expense of posterior gliding of femur on tibia.

Posterior cruciate ligament is the primary physiologic stabilizer of the knee to posterior displacement of the tibia on the femur and this importance increases with increasing flexion. The posterior cruciate ligament also acts as a secondary stabilizer in medio-lateral displacement, varus-valgus angulations, and axial rotation [19].

Studies in animal models and in human cadavers and amputation specimens have demonstrated mechano-receptors in the posterior cruciate ligament[20]. These mechano-receptors powerfully influence gamma motor neurons so that even minor stretch of the posterior cruciate ligament can produce major changes in muscle spindle afferents. Consequently individuals with PCL-retaining prostheses have a more symmetrical gait, especially during stair climbing, than do individuals with PCL sacrificing design[18] due to improved proprioceptive function of the knee. However gait analysis studies by Wilson et al[21] contradict these conclusions after comparing PCL substituting knee with normal control.

The primary function of the patella is to increase the lever arm of the extensor mechanism about the knee, thus improving the efficiency of quadriceps contraction. According to Grood et al[22], the extensor lever arm is greatest at 20 degrees of flexion, and the quadriceps force required for knee extension increases significantly in the last 20 degrees of extension. The inferior articular surface of the patella first contacts the trochlea in approximately 20 degrees of knee flexion. The midportion of patella articulates with the trochlea in approximately 60^{o} degrees of flexion, and the superior portion of the patella articulates at 90^{o} degrees of flexion. In extreme flexion, beyond 120^{o} degrees, the patella articulates only medially

and laterally with the femoral condyles and the quadriceps tendon articulates with the trochlea [23](fig. 3).

Patellofemoral stability is maintained by a combination of the articular surface geometry and soft tissue restraints. The Q angle is the angle of pull of quadriceps on patella. Limbs with larger Q angle have a greater tendency for lateral patellar subluxation[24].

DESIGN GOALS

In broad terms, the design goals of any knee replacement are relief of pain, unlimited functional ability, durability for the life of the patient, reproducibility in the operating room and low cost. Although simplicity of surgical technique is ideal, present-day systems show increasing complexity because of the wide range of sizes, design types, and modular options. The variation of inherent functional capabilities in different designs of the standard condylar replacements, with surfaces ranging from flat to fully dished, indicates the lack of comparative biomechanical data on performance. Other design issues today include the question of whether meniscal bearing design indeed offer enhanced durability and performance, and whether rotating hinged designs, which offer reliable stability, should take the place of unlinked constrained condylar type of designs, which are more prone to instability. An inevitable consequence of expanding component options and complexity of instrumentation has been that cost has increased to some extent.

SURFACE GEOMETRY AND CONTACT STRESS

To achieve normal joint mechanics the surfaces of a joint replacement should be reasonably anatomic and provide normal laxity and stability in combination with remaining soft tissues. The femoral profile that articulates with the tibial surface in the sagittal plane has three radii. An important parameter is the angle between distal and posterior radii. For the natural knee, this angle is around 10 to 15 degrees and divides the posterior radius,

about 20 mm on average, from distal radius. The lateral distal radius is much larger than that on the medial side, facilitating the internal rotation that occurs in early flexion as a result of the relatively different medial and lateral rolling distances. Similarly femoral profile that articulates with the tibial surface in the coronal plane has two radii. In the sagittal plane three parameters are important, the first being the location of the lowest point on the tibial surface, which is a key parameter. This defines the femoral- tibial contact point at all angles of flexion when axial compressive forces are acting. The other two parameters are the anterior and posterior proximal tibial radii in the sagittal plane. The smaller anterior radii contributes to stability and the larger posterior radii facilitates rollback of the above mentioned contact point.

The goal is to minimize the stresses on the plastic surface, because this is one of the factors that minimizes the deformation and wear of the material. The goal implies that the highest possible conformity in both planes is preferable. Lowest stresses occur when femoral and tibial surfaces conform closely in both the coronal and sagittal planes. Low conformity in both planes produces point contact situation producing maximal stresses. This applies to round on flat total knee designs. An intermediate situation occurs when there is close conformity in the frontal plane but relatively low conformity in sagittal plane. This configuration has the potential advantage of allowing for adequate anteroposterior displacement and internal – external rotation.

In the natural joint, laxity and stability depend on the geometry of the articulating surfaces, combined with the tension patterns and elastic properties of the ligaments and soft tissues during flexion range. It appears that higher constraint designs with differences in sagittal femoral and tibial radii in early flexion of around 12 mm provide complete stability to forces that apply to normal walking, with only a few millimeters of anteroposterior

sliding. The soft tissues contribute little if anything to stability and the entire shear forces are carried at the condylar surfaces. In the low constraint designs with radii difference averaging 17mm, the surfaces are capable of providing all of the stability while walking, but the amount of anteroposterior in laxity is likely to result in some contribution from soft tissues. As the radii difference increases beyond 20 mm, more and more shear forces are carried by soft tissues and less by condylar surfaces.

WEAR AND DAMAGE OF THE PLASTIC

There are three types of wear mechanisms in plastic material. The first is adhesive wear, occurring at local contact points between the metal and the plastic within the overall contact area. Typically, this generates small particles and shreds in the range 0.1-10 micrometer, as well as up to thin sheets of 10 micrometer width. Abrasive wear is caused by cutting of the plastic surface by harder surface or particles. In two body abrasion, the roughness is integral with the hard surface, such as carbide inclusion or a scratch. In three body abrasion, interposed particles or metal, acrylic cement, bone or other material cause the surface cutting. Finally, there is delamination wear, which is a fatigue phenomenon whereby high subsurface stresses lead to propagation of cracks within the plastic, with the crack eventually coalescing and reaching the surface. This typically results in surface destruction to depths of millimeters, even down to metal base plate.

Surface wear occurs at microscopic adhesive points. When there is sufficient lubrication between the tibial and femoral surfaces, the plastic surface displays fine ripples with spacing from 2-10 micrometers. Thin sections through such surfaces, viewed under polarized light, showed that at these contact points there is a considerable build up strain energy. When this energy reaches a critical level, particles are released from the surface. This type of wear results in very small particles and shreds, of approximately 1 micrometer or less.

However, the most severe type of wear is delamination wear, which causes destruction of plastic to a depth of millimeters. The important characteristic of delamination is that it is time dependent. Up to 8 years, the delamination scores were close to zero, but after 8 years, the score increased rapidly. Hence, it would be misleading to judge the wear resistance of a particular design in relatively short term follow-up, because the more severe delamination wear could take place precipitously after a certain elapsed time. The lines of maximum shear stress show that the highest value occurs below the surface. The significance of this is that the initiation and propagation of the cracks depends on the input of strain energy, which is highest in the regions of highest shear stresses. For direct loading with no sliding, the depth below the surface is 25 % the width of the contact area, or, typically, 1-2 mm.

However subsurface stresses to produce delamination wear, there need to be the sites for the initiation of cracks. There is good evidence that these sites are inter granular defects where inadequate bonding has taken place between polyethylene granules during the extrusion of molding processes. Once a crack has initiated in this way, it can propagate as a result of the energy provided at the crack tip by the cyclic stresses. Multiple cracks can occur if there are sufficient numbers of defects in the regions of high shear stress.

A disadvantage of flat plastic surfaces with low constraint is that the contact point locations during activities are both variable and unpredictable. Although the ideal contact region is in the middle third of the plastic surface, small variations in the tibial slope or PCL tension can result in abnormal contact locations and excessive sliding motions. The sliding is a result of anteroposterior or internal-external rotation. This produces extensive wear over the surface as well as severe wear damage at the anterior or posterior edge of the plastic. Wear studies on specimens have highlighted the

increased wear caused by sliding, which is greatly reduced under rolling or when the contact point is in the same location.

At other end of the spectrum, designs that have high constraint and hence large contact areas and low contact stresses are often thought to produce extremely low wear rates and be free of delamination wear.

From stand point of minimizing wear of the plastic, a number of design and materials criteria can be specified. The provision for functional laxity by partial constraint is seen to be compatible with reducing wear because of the adverse consequences of excessive constraint, not only for wear but for fixation also. Although cobalt –chromium surfaces are adequate, to minimize the surface wear in the long term surfaces such as ceramics, which are harder and more wettable, are preferable. Perhaps the most important variable is the quality of the plastic itself, in terms of complete consolidation with a minimal number of fusion defects or voids, with the minimal amount of oxidation at the time of implantation.

POSTERIOR STABILISED CONDYLAR KNEE PROSTHESIS

Although the total condylar prosthesis, which was introduced in 1974, is considered to be the predecessor of the posterior stabilised condylar knee prosthesis the total condylar knee prosthesis and the posterior stabilised condylar knee prosthesis are separate types of arthroplasty.

The total condylar knee prosthesis is a “posterior cruciate ligament-sacrificing” prosthesis, which allows for a larger proximal tibial cancellous surface area for tibial component fixation. The posterior-stabilised condylar knee prosthesis is similar to the total condylar knee prosthesis in that, both technically require excision of both cruciate ligaments for prosthesis implantation; however, the posterior-stabilised condylar knee prosthesis is radically different. It is a “posterior cruciate ligament-substituting” prosthesis, which has a tibial and femoral component articulation, that allows for femoral rollback during knee flexion. This “posterior cruciate ligament-

substituting" mechanism makes the posterior-stabilised condylar knee prosthesis both clinically and mechanically a better prosthesis of choice for patients requiring a total knee arthroplasty. The Insall–Burstein I was the original posterior-stabilised condylar prosthesis developed at the Hospital for Special surgery and was the successor of the total condylar prosthesis. It was introduced as a modification of the total condylar prosthesis to specifically improve joint stability, range of motion, and ability to climb stairs. These goals were to be achieved with the use of a "posterior cruciate ligament-substituting mechanism". A transverse cam on the femoral component articulating with a central polyethylene post on the tibial component combined with a change in the center of curvature of the femoral condyles allowed for femoral rollback during flexion to improve motion and knee stability.

However, it became evident that patellar complications were increasing with this new design. These complications have since been attributed to overstuffing of the patellofemoral joint and to the increased motion realized by the new design rather than to the femoral rollback mechanism of the femoral cam and tibial post.

There was another troublesome clinical occurrence with the patellofemoral articulation in the new design. Fibrous tissue tended to accumulate in the quadriceps tendon just above the patellar button. This fibrous tissue frequently became lodged between the leading edge of the femoral intercondylar box and the patellar button when the knee extended from a flexed position. This phenomenon has been well described in the original report on the posterior-stabilised condylar prosthesis and has been called the "patellar clunk" syndrome.

In 1982 the leading edge of the femoral box at the distal end of the trochlear groove was cambered to prevent this quadriceps irritation. In 1983, the trochlear groove was deepened to enhance the patellofemoral tracking.

A major change to the posterior-stabilised condylar knee prosthesis came about in November 1980, when a posterior-stabilised prosthesis with a metal-backed tibial component was first implanted at the Hospital for Special Surgery.

In September 1988, the Insall-Burstein II was introduced. Stem and wedges became available to enhance component fixation and constrained condylar components became available to enhance stability. Other changes were incorporated including deepening of the trochlear groove to facilitate patellar tracking. The radii of curvature of the femoral condyles and the tibial articular surfaces in the coronal plane were increased to enhance medio-lateral rotation. The tibial polyethylene insert was also significantly changed to enhance knee flexion by shortening the tibial post by 2 mm and translating it posteriorly by 2 mm.

There was a statistically significant higher incidence of Insall-Burstein II dislocation versus Insall-Burstein I dislocations. This was attributed to the shortening and posterior translation of the tibial post with the Insall-Burstein II. In January 1990, the Insall-Burstein II tibial polyethylene insert was modified by beveling the anterior margin of the polyethylene to decrease patellar button impingement. The tibial post was also lengthened by 2mm and translated anteriorly by 2 mm. This Insall–Burstein II modified version is known as “2+2” design, and it remains as the present posterior-stabilised condylar knee tibial insert. With this design, the cruciate-substituting mechanism of the femoral cam and the tibial post engages at about 75 degrees of knee flexion. This articulation causes femoral rollback during flexion, but it does tend to “ride up” the tibial post with increased knee

flexion. This is thought to predispose the prosthesis to dislocate with increasing amounts of flexion.

The constrained condylar knee, a more constrained version of the posterior stabilized condylar knee prosthesis, was developed in 1987 to provide more constraint in both flexion and extension. It descended from an earlier design developed at the Hospital for Special Surgery, known as the total condylar III prosthesis. The major difference between the constrained condylar knee and the total condylar III prosthesis is stem fixation of the femoral and tibial components. The femoral and tibial stems in the constrained condylar knee prosthesis are completely modular and do not require cement fixation. The total condylar III prosthesis stems are non-modular and were designed for supplemental cement fixation. The femoral intercondylar box and tibial post articulation are identical in the two prostheses.

The constrained condylar knee prosthesis, in addition to increasing articulation constraint, also enhances component fixation in the presence of bone deficiency in both primary and revision total knee arthroplasty with the use of stems, wedges, and augments. The constrained condylar design has the same femoral condyle design as the posterior-stabilized condylar knee prosthesis but it incorporates a deeper intercondylar box to accommodate a higher tibial intercondylar post. The constrained condylar knee femoral intercondylar box and tibial post articulation allow for 0 to 120° of knee flexion, 5° of internal and external rotation, and 3° of varus and valgus freedom in full extension. The higher tibial post prevents knee dislocation in flexion by creating a longer “jumping distance” for the femoral cam.

MOBILE BEARING KNEE – PRINCIPLES AND TECHNIQUES

Rotation around the tibial axis occurs at the knee during the most activities including walking. It has been calculated in walking volunteers that 5° of internal tibial rotation take place during the swing phase.

During physiologic motion of the knee femoral rollback occurs in flexion. This is more evident in the lateral compartment. This fact causes a simultaneous internal tibial rotation in flexion, which occurs around a center located in the medial compartment. At the same time a few millimeters of anteroposterior motion take place again more pronounced laterally. The interpretation of these events is not universally accepted. Some authors believe that the roll back phenomenon is apparent and is due to the shape of the femur. According to them a good kinematics can re-establish simply by placing the axis of flexion permanently in a posterior position rather than by imposing a femoral rollback with the posterior cruciate ligament (PCL).

Classic femoral anatomy describes a decreasing radius for the posterior condyles, but recent studies have shown a constant posterior condylar radius in the order of magnitude of 21 to 23 mm for the medial femoral condyle.

Wear is a long-term problem that may become apparent only years after implantation. It involves three mechanism, adhesive and abrasive wear (superficial wear), and fatigue delamination or deep wear. The latter modality is predominant in knee prostheses, whereas the first two predominate in hip replacements.

Polyethylene wear in knee prostheses is related to the sliding motion between femur and polyethylene and to high contact stresses. Contact stresses increase significantly when the ratio between the radii of the prosthetic surfaces becomes larger. An increasing potential for polyethylene damage occurs with increasing contact stresses. Ten MPa or even better 5 MPa is considered the safe limit. For a load of 4000 N, equivalent to 5 times

body weight, a contact surface of at least 400 sq mm is required to stay within 10 MPA limit.

For the reason mentioned earlier PCL preservation with a flat tibial component design without a functioning ACL does not restore a normal kinematics and increases the risks of wear.

The MBK prosthesis has complete femoro-tibial conformity throughout motion owing to the fixed radius of the posterior femoral condyles. The radius ratio is 1 : 1 in both the sagittal and frontal planes. Axial rotation takes place between the tibial tray and the polyethylene insert, around a medial center of rotation for a total of about 25°. Some anteroposterior motion (3-4mm) is also possible between the polyethylene insert and tibial tray. The PCL is preserved but may be released.

The femoral component has separate femoro-patellar and femoro-tibial surface. The femoro-tibial surface (the posterior femoral condyles) is separated from the patellar flange by two condylo-trochlear grooves. The femoral condyles have a constant radius of curvature.

The polyethylene insert can rotate externally by 8° and internally by 17°. The upper surface of the polyethylene insert has two cupped surfaces for articulation with the femoral condyles and a prominent intercondylar “saddle” eminence to prevent translocation. The prosthetic design allows 12° of hyperextension. This is necessary because the tibial component is implanted with 5° to 7° of posterior tilt and the femoral component with 3° of flexion.

FUTURE DESIGNS

The basic design principles for successful total knee replacements are well established. Today, most designs show similar general characteristics, yet it is likely that relative small differences in radii and fixation methods could result in significant differences in performance, long term wear, and long term fixation, although such differences may not become apparent until after 10 years of follow up. There is growing perceived need for a “high performance” knee that will provide superior performance, especially flexion, and longevity. It was hoped that a design form of mobile bearing type would be the most likely candidate to fulfill this role. To date this expectation has not been realized. At the same time, the durability of the standard condylar knee is likely to be further improved by an upgrade in the polyethylene quality and, possibly, by a harder material or coating for the femoral component. Performance itself, as well as consistency, is likely to be enhanced by advances in instrumentation, with respect to bone cuts and soft tissue tension. Most knee problems can be addressed by modern systems, which include several designs forms and augmentations, although a customized approach for the more unusual or difficult cases is advisable. A significant reduction in cost of knee components is only likely if there is a radical change of manufacturing methods and materials.

REVIEW OF LITERATURE

The first attempts to replace tibial and femoral articular surfaces appeared in the 1950s as hinged implants with intramedullary stems. These simple hinged implants failed to account for the complex components of knee motion. This led to unacceptably high loosening rates. Later, the GUEPAR hinge was developed with its axis of rotation placed more posteriorly. The Spherocentric prosthesis, introduced in 1981, used a ball joint linkage to allow rotational freedom in addition to a condylar replacement type design. Finally the Kinematic Rotating hinge exemplifies the current status of truly linked hinged knee replacements. This type of prosthesis is used usually in patients with severe ligamentous insufficiency and in limb salvage procedure.

Gunston[60] prosthesis was introduced in 1971 after he reported his early results with the polycentric knee. He recognized that femoral condyles roll and glide on the tibia with changing center of rotation. This concept is known as femoral roll back. Gunston's prosthesis was a round on flat design and it enjoyed early success with its improved kinematics over hinged implants. Coventry et al[61] at the Mayo clinic introduced the Geomedic Knee in 1973. It was a round on round posterior cruciate retaining design, ignoring the kinematic principles described by Gunston. Accordingly attaining motion was problematic with the Geomedic Knee unless the cruciate ligaments were removed. Vince[62] described this as "The Kinematic Conflict". The other models which were prevalent during this period included Freeman and Swanson "roller- in- trough" design where both the cruciates were sacrificed and Duocondylar design which was an anatomical replacement similar to the earlier polycentric prosthesis.

Posterior cruciate-sacrificing total knee arthroplasty was popularized in the 1970 at the Hospital for Special Surgery. It was there that Walker, Ranawat, and Insall designed the total condylar knee (fig. 4) (Howmedica, Rutherford, NI). Stability was imparted by a congruent prosthesis articulation, soft tissue balance, and proper axial limb alignment. Ranawat et al[4] reported a prosthesis survivorship of 94% at 15 year follow-up. Total condylar design is limited in flexion by posterior impingement of femur on tibial polyethylene component due to absent femoral rollback.

The posterior-stabilized condylar knee prosthesis is one of the many successful condylar prostheses developed at Hospital for Special Surgery[8]. It was introduced as a modification of total condylar knee prosthesis which, with its unmatched durability, has been called the "gold standard" for total knee arthroplasty longevity[4]. In 1978 the posterior-stabilized condylar knee prosthesis was first implanted at the Hospital for Special Surgery. The posterior-stabilized condylar knee prosthesis is similar to the total condylar knee prosthesis in that, both technically require excision of both cruciate ligaments for prosthesis implantation; however, the posterior-stabilized condylar knee prosthesis is radically different. It is "posterior cruciate ligament-substituting" prosthesis, which has a tibial and femoral component articulation, that allow for femoral rollback during knee flexion. This posterior cruciate "ligament-substituting" mechanism makes the posterior stabilized condylar knee prosthesis both clinically and mechanically a better prosthesis of choice for patient requiring a total knee arthroplasty (fig. 5 and 6). In a study of the posterior-stabilized condylar knees using a metal backed tibial component, 96.4% clinical survivorship at 11 years was reported [9].

In late 1970s and the early 1980s, implant fixation and polyethylene wear became recognized as long-term causes of late failure. Mobile bearing knee replacements, with a polyethylene insert that articulates with a metallic femoral component and a metallic tibial tray, were designed to create a dual surface articulation. This feature is intended to reduce the surface and subsurface stress status at the bearing surface and at the bone implant surfaces by maximizing the conformity of the tibial and femoral components and allowing mobility of the bearing surface. This design permits the lowering of contact stresses to within the reported medical load limit of 5MPa[10] while allowing kinematically acceptable motion. This provides a meniscal bearing surface that is resistant to fatigue wear and demonstrates normal abrasive wear behavior over a 10 year period as seen in both simulator and retrieval studies[12].

Good fellow and O'Conner[11, 13] introduced the meniscal bearing knee replacement (the Oxford knee) in 1976. The complete systems approach to total knee replacement using meniscal bearing was developed at New Jersey Medical School in 1977 (fig. 7) and first reported in 1986[14].

KNEE FUNCTIONAL SCORING SYSTEM

With the introduction of a multitude of different prostheses with varying degrees of tibio-femoral conformity and different philosophies with regard to the sacrifice of anterior and posterior cruciate ligaments, different methods of evaluating total knee arthroplasty performance were developed by investigators.

The desirability of universal tool for assessing outcome after joint replacement surgery was identified as long ago as 1975 when Kettlekamp and Thompson [25] stated that criteria for such a system included

1. Using important measurable characteristics of the knee
2. Avoiding arbitrary assignment of point values
3. Relating total points score to the clinical results
4. Using clinical variable that can be easily quantified
5. Simplicity

In 1974 Insall published The Hospital for Special Surgery Knee Rating Score[8]. This system is heavily weighted towards pain, 'function' and range of movement. The rating system generates a maximum score of 100 points.

The Knee Function Assessment Chart was published by British Orthopedic Association in 1978 [27]. This was a consensus document from the Research Sub Committee intended to form the minimum date set for recording pre-and post-operative function.

In 1982, Hungerford and Kenna [28] published their results for an uncemented design of total knee replacement. Their patients were assessed using a 100 point rating system of their own design.

In 1989 American Knee Society published its Clinical Rating System [29] (Table 1). This system also published by Insall recognized the deficiencies of the Hospital for Special Surgery system and therefore proposed a system in three difference parts

1. Knee Score
2. Knee Function Score
3. Categorical Score

The Knee Society Clinical Rating System is concise and easy to use. It represents a clear attempt to separate knee function from overall patient function.

In 1991 Hofmann et al [30] published their results of an uncemented total knee replacement system using their own Knee Rating Score Card to evaluate patients both pre and post-operatively. This system makes very little reference to functional status other than in the classification of pain.

In 1992 "Guide to Recording Information about Knee Replacement" was published by University of Nottingham. In 1998 the Oxford Knee Score[31] was published and represents genuine attempts to create a new tool for the assessment of total knee replacement outcomes (Table 2). The score is derived from a 12 item questionnaire which is self administered by the patient.

The Questionnaire contains 12 items each with a possible score of 1-5. These are:

- Pain
- Difficulty with washing and drying self
- Difficulty getting into car / public transport
- Walking duration
- Pain duration
- Pain on standing
- Limp
- Ability to kneel
- Night pain
- Interference with work
- Giving way
- Ability to do shopping
- Ability to descend stairs

The score generated thus has a range of 12 (least symptoms) to 60 (worst symptoms).

The other patient self-reported measures of outcomes are Medical Outcomes Study Short Form 36 (SF 36) and the Western Ontario and McMaster University Osteoarthritis Index (WOMAC).

Functional outcomes and range of motion of mobile bearing and fixed bearing total knee replacements have been compared by many authors and no significant advantage has been shown of one over the other [32-40]. Seon JK[35] compared the range of motion of conventional total knee arthroplasty using high-flexion, posterior cruciate ligament stabilized prostheses and the range of movement of conventional knee arthroplasty using navigation-assisted total knee arthroplasty, with mobile-bearing, cruciate ligament-retaining knees. The authors found no difference between the range of movement and functional outcomes of conventional total knee arthroplasty with high-flexion knees and navigation-assisted total knee arthroplasty with mobile-bearing knees.

Dennis M Douglas[33] has done many kinematic videofluroscopic studies to evaluate the biomechanics of mobile and fixed bearing total knee replacements. His recent study has demonstrated that weight bearing range of movement for fixed bearing is significantly more compared to mobile bearing while non weight bearing range of movement is not showing any significant difference between the two.

Woolson ST and Northrop GD[32] could not find any significant difference in their study comparing mobile and fixed bearing. In fact in their study mobile bearing knee required early revision for failure of rotating patellar or tibial polyethylene implants.

Kotani A, Yonekura A, and Bourne RB[36] studied factors affecting range of motion in 219 total knee replacements. They found that factors significantly affecting the postoperative range of motion of total knee arthroplasties two years after surgery included preoperative diagnosis and preoperative range of motion. Sex, age, body mass index, femoral component size, posterior cruciate ligament status, or fixed vs mobile bearing design did not correlate with knee range of motion two years postoperatively.

There were also comparative studies on mobile bearing and fixed bearing total knee replacement done in the same patient which also has not shown any significant improvement of one over the other [38-40]. Price et al.[39] compared 31 bilateral total knee arthroplasties where one knee was replaced with fixed bearing (AGC knee) and the other side was replaced with mobile bearing knee (TMK knee). He found a small but significant clinical advantage in the mobile bearing design.

A similar study was conducted by Watanabe et al[34] on 21 bilateral total knee replacements with fixed and mobile bearing in each side. At the end of follow up, the knee score and range of motion was similar in both the groups. Five patients favored the fixed-bearing prosthesis, but 16 found no difference. In patients with bilateral total knee replacements, they could not find any difference in the short-term result between mobile-bearing and fixed-bearing prostheses. S Bhan et al[40] have studied 32 bilateral total knee replacements with mobile and fixed bearing knee replacement on either side and could not find any advantage of one over the other in 4.5 years follow up.

SURIGICAL APPROCHES

All operative procedures begin with exposure of relevant anatomy. It is imperative that this visualization of appropriate structures is excellent in order to optimize the surgical outcome. Thus adequate exposure must be attained, while at the same time, maximizing post-operative function.

The anterior approach is the basic workhorse of exposure in knee surgery. It is extensile, allowing easy access to both distal femur and proximal tibia. Anterior midline incision is the most commonly used skin incision for primary total knee arthroplasty.

The commonly used arthrotomy approaches are

- Medial parapatellar arthrotomy [41]
- Subvastus approach [42]
- Midvastus approach [43]
- Lateral approach [44, 45]
- Quadriceps snip [46]
- Tibial tubercle osteotomy [26,47]

Medial Parapatellar Exposure (fig. 8)

This universal approach to the knee is particularly useful for joint replacement arthroplasty in its various forms. Longitudinal skin incisions lateral to the midline are a contraindication to subsequent anteromedial skin incision because the narrow skin bridge is at risk of necrosis. Contracture and scarring of the extensor mechanism preclude adequate exposure through a routine anteromedial approach, thus necessitating an extensile technique.

Subvastus Approach (fig. 9)

The original description of this approach by Erkes dates to 1929, and is found in German literature. This exposure has been revisited and has been popularized by Hofmann et al[42] for knee replacement. This approach has the theoretical advantage of decreasing patellofemoral complications of subluxation, dislocation and avascular insult. Instances in which it is desirable to leave the extensor mechanism intact to facilitate rehabilitation or in circumstances when the patella has been previously operated, raising a question regarding its vascularity, are contraindications to subvastus approach. Relative contraindications include revision total knee arthroplasty, because prior arthrotomy causes scarring of the extensor mechanism, making exposure difficult. Prior proximal tibial osteotomy and short patient stature likewise may result in less than adequate exposure.

Midvastus Approach (fig. 10)

This exposure is suggested as an alternative approach for total knee arthroplasty. Instead of separating the vastus medialis from the quadriceps tendon, the incision proceeds proximally into muscle. A prospective study of White et al[62] documented fewer lateral retinacular releases and less postoperative pain with this approach compared with the parapatellar tendon splitting approach. Another study documented less blood loss with this muscle splitting approach, but 43 % had asymptomatic abnormal electromyography changes in the muscle.

Anterolateral Approach (fig. 11)

This approach is usually indicated for lateral articular adhesions, lateral retinacular release, and as an adjunct to quadricepsplasty, particularly when proximal extension is necessary to observe the vastus lateralis and

intermedius. It is the technique preferred by some surgeons for arthroplasty in valgus knee. The relative contraindication for this approach is joint replacement for a varus knee; because medial displacement of the extensor mechanism is extremely difficult. Medial reflection of the extensor mechanism does not afford an adequate exposure for reconstructive procedures of the knee joint.

Quadriceps Snip (fig. 12)

A more extensile approach may be required for a stiff knee resulting from previous surgery, septic arthritis, prior fracture, or radiation treatment. Other challenging exposures may be associated with obesity, rheumatoid arthritis, severe valgus or varus deformities, and flexion or extension contracture. The pathoanatomy includes a contracted extensor mechanism, contracted collateral ligaments, scarred suprapatellar pouch, and scarred medial and lateral gutters, tibial tubercle malposition, and thick adipose tissue. In such conditions an approach which gives adequate exposure and retains the extensor mechanism is indicated.

In quadriceps snip a standard medial arthrotomy incision is extended at the apex of the rectus tendon in an oblique and lateral direction. Then the patella is everted and the knee is flexed. The repair can be done with or without an accompanying lengthening procedure. The quadriceps snip in the long term has not found to interfere with the strength of the extensor mechanism.

Tibial Tubercle Osteotomy (fig. 13)

The tibial tubercle osteotomy is done in four clinical settings:

1. To realign the extensor mechanism, typically following total knee arthroplasty after demonstration of patellar maltracking.
2. For exposure of stiff knee undergoing knee replacement.
3. For transfer of malpositioned tibial tubercle.
4. For extensor mechanism release after contracture.

GAP RESECTION AND MEASURED RESECTION

Two surgical techniques for total knee arthroplasty have evolved over time. The flexion extension gap technique was introduced by Insall in 1970s. With this method the proximal tibia is cut perpendicular to the mechanical axis of the tibia. Soft tissue releases are performed so that knee is axially aligned in extension. The knee is flexed to 90 degrees and distracted, recreating the ligament tension determined in extension. The proper sized femoral anteroposterior cutting guide is place on the end of the femur, rotated to create a rectangle and the cuts are completed. The flexion gap is measured and a matching sized gap is created in extension with the distal femoral cut. The theoretical advantage of this method is the formation of equally balanced gaps in flexion and extension and a well-aligned extremity. Two potential disadvantages of this method exist. First if the tibia is inadequately cut in varus, the resulting femoral cut is in relative internal rotation, a position not well tolerated by the patella. Also if an inappropriate large flexion gap is created, over-resection of the distal femur must be performed to match the extension gap. This will lead to elevation of the joint line and a relative patella baja, negatively impacting patella femoral

function. Despite these concerns, long term results of this surgical technique have documented reproducible excellent results [3].

The second method is the anatomic measured resection technique. This method has evolved in an attempt to recreate normal knee anatomy and function and has been popularized by the posterior cruciate retaining prosthesis, in which joint line position is of critical importance. Initially the technique required a tibial cut in 3° varus to the mechanical axis. The femur and tibia were resected independent of one another and the amount of the resected bone reflected the thickness of respective components. Rotation of femur was based on posterior femoral condyles in an anatomic manner. Many systems at present recommend a tibial resection at 90° to mechanical axis of tibia, and 3° external rotation of femur is required to maintain an appropriately rectangle flexion space. The advantage of this technique is its ease, and the fact that any error in ligament balance or tibial resection will not influence the femoral cuts. Ligament balance is performed near the end of the procedure with the tibial components in place. Although equally balanced flexion and extension gaps are not assured long term results for this technique are also excellent [48].

Most knee systems available today have combined aspects of flexion extension gap technique and measured resection technique.

LIGAMENT BALANCING

Ligament balancing should be done along with bone surface preparation. Appropriate medial, lateral or posterior releases should be done to get knee in anatomical alignment and to obtain an equal and rectangular flexion extension gaps. The ligament release can be done primarily as in gap resection technique or secondarily as in measured resection technique

Lateral release

STEP 1

Lateral capsule release

Distal iliotibial band release

Posterolateral corner release

STEP 2

Release popliteus

Release lateral collateral ligament

Release lateral inter-muscular septum

STEP 3

Release lateral head of gastrocnemius

Biceps femoris release or Z-lengthening

Fibular head excision

Medial collateral ligament advancement

Medial Release (fig. 14)

Deep medial collateral ligament release

Release posteromedial corner with pes anserinus

Release posterior cruciate ligament

Release superficial medial collateral ligament

Posterior Release (fig. 14)

Posterior capsule

Posterior cruciate ligament

Posterolateral and posteromedial corner release

Release the medial and lateral head of the gastrocnemius

These releases are done in stages depending on the ligament balance attained at each step. In gap resection these releases are done before bony preparation just to achieve an equal and rectangular flexion- extension gap. In measured resection these releases are made after the bony preparation.

PATELLAR PREPARATION

Resurfacing of the patella in total knee arthroplasty is commonly if not routinely performed with present total knee arthroplasty designs. It is commonly assumed that restoration of the native patellar thickness is most desirable. Two primary patellar resurfacing implant types and technique have evolved consisting of outset and inset designs, and onlay and inlay technique.

Onlay technique involves a surface osteotomy of patella removing its articular surface and replacement by patellar button. Articular surface is reamed out to appropriate depth and then replaced with patellar button in inlay technique.

The intra operative assessment of patellar tracking can be done by no thumbs test, towel clips test or by one stitch test[49-51]. After trialling the implant, the knee is taken to its full range of movements with the patella put back to its original position. Then the patellar tracking is assessed for any

lateral subluxation without the surgeon stabilizing the patella over the trochlea with his thumb. If the tracking is normal the patella will not sublux laterally. If the surgeon has to stabilize the patella with his thumb to prevent maltracking then the patient may benefit from a lateral release. The towel clip test and one stitch test is similar to no thumb test. Here the surgeon provisionally attaches the vastus medialis to the remaining quadriceps with a towel clip or a single stitch at the suprapatellar region and then assesses the patellar tacking.

COMPLICATION OF TOTAL KNEE REPLACEMENT

As is any other surgery, knee replacement surgery is also associated with immediate and late complications. Some commonly encountered complications are:

1. Thromboembolism: -

Deep vein thrombosis is one of the most significant complications which can possibly result in life threatening pulmonary embolism. The overall prevalence of deep vein thrombosis after total knee arthroplasty without any form of mechanical or pharmaceutical prophylaxis has been reported to range from 40% to 84% [52].

2. Infection: -

Infection is one of the dreaded complications affecting total knee arthroplasty patients. Pre operative factors associated with higher incidences of infection include rheumatoid arthritis, skin ulceration, previous knee surgery, use of a hinged knee prosthesis, obesity, concomitant urinary tract

infection, steroid use, renal failure, diabetes mellitus, poor nutrition, malignancy and psoriaris [53].

3. Patellofemoral complications:

Patellofemoral complication are now-a-days citied as the most common complication for re-operation. This has led many authors to advocate total knee arthroplasty without patellar resurfacing for patients with osteoarthritis and adequate patellar cartilage. The common complications are patellofemoral instability, patellar fracture, patellar component failure, patellar component loosening, patellar clunk syndrome, and extensor mechanism tendon rupture.

4. Neurovascular complication: -

Peroneal nerve palsy is the only commonly reported nerve palsy after total knee arthroplasty. It occurs primarily with correction of fixed valgus and flexion deformities.

5. Periprosthetic fractures: -

Supracondylar fractures are the most common periprosthetic fractures with a reported incidence of 0.4% to 2% seen in the total knee arthroplasty. In a biomechanical study and review of literature Lesh et al[54] reported that 30.5% of periprosthetic supracondylar femoral fractures were associated with a notched femur.

SURVIVORSHIP ANALYSES

Survivorship analysis for mobile bearing in designer series had a 10 year survival rate of 98%[55, 56]. In designer series for fixed bearing posterior stabilized survivorship analysis showed 96.4% in 10 years follow-up[9]. For mobile bearing, individual authors have reported a survivorship ranging from 95% to 100% in 11 to 12 year follow up. Durable long term fixation has also been documented for many designs of fixed bearing total knee replacement by individual authors[3].

The clinical results are influenced by surgical technique. The goal of primary total knee arthroplasty is to re-establish the normal mechanical axis with stable prosthesis that is well fixed [fig. 15]. This is achieved by both the bone resection and the soft tissue balance [Table 3].

MATERIALS AND METHODS

Patients who underwent total knee arthroplasty between 2000 and 2005 were studied. These patients underwent total knee arthroplasty using either the mobile bearing system (LCS, Depuy, Ind) or the fixed bearing posteriorly stabilised system (PFC, Depuy, Ind).

A total of 120 patients had undergone this procedure, and all patients were invited to the institution for follow up. The data regarding pre operative status of the patients was collected from the inpatient and outpatient records. Three surgeons performed these replacement surgeries. One surgeon exclusively does PFC, one surgeon exclusively does LCS and another surgeon does both LCS and PFC.

INCLUSION CRITERIA

All patients who have undergone total knee arthroplasty with Low Contact Stress or Press Fit Condylar system for severe pain and disability due to primary osteoarthritis or rheumatoid arthritis.

EXCLUSION CRITERIA

The following criteria were used for exclusion:

- Revision total knee replacement
- Patellar replacement
- Total knee replacement for post septic or post traumatic sequelae
- Patient with disabling polyarthritis
- Ipsilateral total hip replacement

- Patients operated elsewhere

These patients were excluded because the above mentioned conditions will interfere with the functional out come. Most of the revision knee replacements were posteriorly stabilised. Almost all these patients had a quadriceps lag and a poor function compared to primary total knee patients. Similarly in patients with polyarthritis other joint involvement interfered with the functioning of the replaced knee joint. Patients with post septic sequelae and post traumatic sequelae had altered joint biomechanics and soft tissue balance. Most of these patients underwent a constrained condylar prosthetic replacement (TC3) and therefore was excluded from the study.

PRE OPERATIVE CHECK LIST

The following preoperative tests were routinely done in all patients

1. ESR, PCV, BBVS, (Blood Bone Virus Screening) Creatinine, Random Blood Sugar, ECG and Rheumatoid factor
2. A screening was done to rule out skin, urine or dental infection
3. Plain radiographs were done as follows:

    - Standing antero-posterior view of both knees
    - Lateral view of both knees
    - Chest X ray

All patients were given preoperative prophylactic antibiotics before inflating the tourniquet. Two patients underwent surgery without tourniquet. Anesthesia employed was either regional (Spinal or epidural), general or combined.

SURGICAL TECHNIQUE FOR LCS

This system uses gap resection technique. The surgical approach involves a straight longitudinal skin incision with anteromedial arthrotomy and lateral eversion of the patella. Adequate medial and lateral releases are performed for correction of angular deformities.

The proximal tibial cut (fig. 16) is accomplished using an extra medullary guide, which references off the malleoli distally. The alignment of the cut is perpendicular to the tibial axis in the frontal plane and with a 5° to 7° posterior slope according to individual variations. About 1mm of bone from the most involved tibial plateau is thus removed. The PCL and the collateral ligaments are protected during this cut. Following this the flexion and extension gaps are assessed.

The femoral cuts are performed using an intramedullary aligned instrument with an extramedullary check. The starting point for the initial drill is just medial to center, above the insertion of posterior cruciate ligament on the femur (fig. 17). Femur is sized using the femoral templates or with the femoral sizing calipers referencing on the least involved condyles. The intramedullary fluted plate of appropriate valgus is then chosen and inserted into the pre-drilled hole (fig. 18).

The anteroposterior resection block is then fixed to the intramedullary plate. Following this the stylus is assembled on to the cutting block. The block is lowered on the intramedullary plate, until the stylus is in contact with the crest of the anterior femur. The anteroposterior cuttings block yields an anterior cut 1.5mm higher than the final cut. The posterior cut is final. Then femoral guide positioner is introduced into the joint space and to the

slot of anteroposterior cutting block. This gives appropriate rotation to the anteroposterior cut which is usually in 3° of external rotation (fig. 19).

Once the anterior rough cut and posterior final cut is made the flexion gap is measured and assessed used spacers (fig. 20). Then the distal femoral valgus cutting block is assembled on to an intramedullary alignment guide and inserted on to the distal femur (fig. 21). The cutting block is fixed according to the flexion gap measured so that the distal femoral cut gives an equal and rectangular extension gap. An extramedullary alignment guide is used to confirm the alignment (fig. 22). Then the distal femoral cut is made. Once again the flexion and extension gaps are assessed (fig. 23). The 6 in 1 finishing jig is assembled on to the distal femur and the final anterior cut and the champher cuts are made (fig. 24).

Following this the proximal tibia is prepared and the implants are trialled (fig. 25). Then the tibial followed by the femoral implants are cemented on to prepared surface (fig. 26). Tibial insert size used is usually 10 mm or larger depending on the flexion extension gap.

Tourniquet is then released and wound is closed over a closed suction drain in layers after checking the patellofemoral tracking using no thumb test.

SURGICAL TECHNIQUE FOR PFC

This system uses the measured resection technique with Specialist 2 Instrumentation system.

The surgical approach is same as in LCS (fig. 27 and 28). Starting drill hole is made in the distal femur and fluted intramedullary guide is inserted

(fig. 29). The distal femur cutting block is assembled to make a distal femur cut at 6^{o} valgus and remove 9mm of bone from the least involved condyle (fig. 30).

After the distal femoral cut is performed, the femoral sizing jig is used to determine the appropriate size of the femoral component, (fig. 31) referencing from the anterior cortex of femur. Then the appropriate size anteroposterior and champher cut jig is assembled on the distal femur employing the posterior condylar axis for rotational alignment. Finally the box cut is made for the cam of femoral component (fig. 32).

The proximal tibial cut is then made perpendicular to the mechanical axis almost similar to that of LCS (fig. 33). The tibia is then prepared and the implants are trialled. Then the tibial base plate is cemented on to the prepared surface. The insert is then locked on to the base plate and femoral components are cemented on to the bone (fig. 34). Wound is closed over a closed suction drain in layers, compression bandage applied and tourniquet is then released.

POSTOPERATIVE REHABILITATION

All patients received post operatively in special rooms so that the chance of infection is reduced. Intravenous antibiotics are administered for 48 hours. After 48 hours oral antibiotics are given till sutures are removed. Anti-thrombotic mechanical prophylaxis is started immediately they reach the ward. For the first 48 hours, this includes calf massage and ankle mobilization. This is done by the patient's relatives every half an hour for 10 minutes. Isometric quadriceps exercises are started after 24 hours. Patients are advised to do straight leg raising initially, with the help of a brace till

they regain a quadriceps power of up to grade three. Then ambulation with crutches or walker is started. Knee flexion exercises are started after 48 hours according to the pain tolerance of the patient. Within ten days stair climbing is taught. Suture removal is done at 14th day and patients are advised to discard crutches by 3-4 weeks and review after 6 months and then once every year.

POSTOPERATIVE EVALUATION

All selected patients are invited for assessment after a minimum of one year since surgery to the institute. They are assessed clinically and radiologically. The functional outcome is evaluated both subjectively and objectively. The Oxford Knee Society Score and the American Knee Society Knee score are used for the same. The non weight bearing range of flexion of all patients are assessed postoperatively using a goniometer in the outpatient department. Preoperative values are collected from inpatient and outpatient records. The postoperative functions of patients are compared for PFC and LCS. Similarly the preoperative flexion range is also compared.

Standing anteroposterior and lateral plain radiographs of the knees are taken. The joint line is then measured in both the knees in preoperative and postoperative radiographs. The method described by Figgie et al [57] is employed in lateral view (fig. 35). Here a perpendicular line to the anatomical axis is drawn at the level of proximal tibial articular surface in the preoperative and postoperative films. Then the distance is measured from this line to another parallel line drawn at level of tibial tuberosity.

Similarly, using the anteroposterior view films, the joint line can be measured off two distinct land marks. These are the adductor tubercle (fig. 36) and the fibular head (fig. 37).

The change in the joint line is measured from the preoperative and postoperative values. Then the mean of these three values are taken as the final change in the joint line.

The software system used in all measuring purpose is GE Centricity version 1.0 (Mountprospect, Milwakee, USA). The Insall Salvati index was not used in the study to assess the changes in the joint line. This was because, the position of inferior pole of patella cannot be reliably used as a landmark. Moreover, intra operative release of patellar tendon, the postoperative fibrosis of the tendon or the quadriceps also can alter the landmark, and the measurement values. The change in joint line is then correlated to the postoperative range of flexion.

STATISTICAL ANALYSIS

Non parametric Mann_Whiteny U test and Wilcoxon Signed Ranks test are used for comparative study. Spearman Rank Correlation test is used for correlating the change in joint line with postoperative flexion range. Statistical analysis is performed with SPSS software (SPSS, Chicago, Illinois)

RESULTS

A total of 120 patients had undergone total knee replacement with either the LCS or the PFC systems between the years 2000 and 2005. After applying the inclusion and exclusion criteria, there were 100 patients who fulfilled the same. These patients were invited for follow-up.

Data was available from the follow up recordings for 51 patients. The others were lost to follow-up. Our hospital being a tertiary referral centre, caters to patients from all over the country and hence such a large number of attrition may be expected.

Among these 51 patients, 30 patients had LCS total knee system and 21 patients had PFC system. Seventeen patients had bilateral LCS and 5 patients had bilateral PFC. Hence a total of 73 knees were analyzed. One patient who had undergone a bilateral total knee replacement using PFC on one side and LCS on other was excluded from study because he was thought to be ineligible to answer the subjective questions regarding each of these systems.

Forty five patients had primary osteoarthritis and 6 patients were diagnosed to have rheumatoid arthritis. There were 39 left sided knee replacements and 34 right sided replacements.

The mean age of patients who underwent LCS total knee arthroplasty was 57 years (ranging from 35-71 years) and for the PFC system the mean age was 60.46 years (ranging from 45-73 years).

There were 11 males and 19 females in the LCS group and 11 males and 10 females in the PFC group.

The LCS had a mean follow up of 3.76 years (1-5 years) and PFC had a mean follow up of 2.37 year (1-4 years). Both the groups are matched for age, sex and duration of follow up (Table 4).

RANGE OF MOVEMENT

The mean preoperative range of movement in the PFC group was 111.53°±20.4° (ranging from 70-140°). This showed an improvement to a mean flexion of 113.26°±13.9° (ranging from 90-140°) post operatively (fig. 38). The mean preoperative range of movement in the LCS group was 94.68°±29.3° (ranging from 20-130°) (Table: 5). This showed an improvement to a mean flexion of 98.2°±14.8° (ranging from 50-140°) post operatively (fig. 39 and fig. 40).

FUNCTIONAL SCORE

The mean Oxford Knee Society Score was calculated to be 17.46±1.6 in the PFC group and 17.91±2.1 in the LCS group. This difference in the score between the two groups was not found to be statistically significant (p=0.895) (fig. 41). There were 29 patients belonging to Category A and 22 patients belonging to Category B of American Knee Society Score. The mean American Knee Society Score was found to be 94.15±3.9 in the PFC group and 90.61±3.6 in the LCS group. This difference was found to be small but significant (p=0.001) favoring the PFC system (Table 6). All these scores were calculated post operatively.

RADIOGRAPHIC RESULTS

The mean change in joint line as calculated by using the Figgie method was 2.28±0.94mm in the PFC group and 3.63±1.74mm in the LCS group. This difference was found to be significant (fig. 42)

The change in the joint line for each patient was correlated with the post operative range of movement. The fixed bearing group showed significant correlation indicating that any significant alteration in the joint line affected the post operative range of movement (fig. 43). Conversely in the LCS group the change in the joint line did not show any correlation with the post operative range of movement (fig. 44).

COMPLICATIONS

Infection:

One patient in the PFC group had superficial skin infection which settled with anti-inflammatory and antibiotic medications. One patient had deep infection with significant bone loss. She underwent joint debridement and revision with bone grafting.

Two patients in the LCS group had deep infections. One had to be treated with implant removal, debridement and antibiotic spacer insertion. The other patient underwent debridement and exchange of the tibial insert.

Death:

One patient who had rheumatoid arthritis was grossly restricted in her ambulation due to polyarticular involvement. She developed deep vein thrombosis six months after surgery and later died of pulmonary embolism.

One patient died of myocardial infarction two years after surgery and hence this death cannot be listed as a post operative complication.

Other complications:

There were no other complications like dislocations, subluxations, mid-swing instability, patellar clunk syndrome, insert spin-offs, insert breakages, implant failures, periprosthetic fractures, or wound dehiscence in this series.

DISCUSSION

Fixed bearing prosthesis have provided long term fixation with prosthesis survival rates of 95% to 97% at ten to fifteen years of follow-up[58]. Various independent studies for both the mobile bearing and fixed bearing prostheses involving 62 to 473 knee arthroplasties have documented results that are comparable in terms of performance and survival, with overall revision rates of approximately 1% per year for both types of implants[9,17]. No previous comparative studies have been able to show any advantage of mobile bearing over fixed bearing with respect to clinical function and longevity.[59]

There are no studies in literature, correlating change in joint line to postoperative range of movement, and comparing it between mobile bearing and fixed bearing total knee arthroplasties.

A majority of our patients come from North India and neighbouring countries. Their mean age is around 60 years. The travails of travel and advancing age prevent many of them to come for regular follow-ups. Despite these drawbacks above 65% of the patients came for follow up and after applying the exclusion criteria there were 51% patients who were followed up.

Many of our patients belong to cultural and social backgrounds which places them in situations that demands extreme flexion at the knee joint. A large majority of our patients need to perform poojas (religious rites) which require them to sit in the “padmasana” position (sitting cross legged). A significant number of our patients perform ‘namas’ by kneeling on a hyperflexed knee. Our women folk sit on the floor to do most of their

household chores including washing the clothes and mopping the floors. They are so used to sitting cross legged that even while sitting on a chair they adopt this posture. Therefore the Indian knee goes through a very significant hyperflexion range of movement (fig. 45, 46 and 47).

While interviewing them using the two western knee society scoring systems, some of the questions had to be modified to suite the oriental lifestyle.

We had to modify the Oxford knee society scoring questionnaire suitable for our community. Instead of asking “could you kneel down and get up again afterwards?” we had to ask “how difficult is it for you to sit down on the floor for poojas, namas or prayer”. Similarly instead of “could you do the household shopping on your own?” we had to ask “How difficult did you feel today while walking from the lodge to the hospital?”

We changed the question “could you walk down a flight of stairs?” to “how did you feel while coming down from the X-ray department?” Similarly we changed “After a meal, how painful has it been for you to standup from a chair because of your knee?” to “does your knee give you any pain while getting up after waiting for such a long time?” Instead of “have you been troubled by pain from your knee in bed at night?” we asked “after surgery is your knee disturbing your sleep at night?”

Since most of our patients were adviced not to squat, the Oxford Knee Society score did not show any significant difference between the mobile bearing and fixed bearing total knee arthroplasty. Even though we had a few patients who were squatting in spite of advice given to them, we had no dislocations or spinouts.

The patients belonging to the PFC and the LCS group were matched for sex and the duration of follow up. The PFC group was slightly older. A survivorship analysis could not be done because the earliest surgery included in this series was done in the year 2000.

The cost factor did not affect the selection of implants for the patients. One surgeon does exclusively the PFC system while another surgeon does only the LCS system. The third surgeon prefers LCS system but does the PFC system if the patient has a severe deformity, ligament instability or bone deficiency.

RANGE OF MOVEMENT

The single most important factor that determined the post operative range of movement was the preoperative range of movement in both the PFC and the LCS group. However it was noted that 63% of patients in PFC group retained or improved their range of movement after surgery. In the LCS group 44 % showed a decrease in range of movement post operatively during this period of follow- up.

This resulted in a significant difference between the two groups while applying the American Knee Society Score.

FUNCTIONAL OUTCOME

In the PFC group, the patients had an Oxford Knee Society Score of 17.46 (ranging from 12-20) and LCS group had a score of 17.91 (ranging from 16- 26). This objective scoring system has revealed that all our patients

had high satisfaction values. They said that they were able to carry out most of their functions satisfactorily.

While applying the American Knee Society System the PFC group had a score of 94.15 (ranging from 86-100) and LCS group had a score of 90.61 (ranging from 81-97). This system assesses the knee function independent of the overall patient function. While applying this system we found that the PFC group faired significantly better.

JOINT LINE

Many of our patients did not have standardized pre-operative radiographs. Joint deformities and bone deficiencies compounded the problems of accurately assessing the bony landmarks. Hence three different methods were used to identify the preoperative and post operative changes in the joint line. Patients in the PFC group showed a good correlation between change in the joint line and post operative function, whereas patients in LCS group exhibited a post operative range of movement independent of changes in the joint line.

This observation has not been reported in the literature previously.

We also found that the change in the joint line was less (2.28±0.94) in the PFC group whereas it was 3.63±1.74 in the LCS group. This difference was statistically significant but as discussed earlier, this change in joint line did not affect the range of movement in the LCS group.

CONCLUSION

1. The post operative range of movement is dependent on the preoperative flexion range.

2. The post operative range movement in the LCS group is independent of the mean joint line change.

3. PFC exhibits a better range of movement if the joint line is maintained close to the preoperative status ($p = 0.01$).

4. Fixed bearing posteriorly stabilized total knee replacement has a significantly more range of flexion than mobile bearing total knee replacement ($p = 0.000$).

5. Measured resection maintains the joint line better than gap resection.

6. Oxford society score was found to be equal among both the implant design.

7. PFC had a small but significantly better American knee society score compared to LCS.

BIBLIOGRAPHY

1. Scuderi GR, Insall JN, Windsor RE, Moran MC. Survivorship of cemented knee replacements. *J Bone Joint Surg. 1989; 71B: 798-803.*
2. Cobb AC, Ewald FC, Wright J, Sledge CB. The kinematic knee: survivorship analysis of 1943 knees. *J Bone Joint Surg.1990; 72B:532.*
3. Stern SH, Insall JN. Posteriorly stabilised results after follow-up of nine years *J Bone Joint Surg .August 1992; 74A:980-986.*
4. Ranawat CS, Flynn WF Jr, Sadder S, Hansraj KK, Maynard MJ. Long-term results of total condylar knee arthroplasty: a fifteen year survivorship study.*CORR.1994; 309:136-14.*
5. Insall JN, Binazzi R, Soudry M, Mestriner LA. Total knee arthroplasty. *CORR.1985; 192:13-22.*
6. Diduch DR, Insall JN, Scott WN, Scuderi GR, Font Rodrigues D. Total knee replacement in young, active patients. *J Bone Joint Surg. April 1997; 79A:571-582.*
7. Stern SH, Bowen MK, Insall JN, Scuderi GR. Cemented total knee arthroplasty for gonarthrosis in patients 55 years old or younger. *CORR. 1990; 260: 124-129.*
8. Insall JN, Ranawat CS, Aglietti P, Shine J. A comparison of four models of total knee replacement prostheses. *J Bone Joint Surg.1976; 58A:754-765.*
9. Colizza W, Insall JN, Scuderi G. The posteriorly stabilized total knee prosthesis: assessment of polyethylene damage and osteolysis after a ten year minimum follow-up. Bone Joint Surg.1995; 77A:1716-1720.
10. Hostalen GUR. Hoechst aktiengellschaft. Frankfurt, Germany, 1982:22.
11. Goodfellow J, O'Conner J. The mechanics of knee and prosthesis design. *J Bone Joint Surg. 1978; 60B: 358-369.*
12. Buechel FF, Pappas MJ. New Jersey LCS knee replacement system: 10 year evaluation of meniscal bearings. *Orthop Clin North Am. 1989; 20: 147-177.*
13. Goodfellow JW, O'Conner J. Clinical results of the Oxford knee. Surface arthroplasty of the tibiofemoral joint with a meniscal bearing prosthesis. *CORR. 1986; 205: 21-42.*
14. Buechel FF, Pappas MJ. The New Jersey low contact stress knee replacement system: Biomechanical rationale and review of first 123 cemented cases. *Arch Orthop Trauma Surg. 1986; 105: 197-204.*

15. Kettlekamp DB: Gait characteristics of the knee: normal, abnormal and post reconstruction. In *American Academy of Orthopaedic Surgeons: Symposium on reconstructive surgery of the knee, St Louis, 1976, Mosby.*
16. Jeffry RS, Morris RW, Denham RA: Coronal alignment after total knee replacement. *J Bone Joint Surg.1991; 73B:709.*
17. Tew M, Waugh W: Tibiofemoral alignment and the results of knee replacement. *J Bone Joint Surg. 1985; 67B: 551.*
18. Andriacchi TP, Galante JO. Retention of posterior cruciate in total knee arthroplasty. *J Arthroplasty. 1988; 3(suppl): S13.*
19. Markoff KL, Mensch JS, Amstutz HC. Stiffness and laxity of the knee-the contributions of supporting structures. *J Bone Joint Surg. 1976; 58A: 583-594.*
20. Schultz RA, Miller DC, Kerr CS, Micheli L. Mechanoreceptors in human cruciate ligaments. *J Bone Joint Surg. 1984; 66A: 1072-1076.*
21. Wilson SA, McCann PD, Gottin RS, Insall JN: Comprehensive gait analysis in posterior- stabilized knee arthroplasty. *J Arthroplasty. 1996; 11: 359.*
22. Grood ES, Suntag WJ, Noyes FR, Buttler DL. Biomechanics of the knee-extension exercise. *J Bone Joint Surg. 1984; 66A:725.*
23. Hungerford DS, Barry M. Biomechanics of patellofemoral joint. *CORR. 1989; 241:203.*
24. Huberti HH, Hayes WC. Patellofemoral contact pressures: the influence of Q-angle and tendofemoral contact. *J Bone Joint Surg1984; 66A:715.*
25. Kettlekamp DB, Thompson C. Development of a knee scoring scale. *CORR. 1975; 107:93.*
26. Whiteside LA, Exposure in difficult total knee arthroplasty using tibial tubercle osteotomy. CORR. 1995; 321: 32-35.
27. Aichroth P, Freeman MAR, Smillie IS, Souter WA. A knee function assessment chart. *J Bone Joint Surg.1978; 60B:308-309.*
28. Hungerford DS, Kenna RV. Preliminary experience with total knee prosthesis with porous coating used without cement .*CORR. 1983; 176:95-102.*
29. Insall JN, Dorr LD, Scott WN. Rationale of the knee society clinical rating system. *CORR. 1989; 248:13-14.*
30. Hofmann AA, Murdock LE, Wyatt RWB, Alpert JP. Total knee arthroplasty *CORR1991; 269:78-88.*

31. Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. *J Bone Joint Surg. 1998; 80B: 63-69.*
32. Woolson ST, Norhtrop GD. Mobile –vs. Fixed – bearing total knee arthroplasty a clinical and radiological study. *J Arthroplasty. 2004Feb; 19(2):135-140.*
33. Brian Haas, Douglas A Dennis, Richard D. Range of motion of posterior-cruciate substituting total knee replacements: the effect of bearing mobility. *J Bone Joint Surg. 2006; 89A:51-56.*
34. Watanabe T, Tomita T, Fujii M, Hashimoto J, Sugamoto K, Yoshikawa H. Comparison between mobile-bearing and fixed-bearing knees in bilateral total knee replacements. *Int Orthop. June 2005; 29(3): 179-181.*
35. Seon JK, Song EK, Lee JY. Comparison of range of motion of high flexion prosthesis and mobile bearing prosthesis in total knee arhtroplasty. *Orthopaedics. 2005Oct, 28(10 suppl): 1247-1250.*
36. Kotani, Tonekura A, Bourne RB. Factors influencing range of motion after contemporary total knee arthroplasty. *J Arthroplasty 2005Oct; 20(7): 850-856.*
37. Biau D, Mullins MM, Judet T, Pirion P. Mobile versus fixed bearing total knee arthroplasty: midterm comparative clinical results of 216 prostheses. Knee Surg Sports Traumatol Arthrosc. 2006March; 25.
38. Young–Hookim, MD; Hee-Kyun Kook, MD; and Jun-Shik Kim, MD. Comparison of fixed bearing and mobile bearing total knee arthroplasties. CORR. 2001; 392: 101-115.
39. 39.AJ Price,JL Rees, D Beard, E Juszczak, S Carter, S White, Rde Stager, CAF D odd, M Gibbons, P Mc Lardy –Smith, J W Goodfellow, DW Murray. Mobile bearing total knee prostheses compared with fixed bearing prosthesis. *J Bone Joint Surg2003; 85B: 62-67.*
40. S Bhan, R Malhotra, E Krishna Kiran, Sourav Shukla and Mahesh Bijjawara. A comparison of fixed bearing and mobile bearing total knee arthroplasty at a minimum follow-up of 4.5 years. *J Bone Joint Surg2005; 87A: 2290-2296.*
41. Boiardo RA, Dorr LD. Surgical approaches for total knee replacement arthroplasty. *Contemporary Orthopaedics 1986; 12:60.*
42. Hofman AA, Plaster RL, Murdock LE. Subvastus (southern) approach for primary total knee arthroplasty .*CORR. 1991; 269: 70-77.*
43. Keblish PA. The lateral approach to valgus knee: surgical technique and analysis of 53 cases with over two year follow-up evaluation. *CORR. 1991; 271:52-62.*

44. Coonse K, Adams JD. Anew operative approach to the knee joint. *Surg Gynecol Obstet. 1943; 77:344-347.*
45. Garvin KL, Scuderi GS, Insall JN. Evolution of the quadriceps snip. *CORR. 1995; 321:131-137.*
46. Aglietti P, Windsor R, Buzzi R, Insall J. Arthroplasty for the stiff or ankylosed knee. *J Arthroplasty.1989; 4:1-5.*
47. Dolin MG. Osteotomy of tibial tubercle in total knee replacement. A technical note. *J Bone Joint Surg.1983; 65A:704-706.*
48. 48.Ritter MA, Campbell E, et al. Longterm survival analysis of the posterior cruciate condylar total knee arthroplasty. *J Arthroplasty. 1991; 6(1): 45-50.*
49. Scott R. Prosthetic replacement of the patellofemoral joint. Ortho Clin North Am.1979; 10:129-137.
50. Insall J. Surgical techniques and instrumentation in total knee arthroplasty. Surgery of the knee. NewYork: Churchill Livingstone; 1993:738-804.
51. Rae P, Noble J, Hodgkinson J. Patellar resurfacing in total condylar knee arthroplasty. *J Arthroplasty. 1990; 5:259-265*
52. Grady-Benson JE, Oishi CS, Hanson PB, etal: Postoperative surveillance for deep venous thrombosis with duplex ultrasonography after total knee arthroplasty. *J Bone Joint Surg. 1994; 76A:1649*
53. Berbari EF, Hanssen AD, Duffy MC, etal: Risk factors for prosthetic joint infections: case control study, *Clin Infect Dis: 1998; 27:1247*
54. Lesh ML, Schneider DJ, Deol G et al: The consequences of anterior femoral nothching in total knee arhtroplasty. *J Bone Joint Surg 2000; 82A: 1096.*
55. Buechel FF, Pappas MJ. NewJersey Low Contact Stress knee replacement system: Ten year evaluation of meniscal bearing. *Orthop Clin North Am. 1989; 20:147-177.*
56. Buechel FF, Pappas MJ: Long-term survivorship analysis of cruciate-sparing versus cruciate-sacrificing knee prosthesis using meniscal bearings. *CORR. 1990; 200:162-169.*
57. Figgie HE, Goldberg VM, Heipel KG, Miller HS, Gordon NH. The influence of tibial patellofemoral location on function of the knee in patients with the posterior stabilized knee prosthesis. *J Bone Joint Surg. 1986; 68A:1035-1040.*

58. Callaghan JJ, Squire MW, Goetz DD, Sullivan PM, Johnston RC. Cemented rotating –platform total knee replacement. A nine to twelve-year follow-up study. *J Bone Joint Surg. 2000; 82A:705-711.*
59. Kim YH, Koo HK, Kim JS. Comparison of fixed bearing and mobile bearing total knee arthroplasties. *CORR. 2001; 392:101-115.*
60. Gunston FH: Polycentric knee arthroplasty: Prosthetic simulation of normal knee movement, *J Bone Joint Surg. 53B:272, 1971.*
61. Coventry MB, Upshaw JE, Riley LH, et al; Geometric total knee arthroplasty.I. Conception, design, indications, and surgical technic, *CORR. 94:171, 1973.*
62. Vince KG: Principles of condylar knee arthroplasty: issues evolving, *Instr Course Lect. 42:315, 1993.*