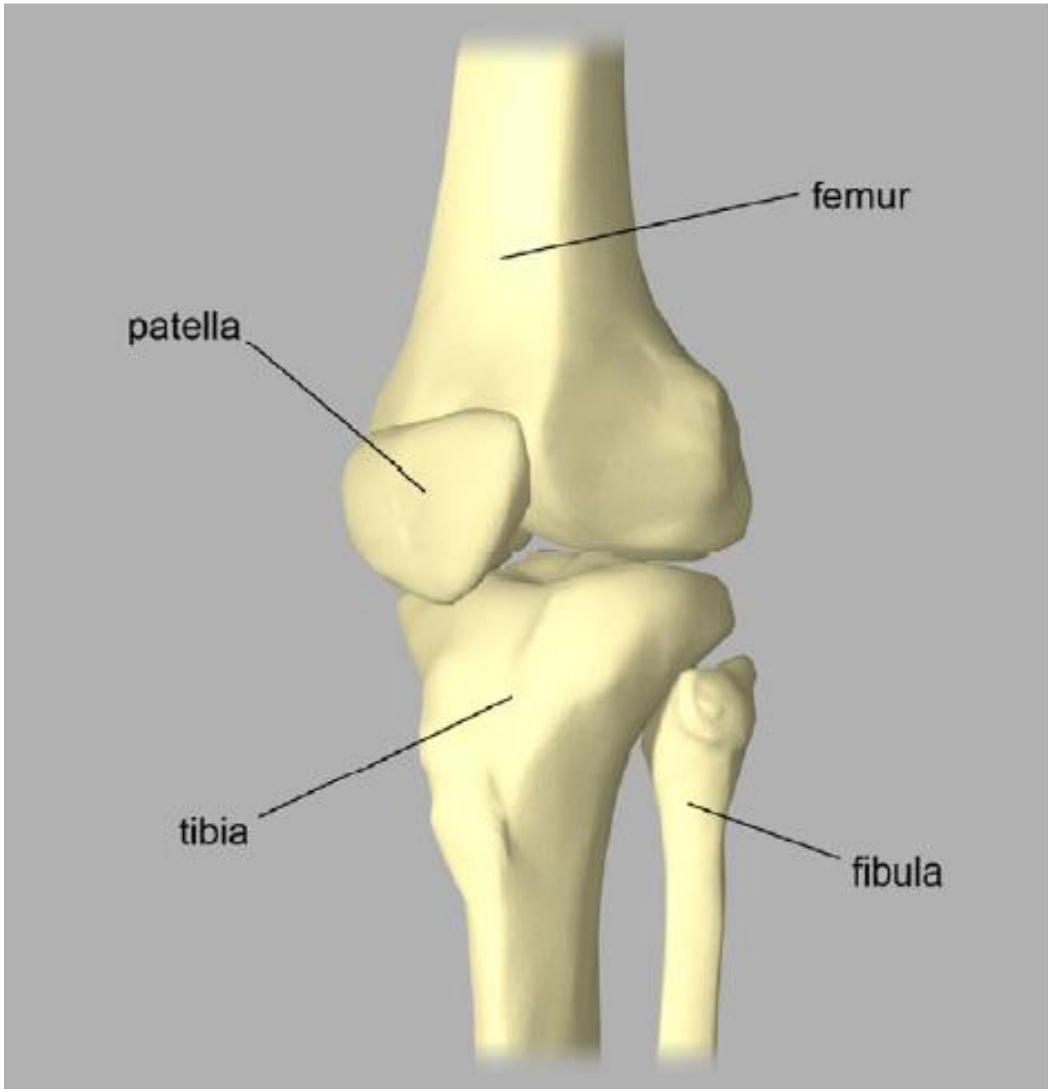
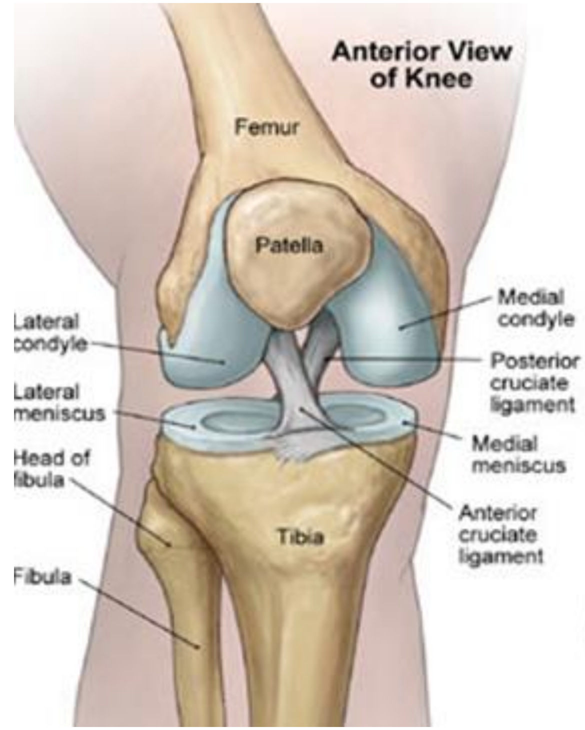
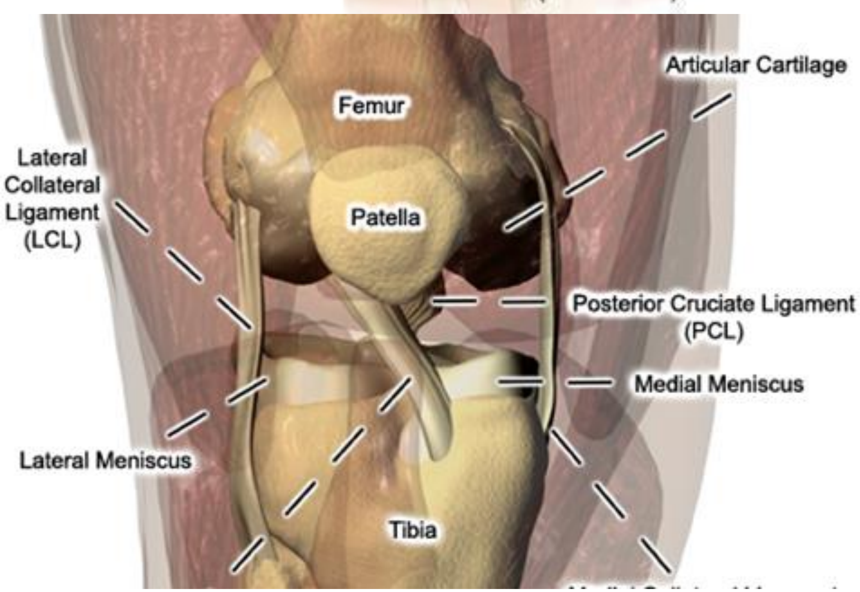
The Knee prostheses

Anatomy

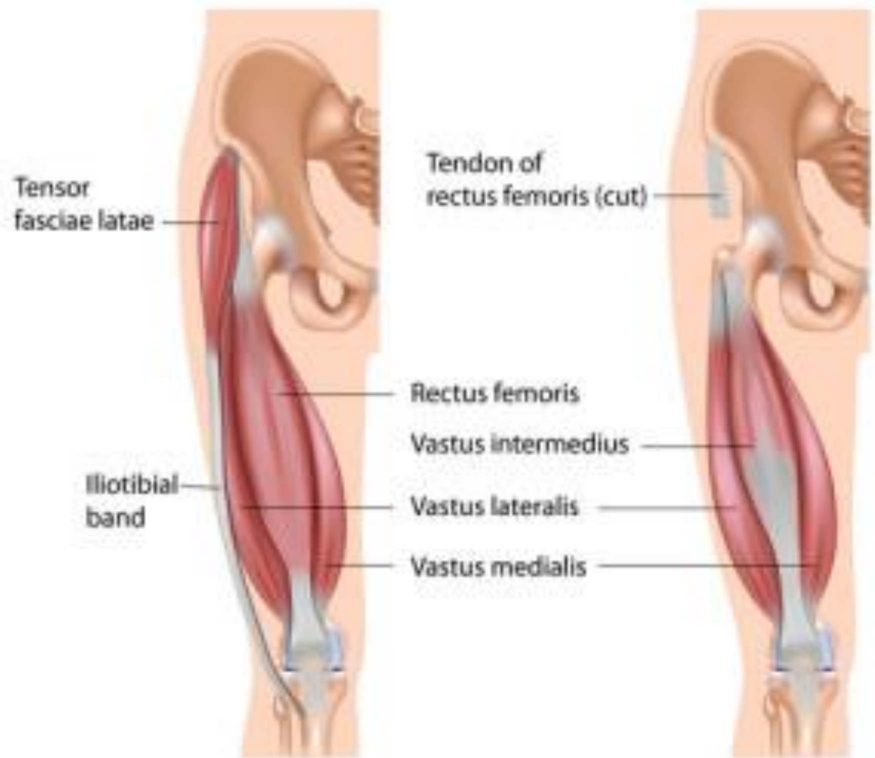


Bones of the Knee

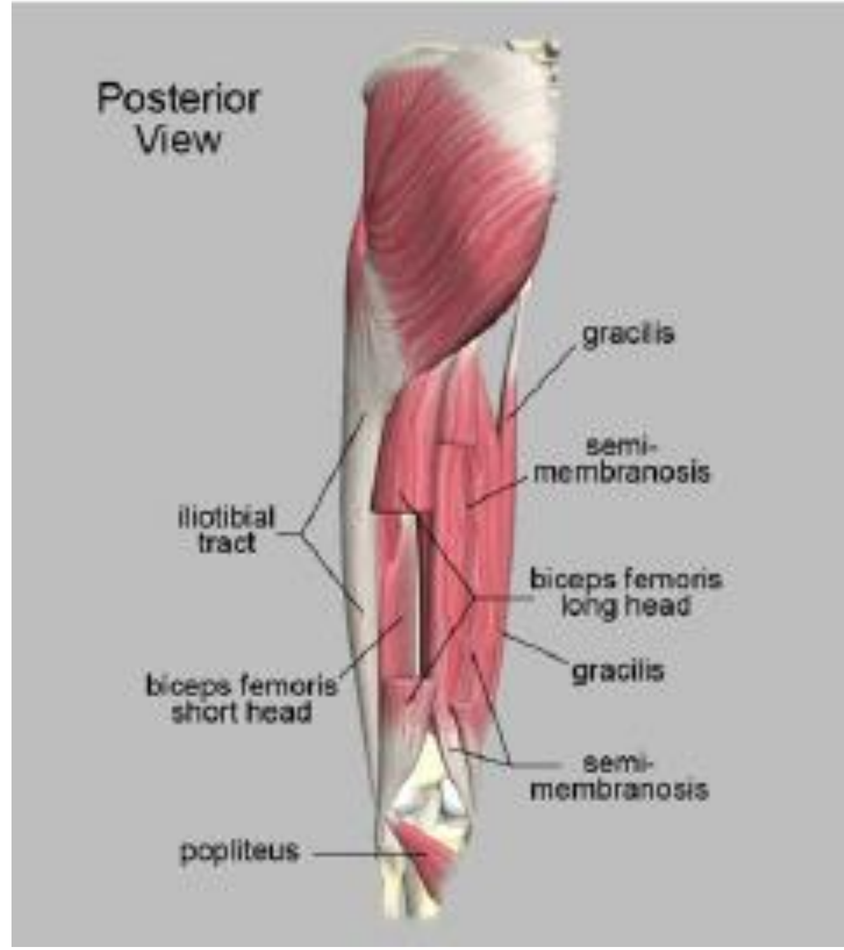




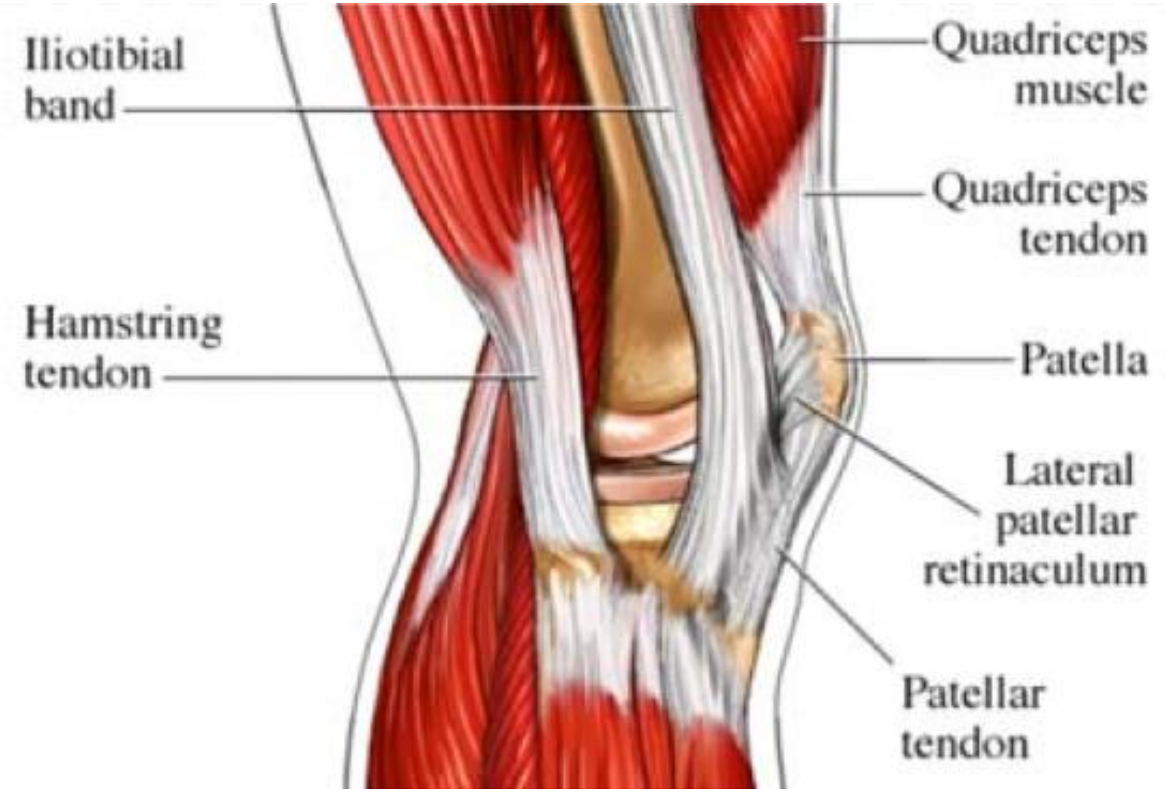
Ligaments of the Knee



Anterior Knee Musculature



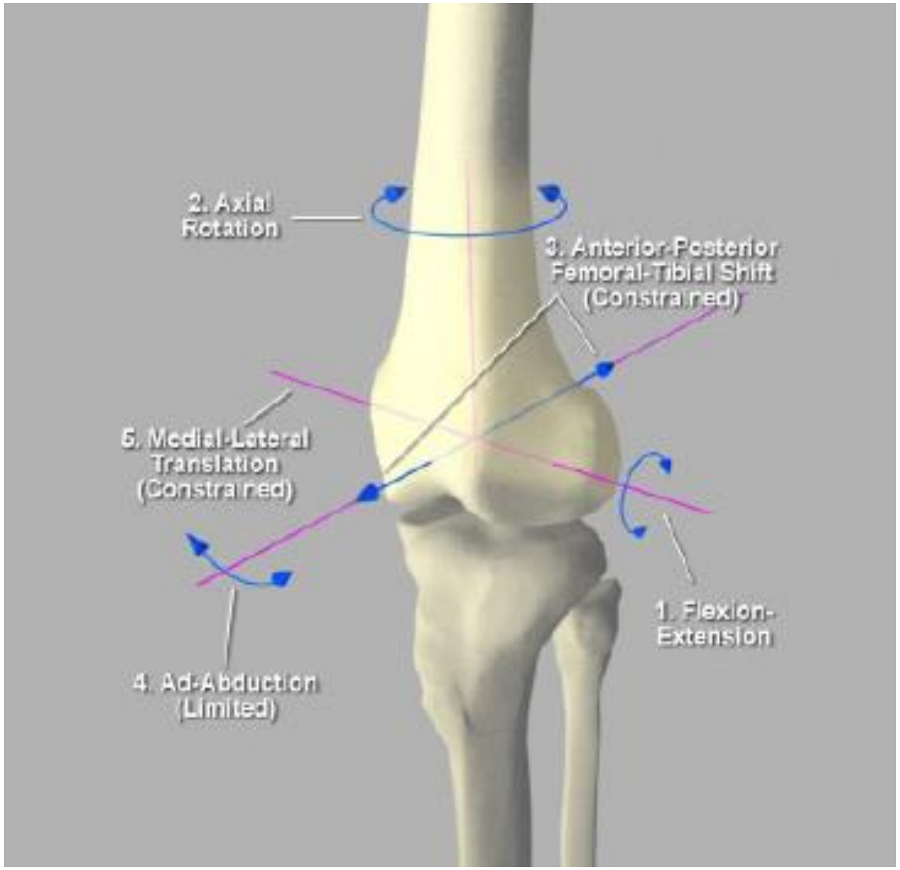
Posterior Knee Musculature



Iliotibial band
Quadriceps muscle
Quadriceps tendon
Hamstring tendon
Patella
Lateral patellar retinaculum
Patellar tendon

Biomechanics

Tibiofemoral Kinematics

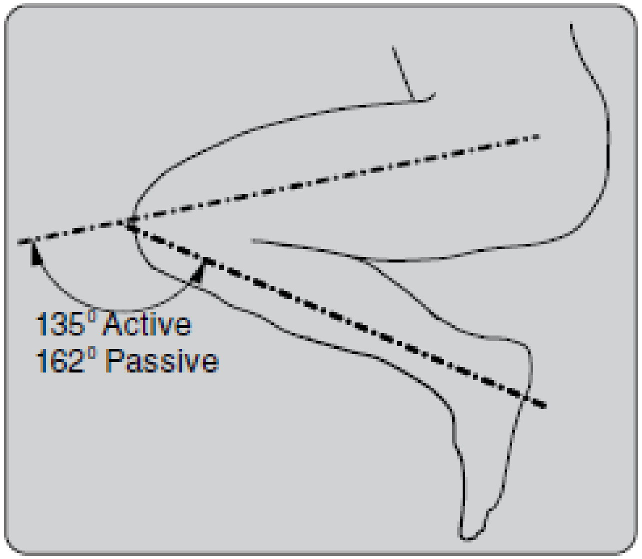


Degrees of Movement and Stability of the Knee

The five degrees of freedom associated with the knee joint are:

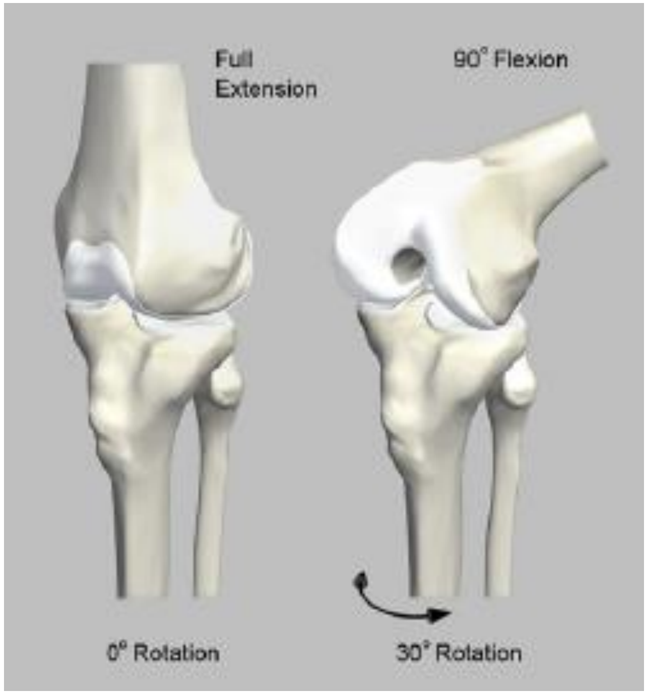
1. Flexion - Extension; this is the principal motion of the joint.
2. Axial rotation; this motion is limited primarily by the ligaments of the knee.
3. Abduction - Adduction; this motion is limited by the ligaments and the tibiofemoral articulating surfaces.
4. Anterior-posterior (A-P) translation; this motion is limited by the ligaments and the tibiofemoral articulating surfaces.
5. Medial-Lateral (M-L) translation; this motion is limited by the ligaments and the tibiofemoral articulating surfaces.

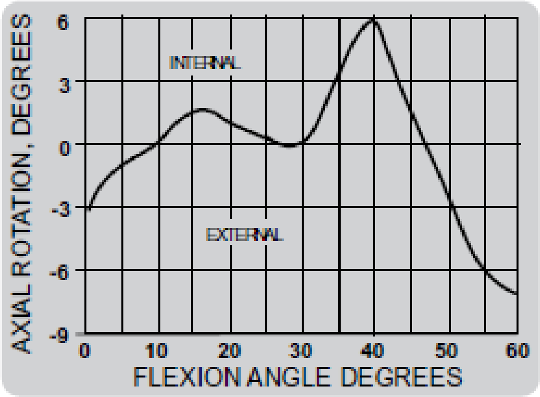
Flexion - Extension



Any restriction of this motion is undesirable as it adversely affects knee function and can produce undesirable loading on the prosthesis, ligaments and bone fixation interface

Axial Rotation





Axial rotation during walking

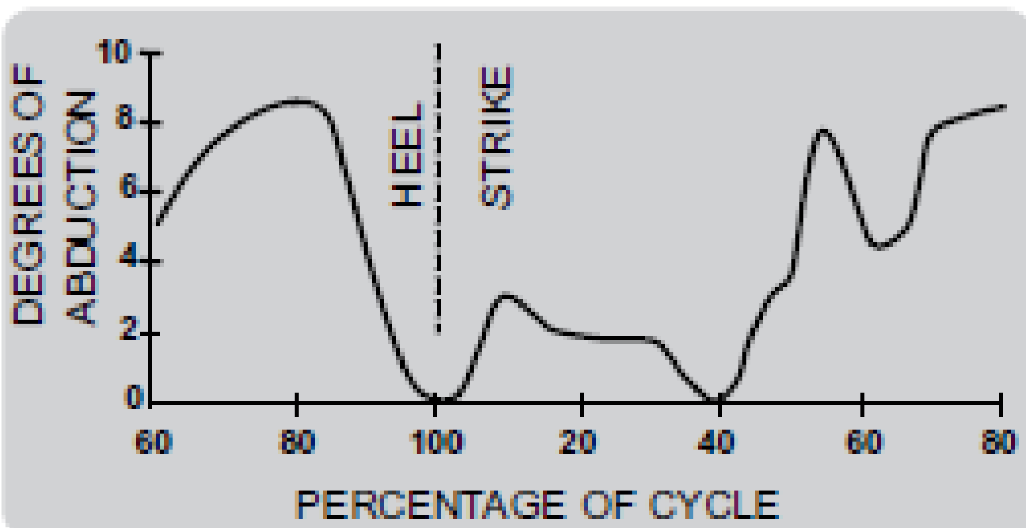
Passive range of motion is typically practiced on a joint that is inactive. The physical therapist may use this exercise on a client who is paralyzed or unable to mobilize a specific joint. This type of exercise can help prevent stiffness from occurring. During this exercise the patient does not perform any movement, while the therapist stretches the patient's soft tissues.

Active range of motion exercises are highly independent, performed solely by the client. The physical therapist's role may be simply to provide verbal cues.

Abduction - Adduction Stability and Motion

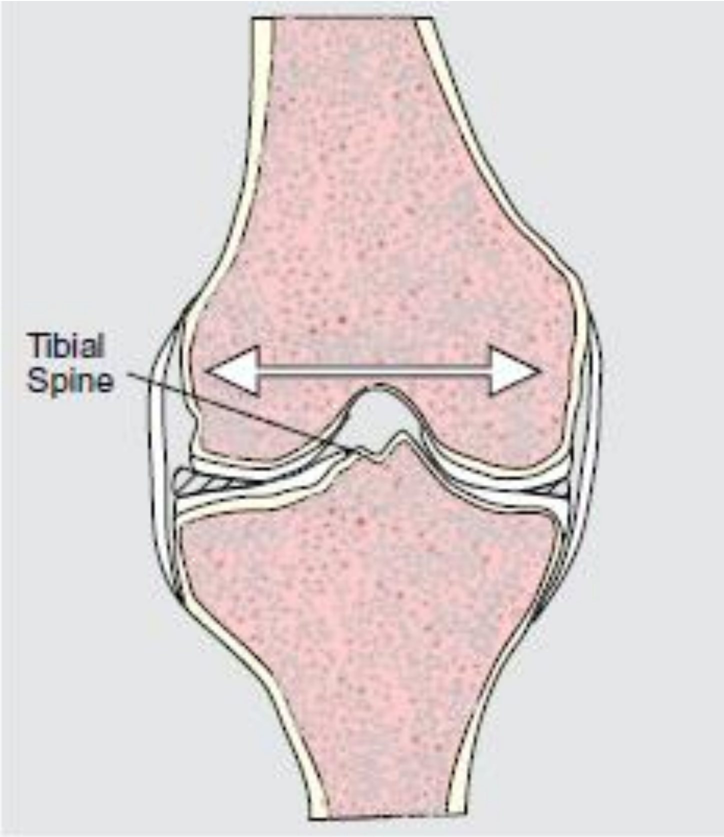
Intrinsic stability provided by the shape of the articulating surfaces and extrinsic stability provided by soft tissues. All except <u>ML stability is essentially extrinsic</u>

Abduction during Walking.



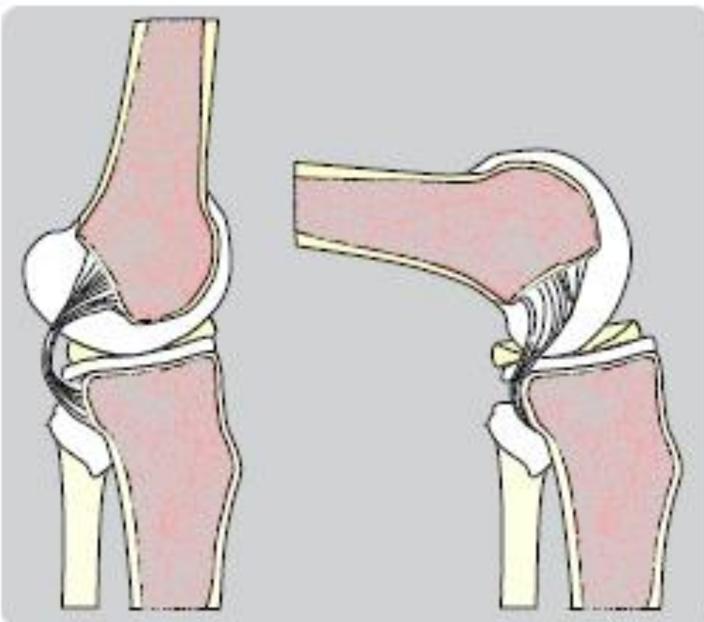
Medial-Lateral

M-L Stability Provided by the Tibial Spine, that is primary intrinsic. But the ligaments also play role. M-L motion in the normal knee is about 2mm

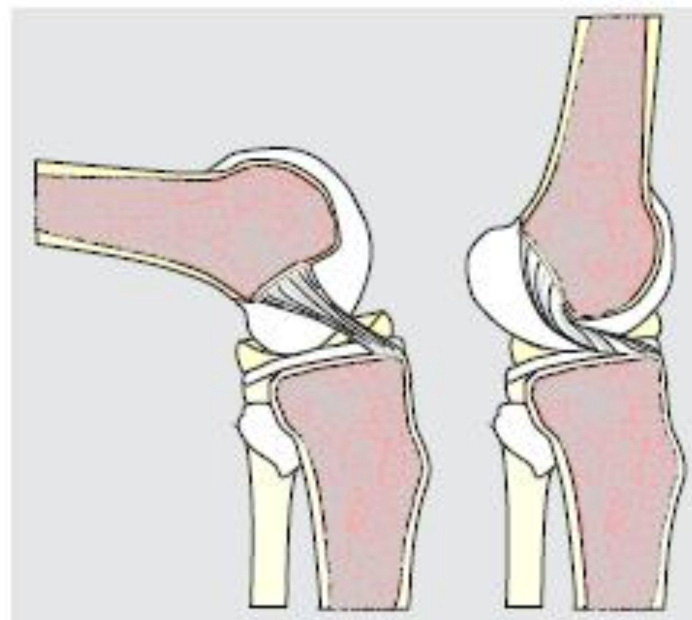


Anterior - Posterior Stability and Translation

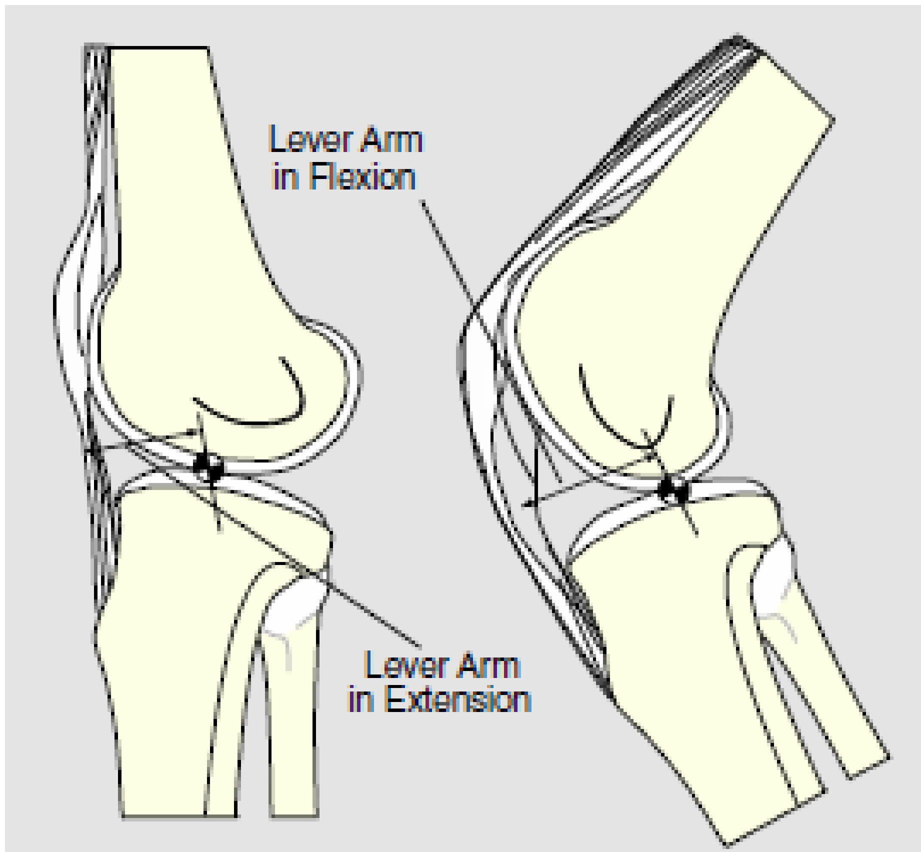
Posterior Cruciate Tightens on Flexion Producing Rollback of the Femur on the Tibia.



Anterior Cruciate Tightens Causing Forward Roll of the Femur on the Tibia.

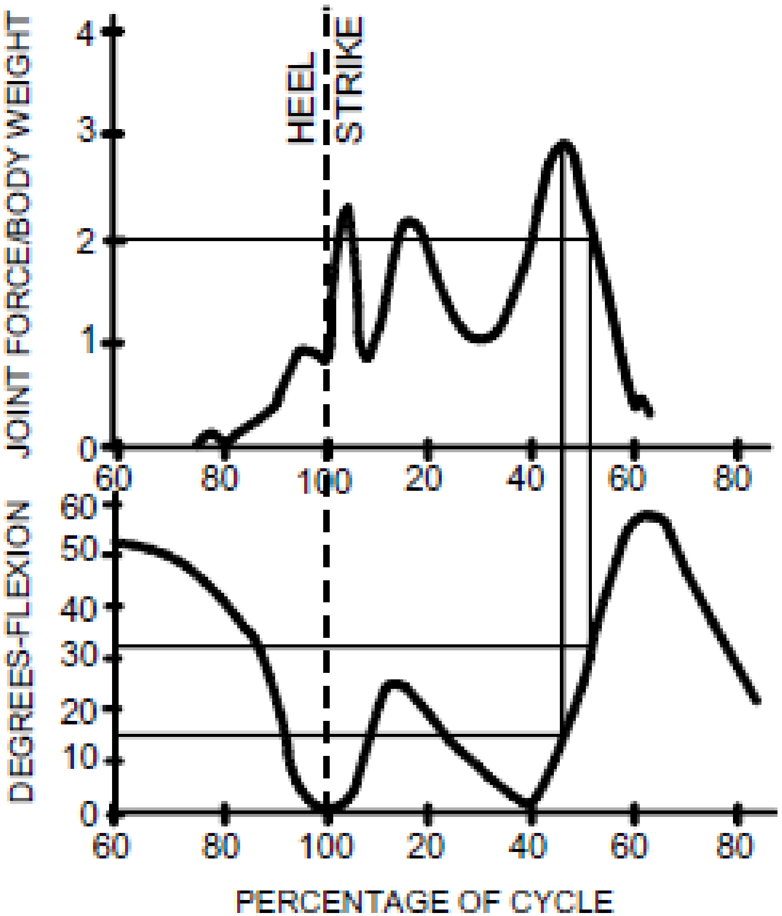


Roll Improves Quadriceps Function, increasing lever arm length

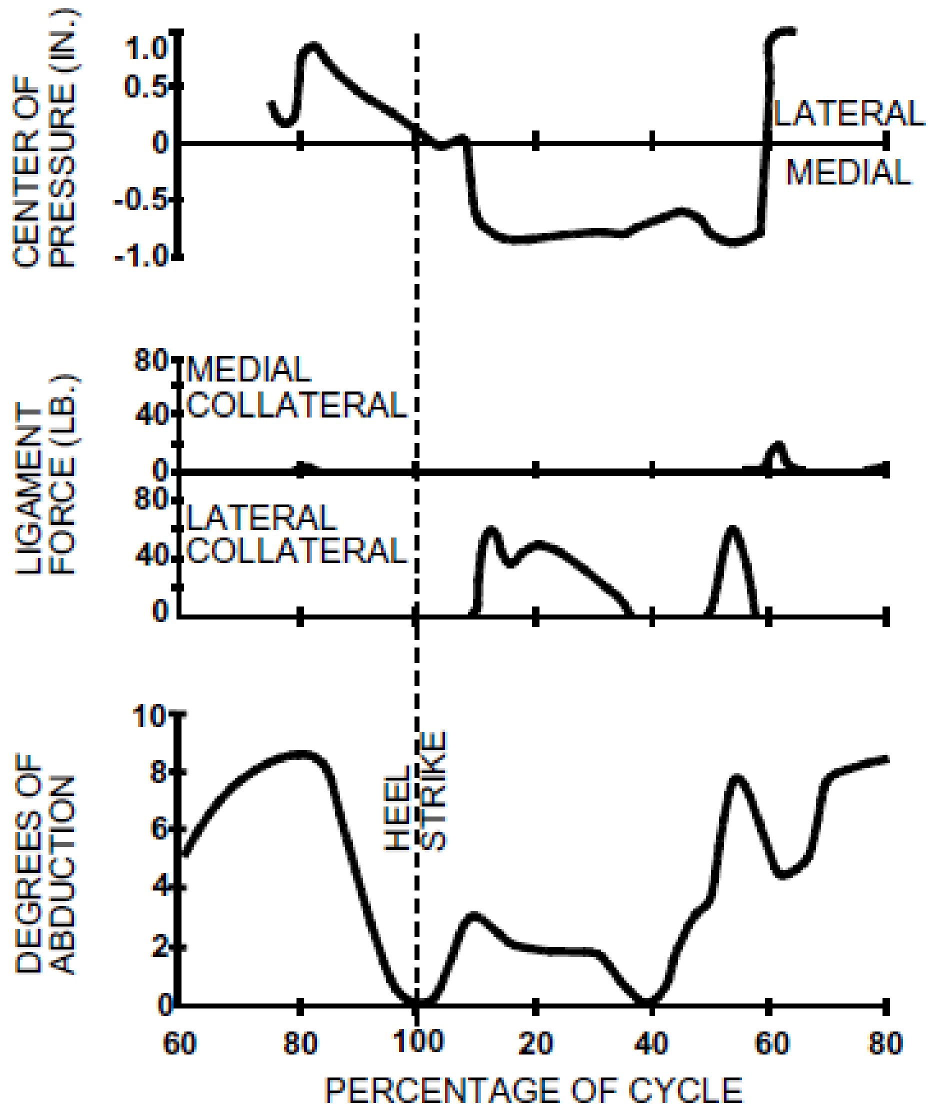


Forces

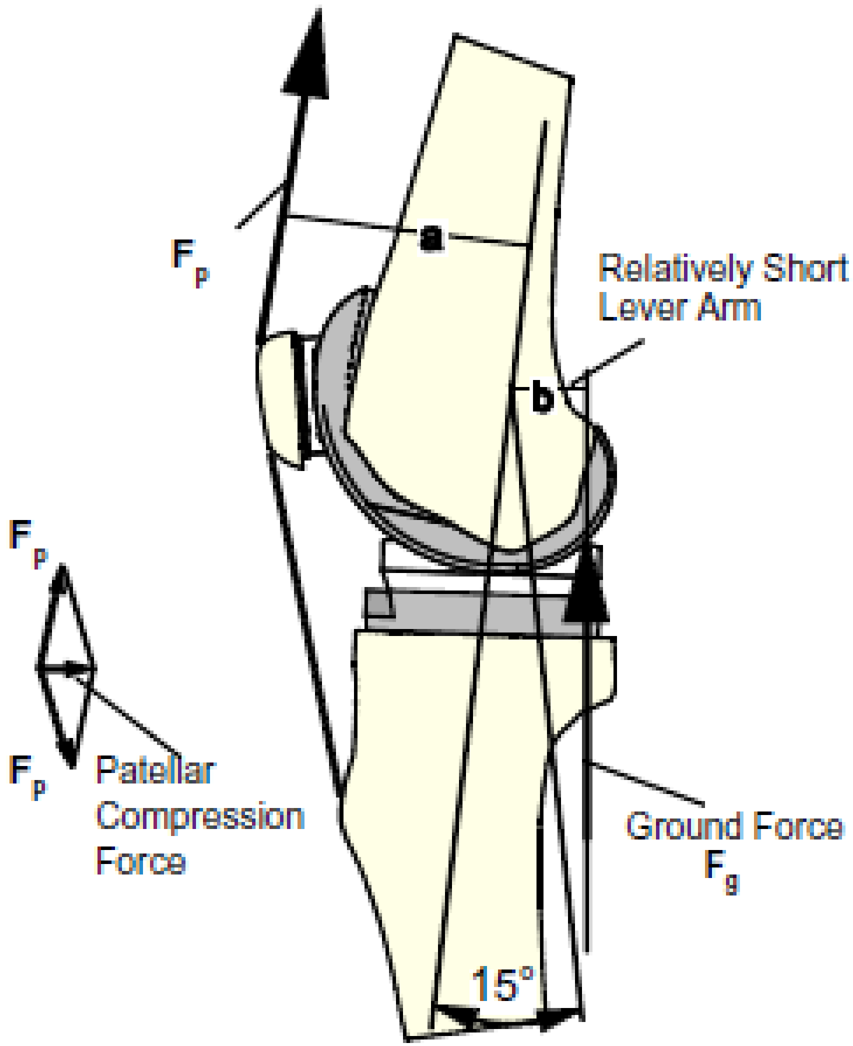
Tibiofemoral Joint Forces and Motion for Normal Gait



Oscillation of Knee Forces and Their Effect on Condylar Loading, Ligaments and Abduction

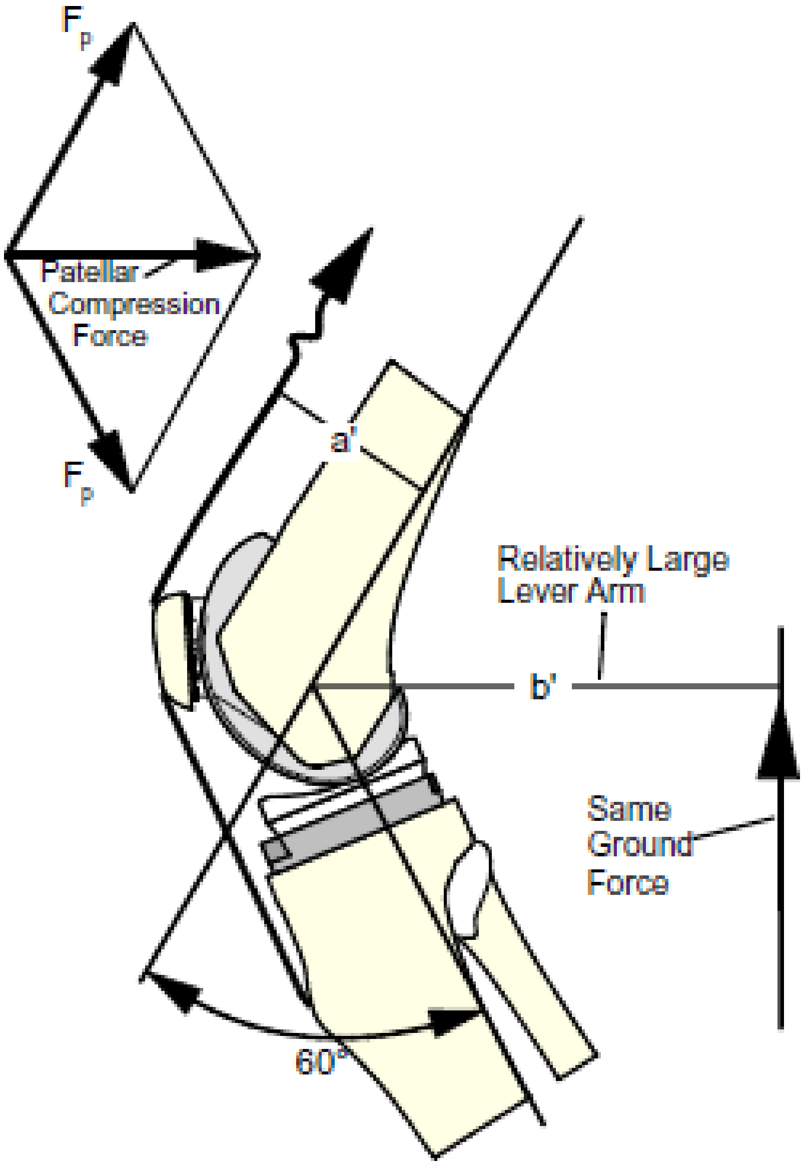


Patellofemoral Loading



Patellar Forces at Low Flexion Angles

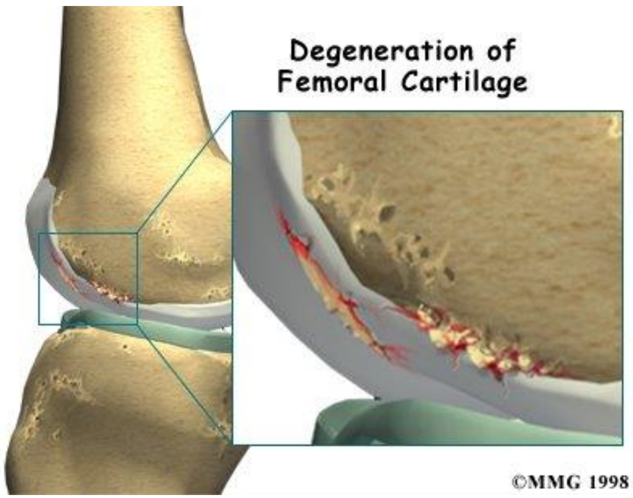
$$F_p = b \times F_g / a$$

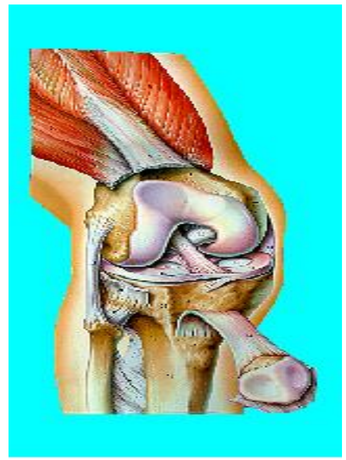


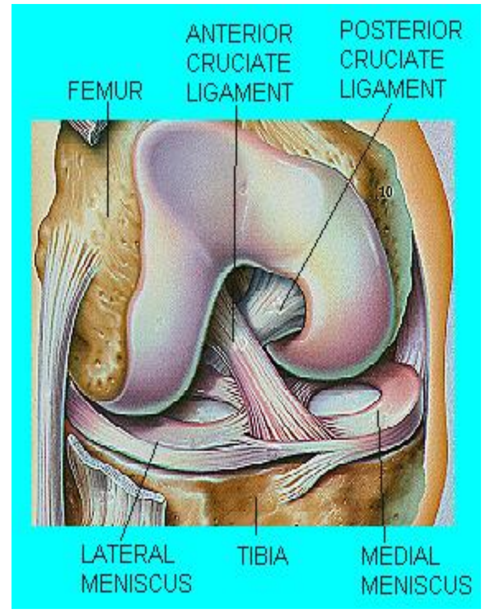
The patellar compression forces are estimated to be 111N at 15° (walking), 1557N at 30° (stair ascent) and 4003N at 110° of flexion (knee bends)

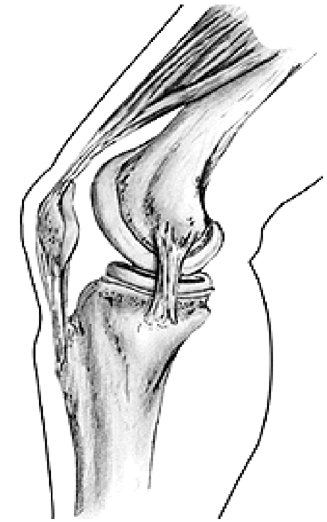
Patellar Forces at Large Flexion Angles

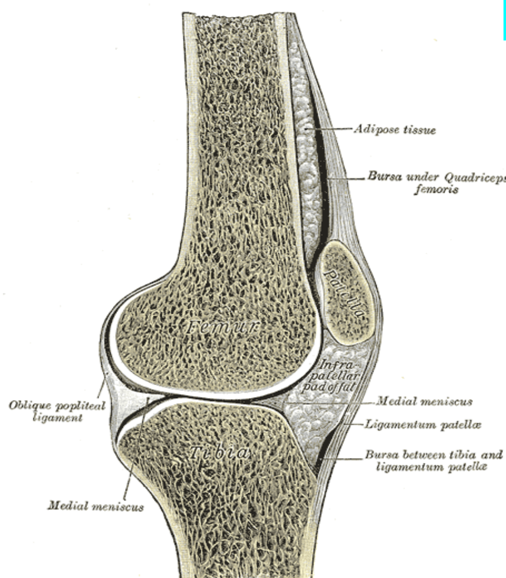
Knee arthrosis-Degenerative diseases

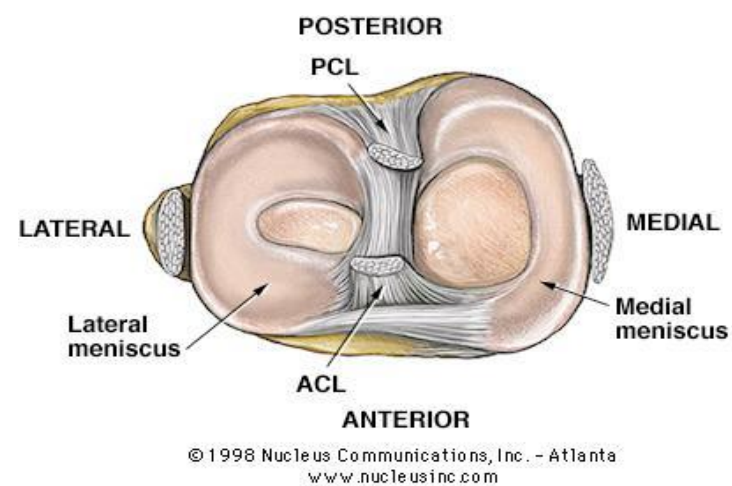




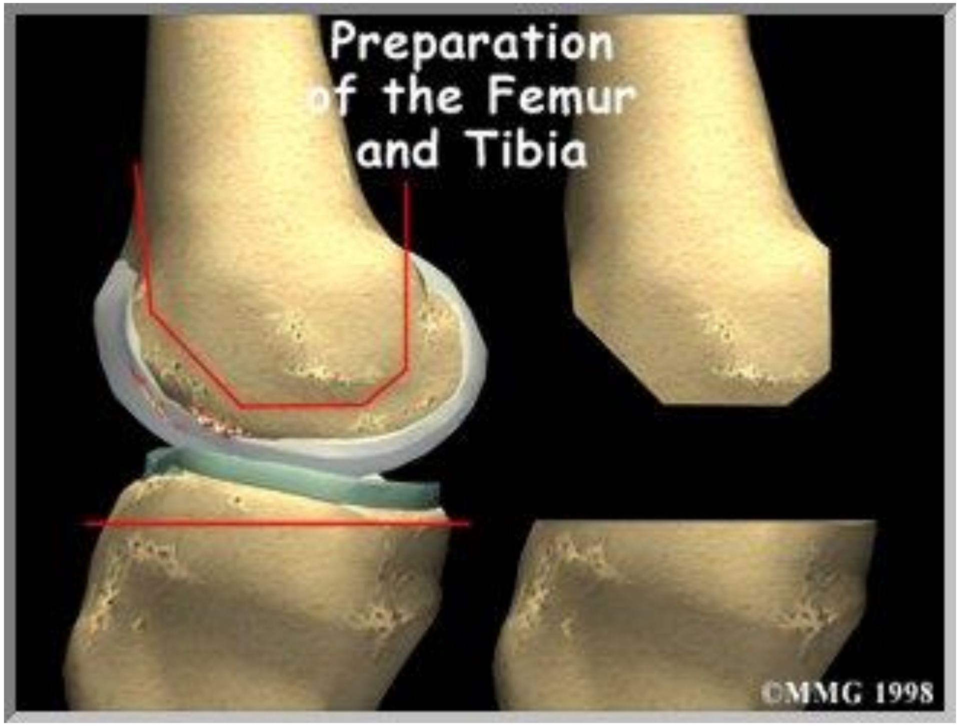








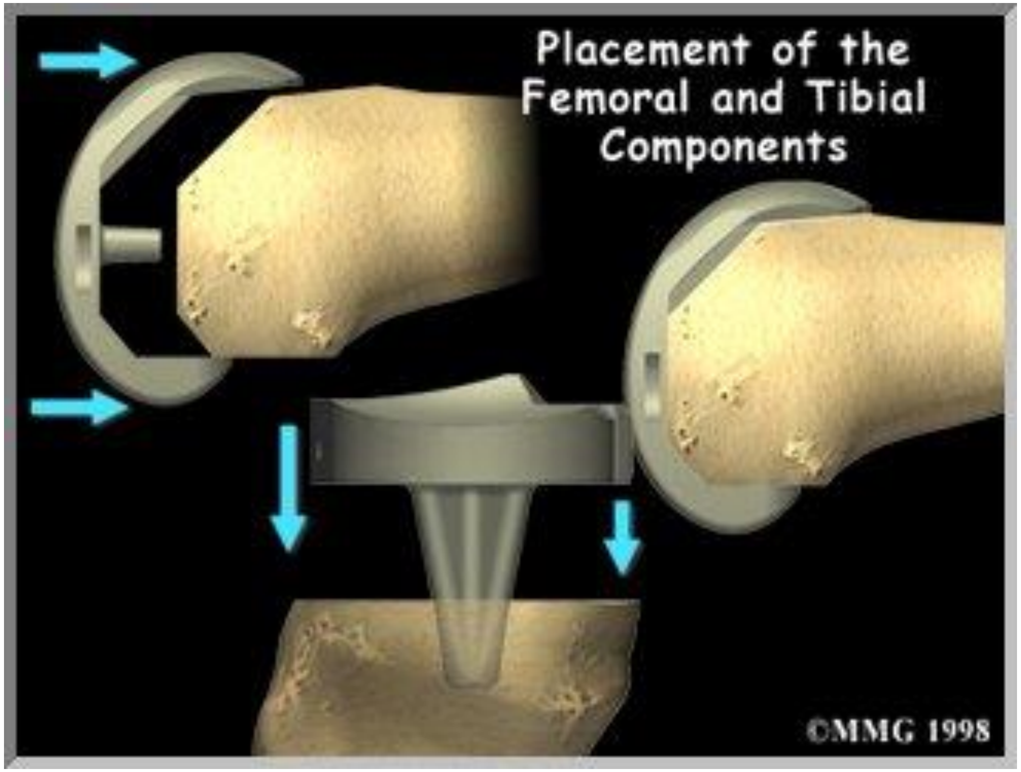
Knee replacement



The steps involved in replacing a diseased knee with an artificial knee begin with making an incision on the front of the knee to allow access to the knee joint.

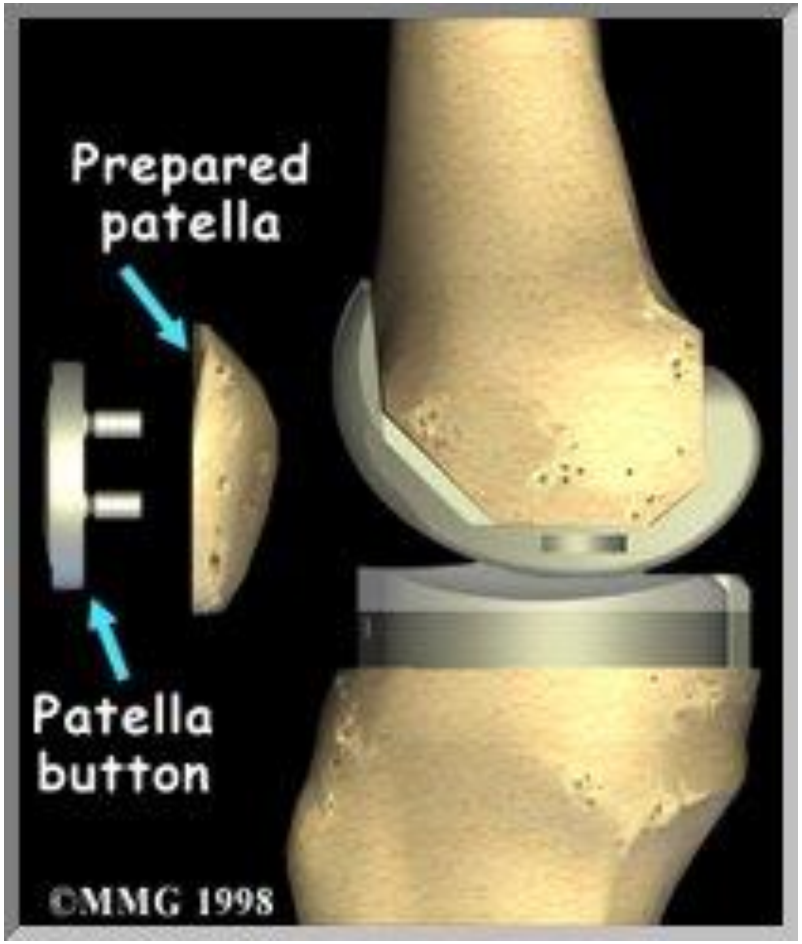
<u>Shaping the Distal Femoral Bone</u>

Once the knee joint is entered, a special cutting jig is placed on the end of the femur. This jig is used to make sure that the bone is cut in the proper alignment to the leg's original angles - even if the arthritis has made you bowlegged or knock-kneed. The jig is used to cut several pieces of bone from the distal femur so that the artificial knee can replace the worn surfaces with a metal surface.



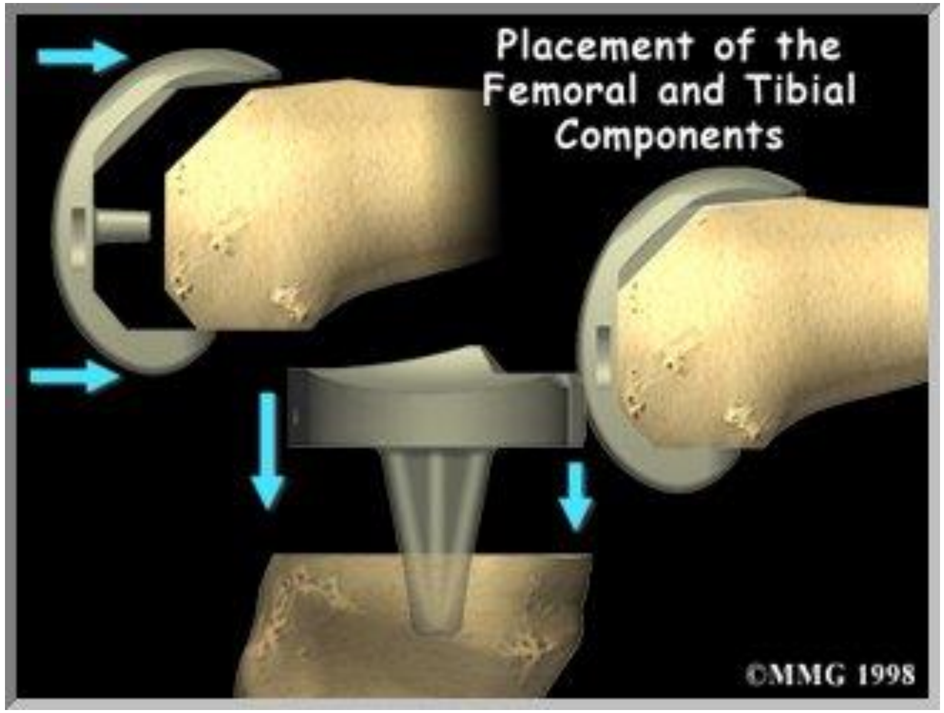
Preparing the Tibial Bone

Attention is then turned towards the lower bone, the tibia. The top of the tibia is cut using another jig that ensures the alignment is satisfactory.



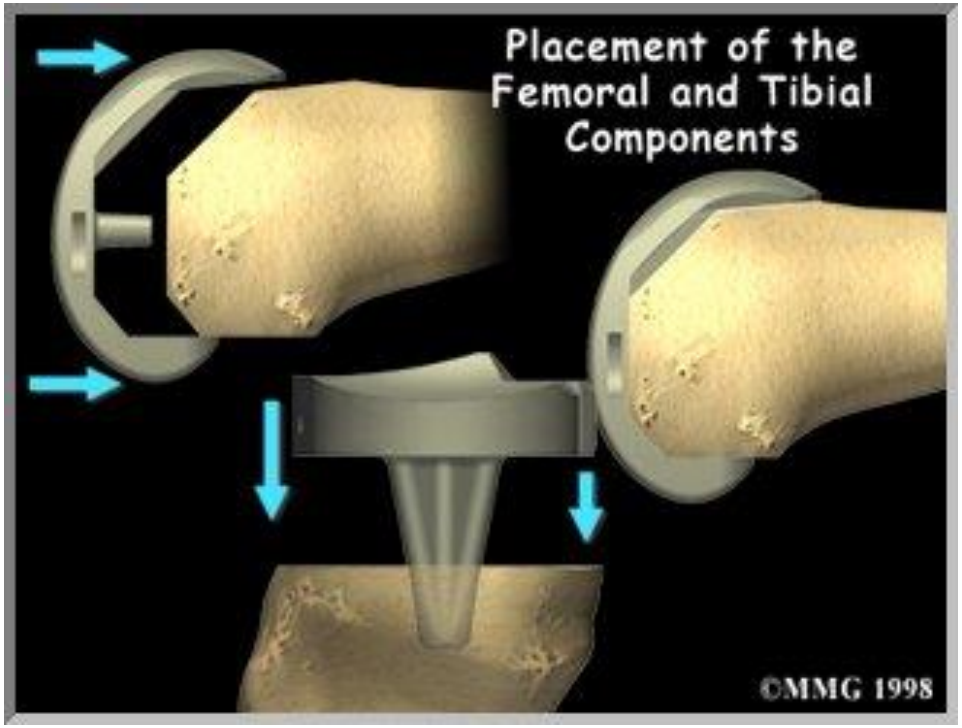
Preparing the Patella

The undersurface of the patella is removed.



Placing the Femoral Component

The metal femoral component is then placed on the femur. In the uncemented variety of femoral component, the prosthesis is held on the end of the bone by the fact that the end of the bone is tapered, and the metal prosthesis is cut so that it matches the taper almost exactly. Driving the metal component onto the end of the bone holds the component in place by friction. In the cemented variety, an epoxy cement is used to attach the metal prosthesis to the bone.



Placing the Tibial Component (metal tray)

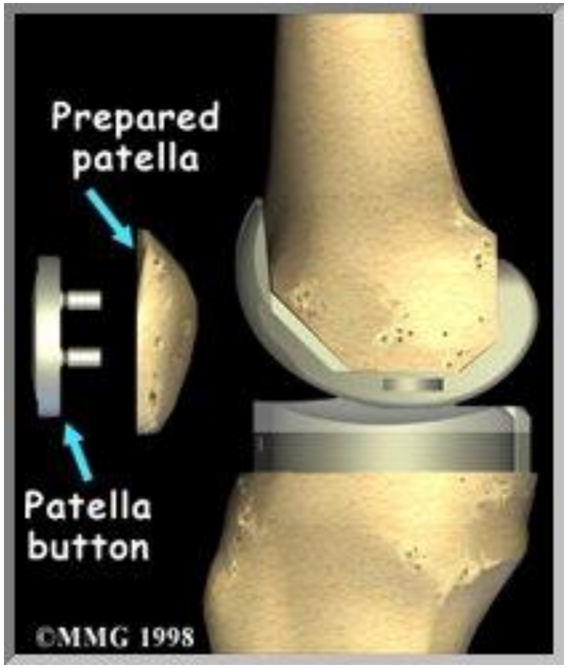
The metal tray that will hold the plastic spacer is attached to the top of the tibia. The metal tray is either cemented into place, or held with screws if the component is of the uncemented variety. The screws are primarily used to hold the tibial tray in place until the bone grows into the porous coating. (The screws remain in place and are not removed.)

Placing the Tibial Component (plastic spacer)

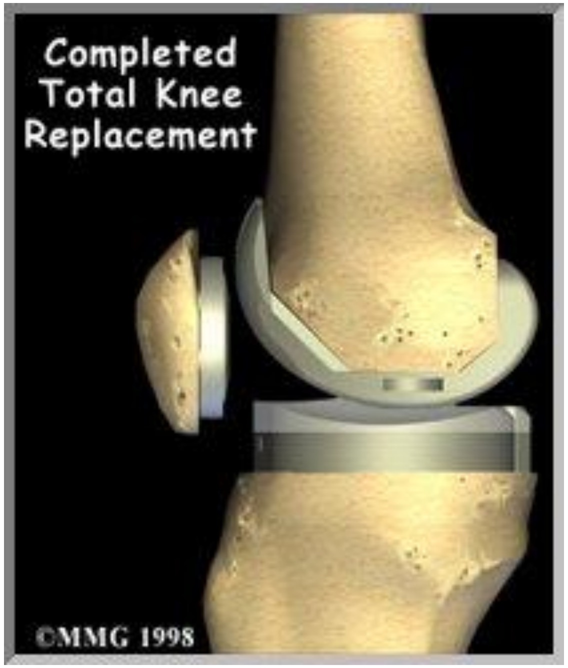
The plastic spacer is then attached to the metal tray of the tibial component. If this component should wear out while the rest of the artificial knee is sound, it can be replaced - a so called *retread*.

Placing the Patellar Component

The patella *button* is usually cemented into place behind the patella.

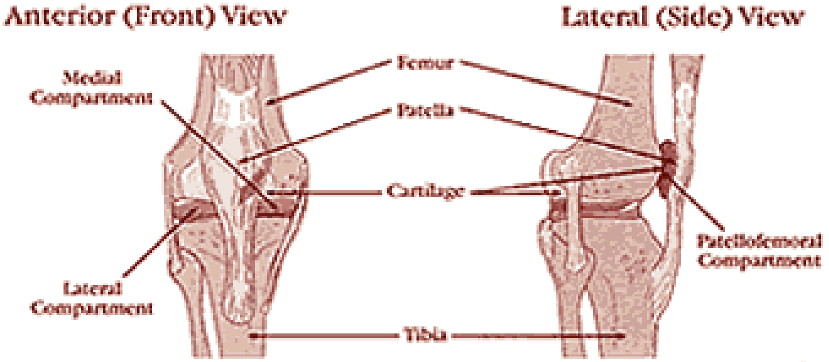


Completed total knee joint replacement

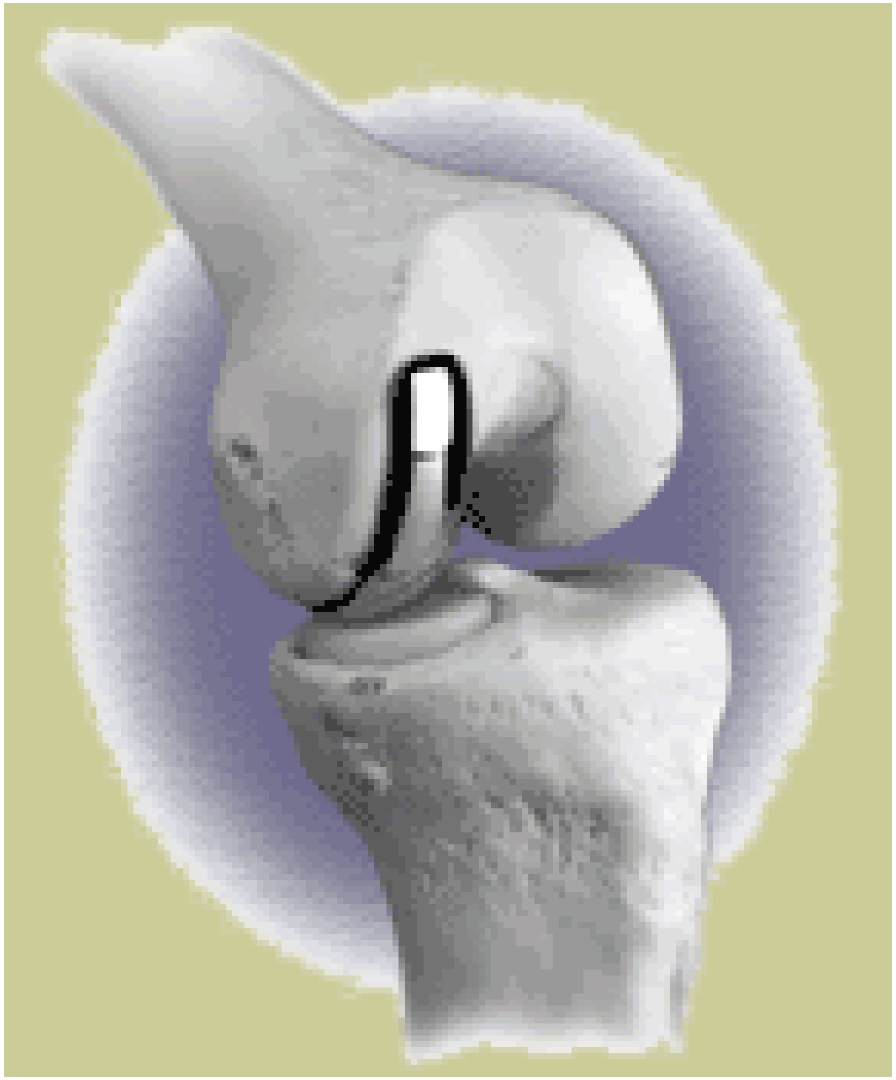


Before
After
A.D.A.M.

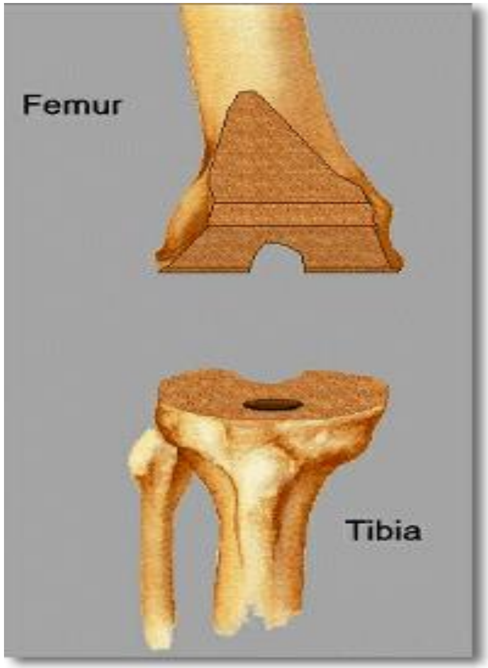
Unicondylar knee replacement

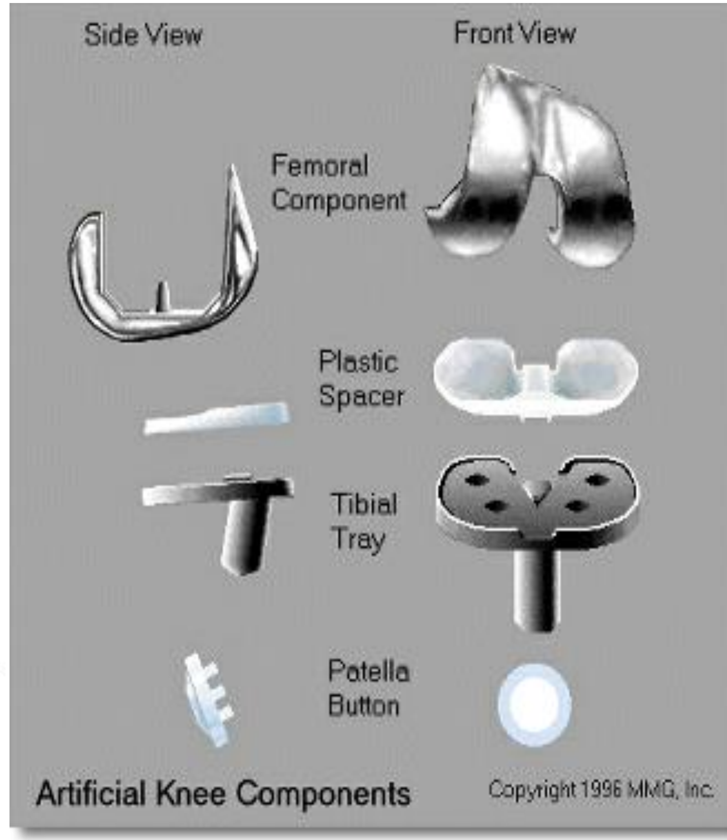


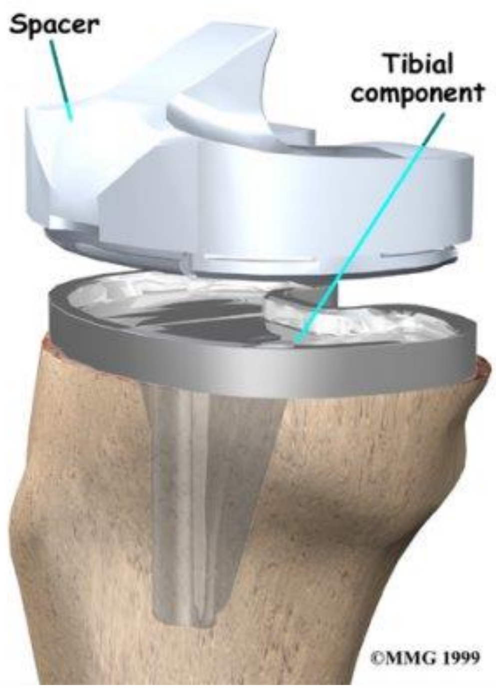
Knee cross-section

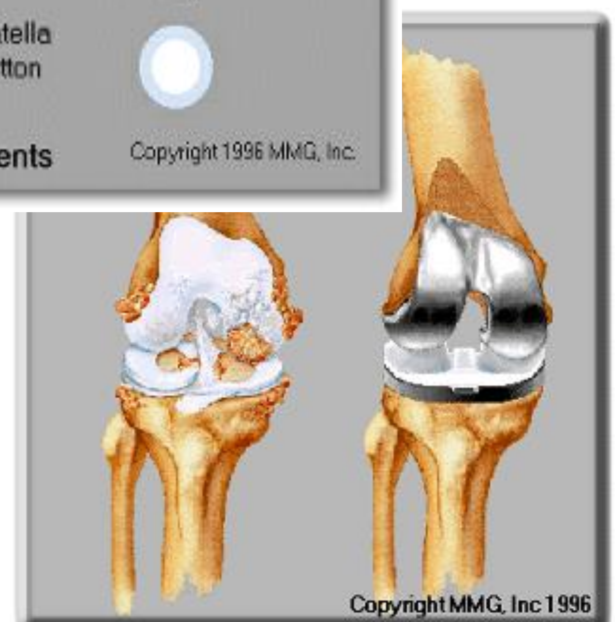


Total joint replacement



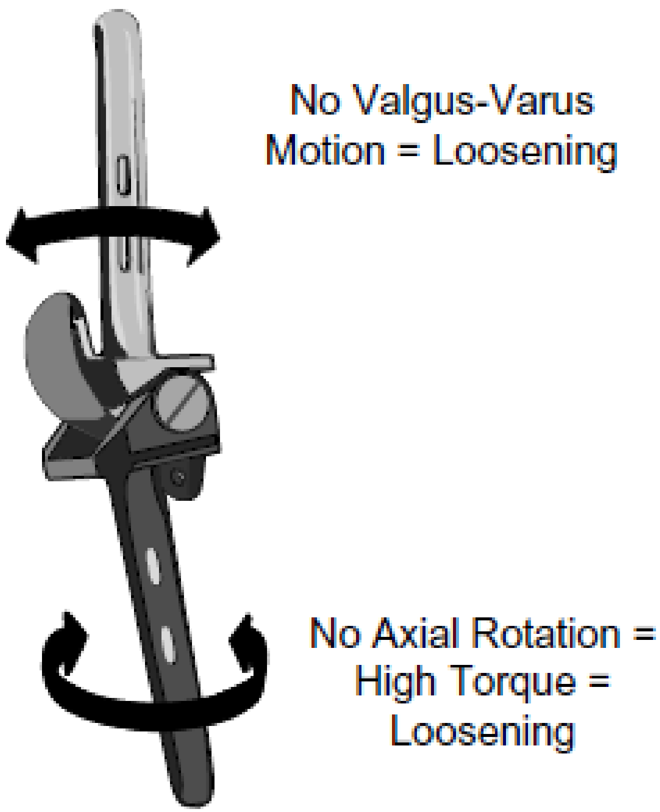


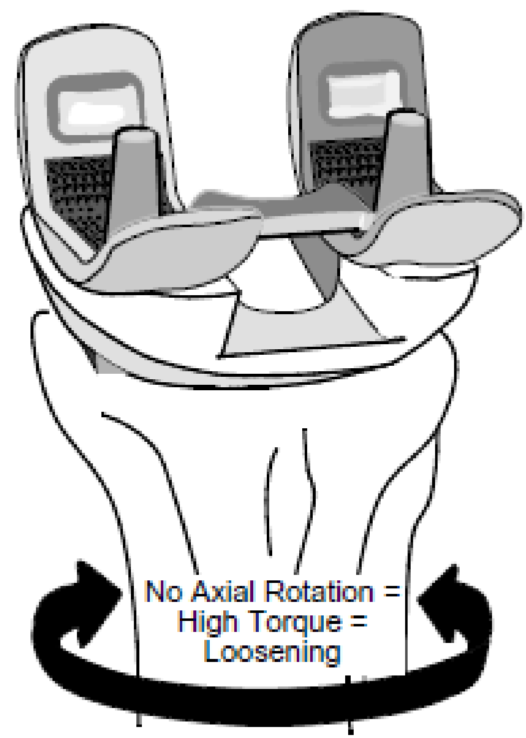




Knee Replacement

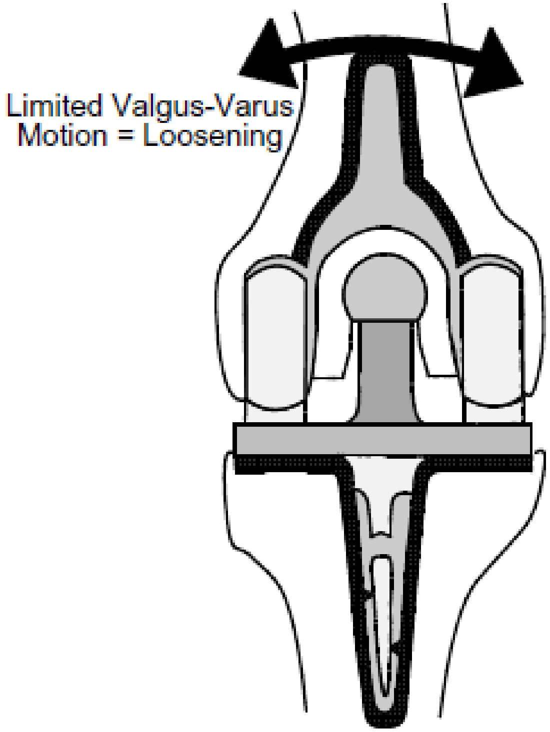
***First Generation Designs**, 1950's, hinge design, press-fit; resurfacing, 1960's*



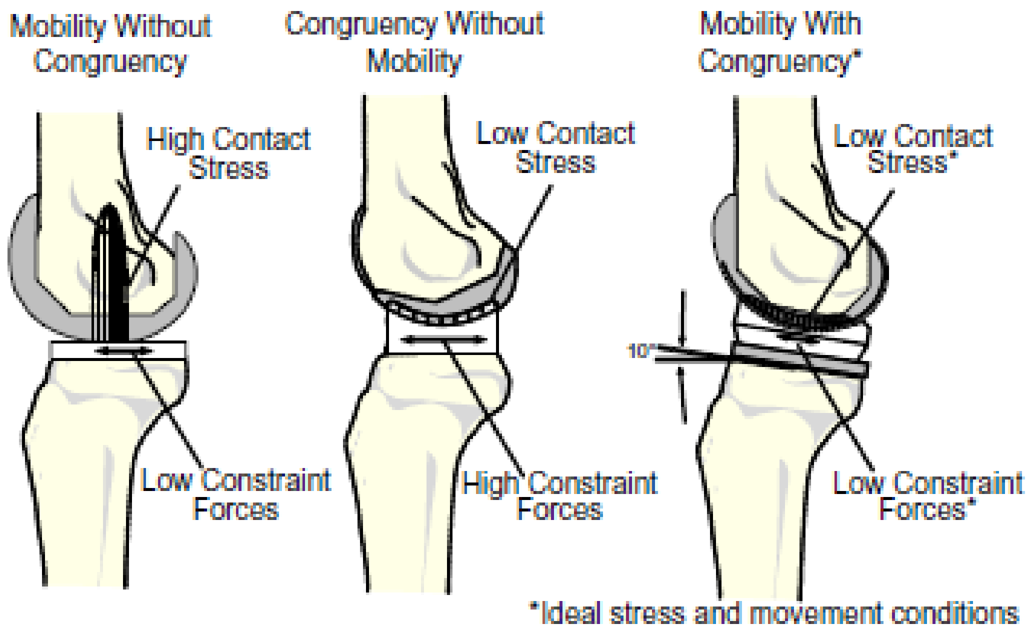


Second Generation Designs, early 1970's

Improved resurfacing designs, <u>hinge designs with axial rotation</u>.
Failure of this design was the result of varus-valgus constraint combined with excessive bone removal and inadequate stem fixation.



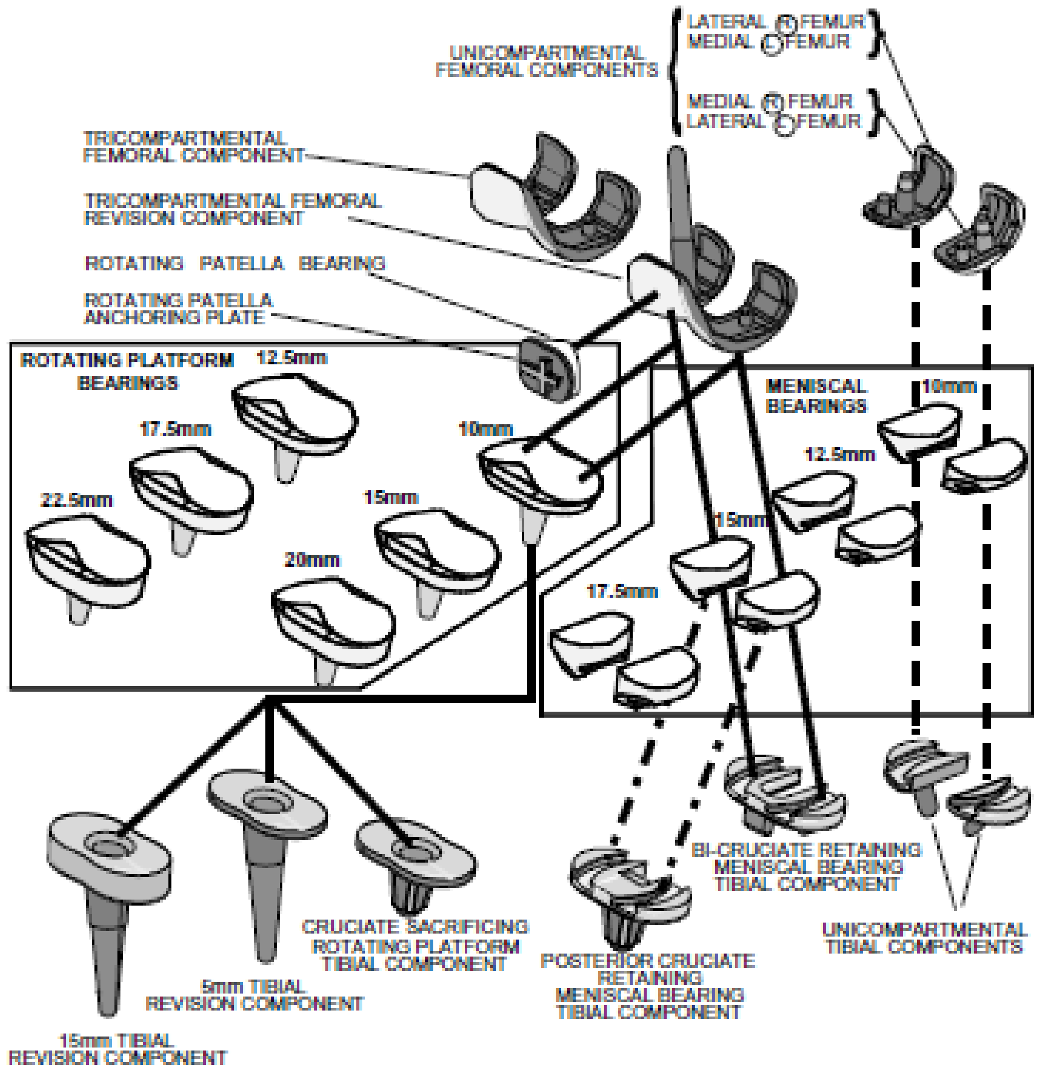
Third Generation Designs, mid, and late, 1970's

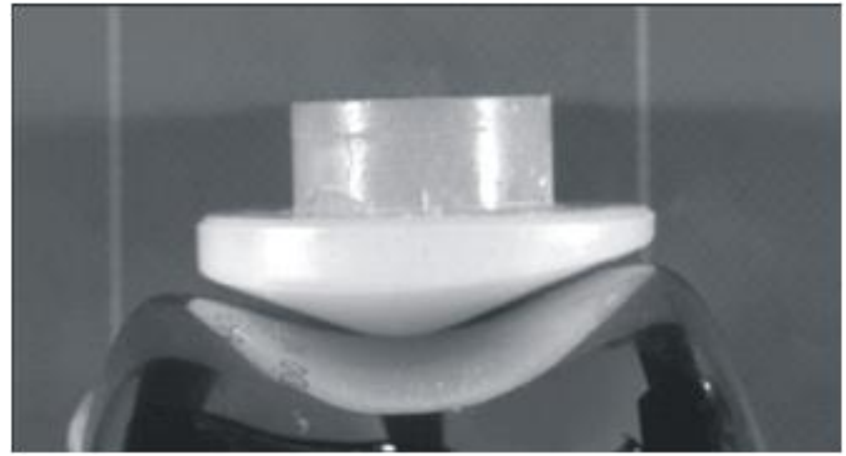


Designs provide mobility and congruency by use of a second bearing surface articulating against a metal tibial platform. The mobile bearing concept solved the dilemma of congruency vs. constraint facing knee designers of the time

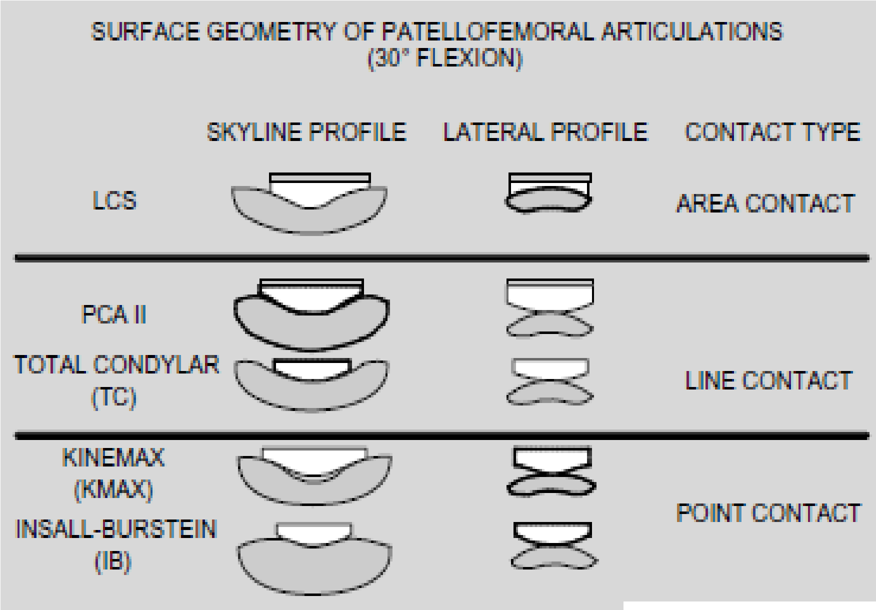
The Oxford Meniscal Bearing Knee, 1976: the first mobile bearing joint replacement , unicondylar replacement

The LCS Knee, 1977 – 1985, the first FDA approved knee replacement available





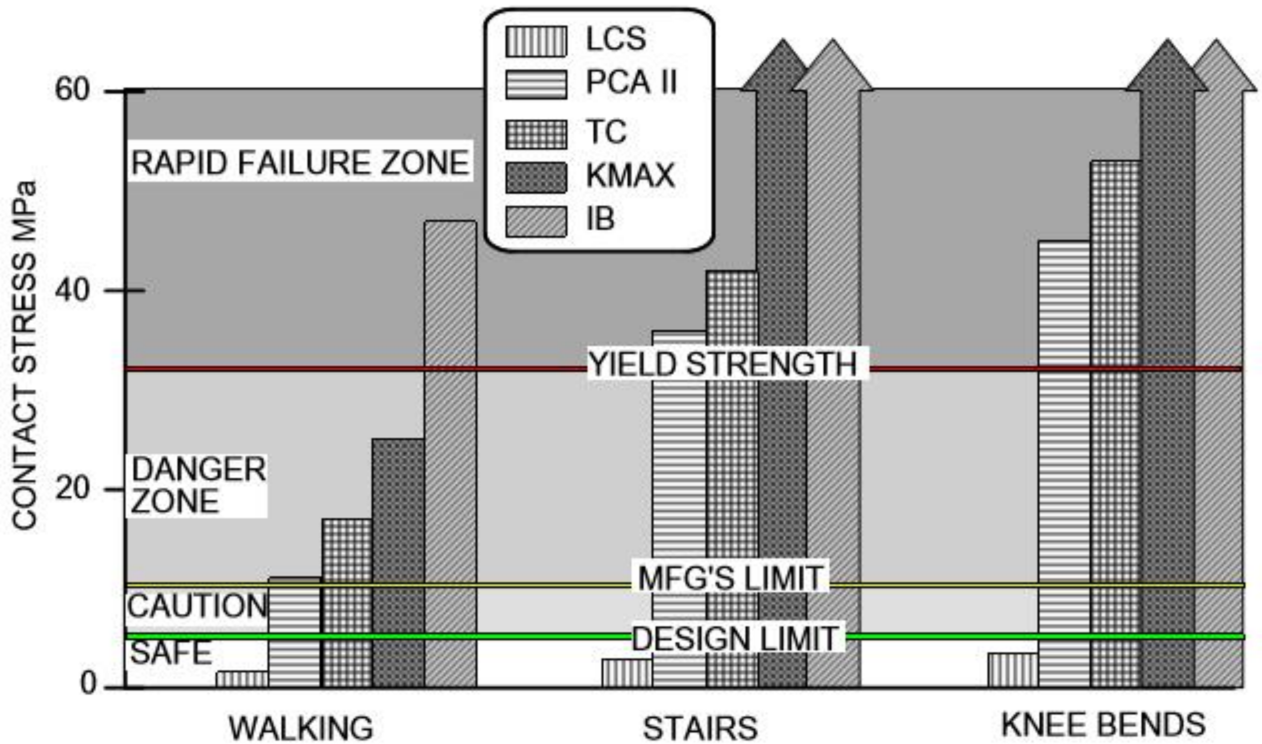
Comparison of Profile Views of a NJ and Button Patellar Replacement



The LCS

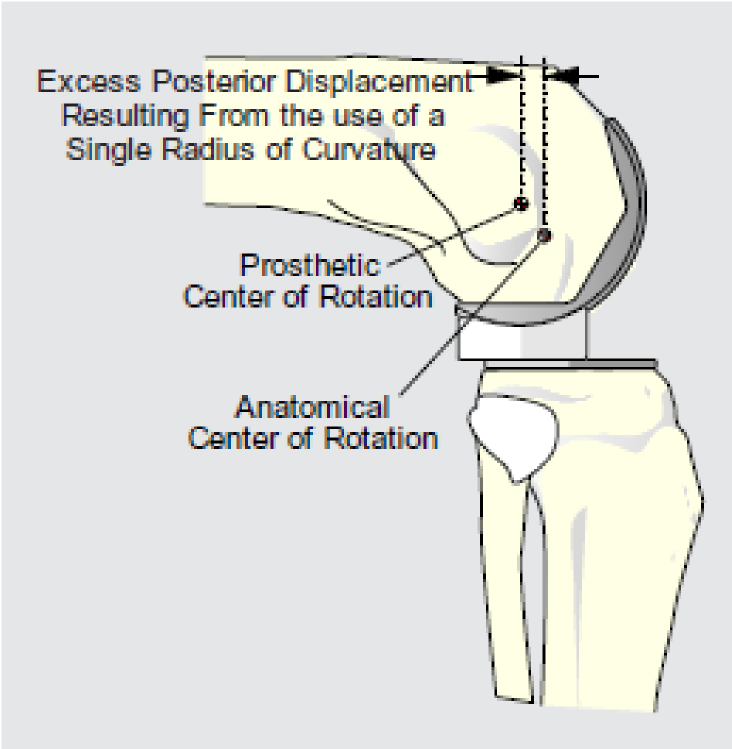
Contact Stresses and Wear

1) Patellofemoral Articulation

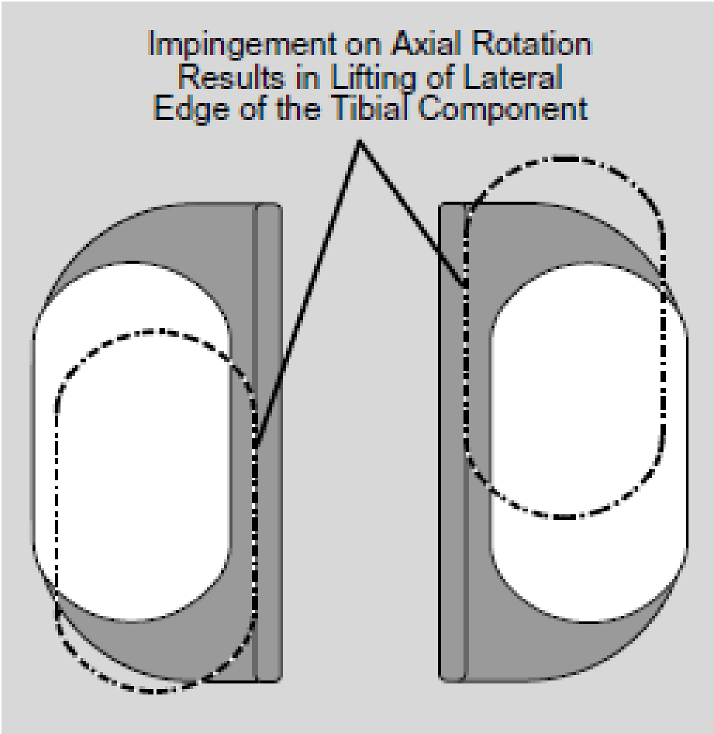


The Oxford Knee: design deficiences

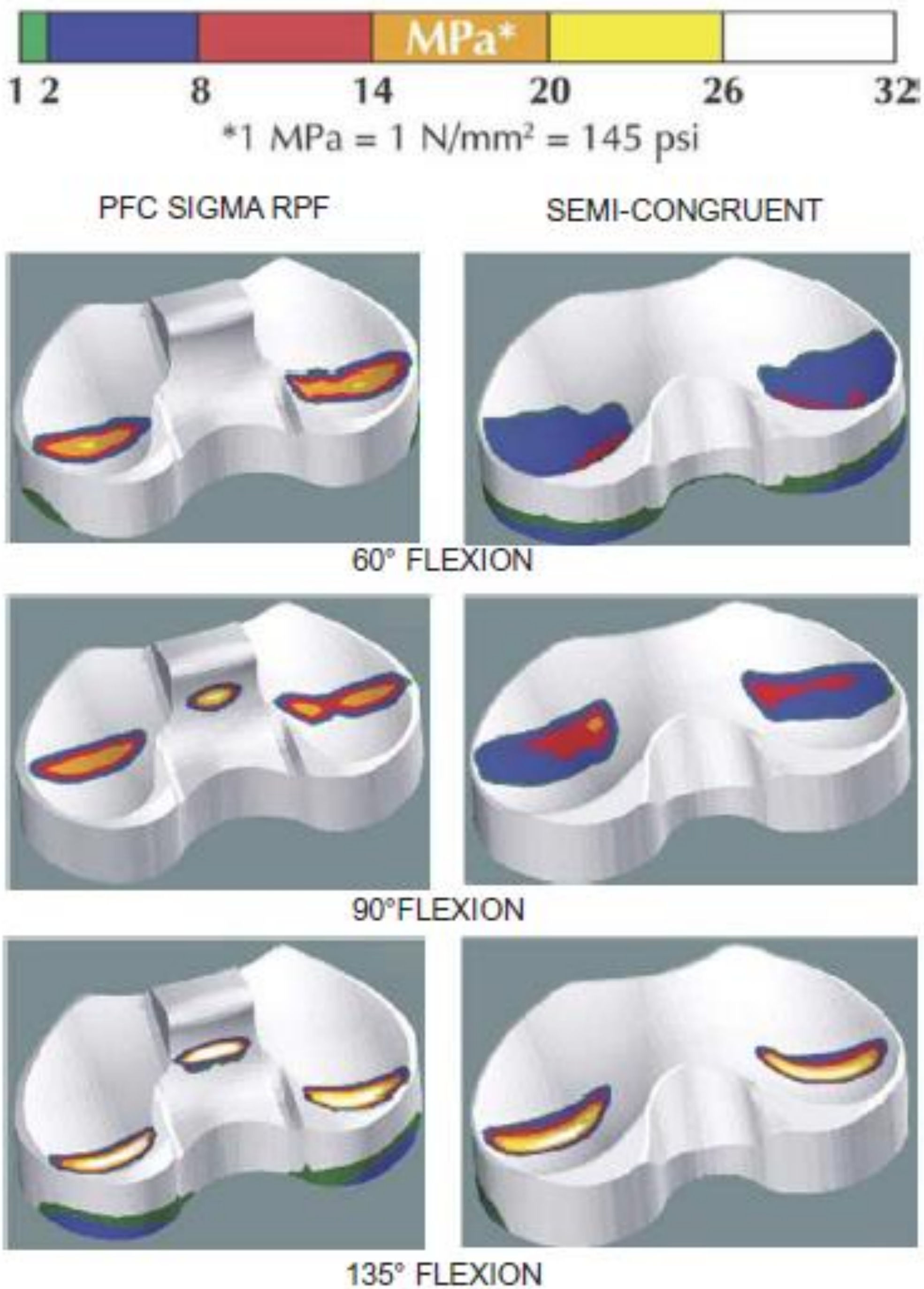
Excessive Posterior Bearing Displacement Due to use of a Single Radius of Curvature of the Femoral Component



Lack of Sufficient Axial Rotation Results in Tensile Stress at Fixation Interface



PFC Sigma RPF Knee Replacement with posterior stability

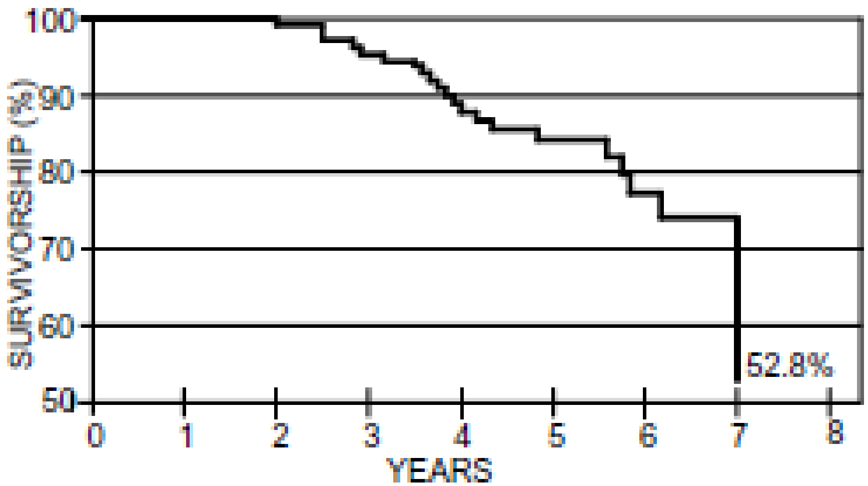


Evaluation of two designs

Comparison of Stresses in the PFC Sigma RPF and a Semi-Congruent Bearing.

Design Evaluation

a) Avoid unnecessary prosthetic constraints where possible
b) Accommodate normal knee motion and loading
c) **Mobile bearings are needed** to provide the necessary degree of congruity and mobility
d) The design of a successful knee replacement is complex



Failure was due to excessive contact stress

Survivorship of 108 Cementless PCA Knees of the 2nd generation.
Failure was due to excessive contact stress

Survivorship of third generation

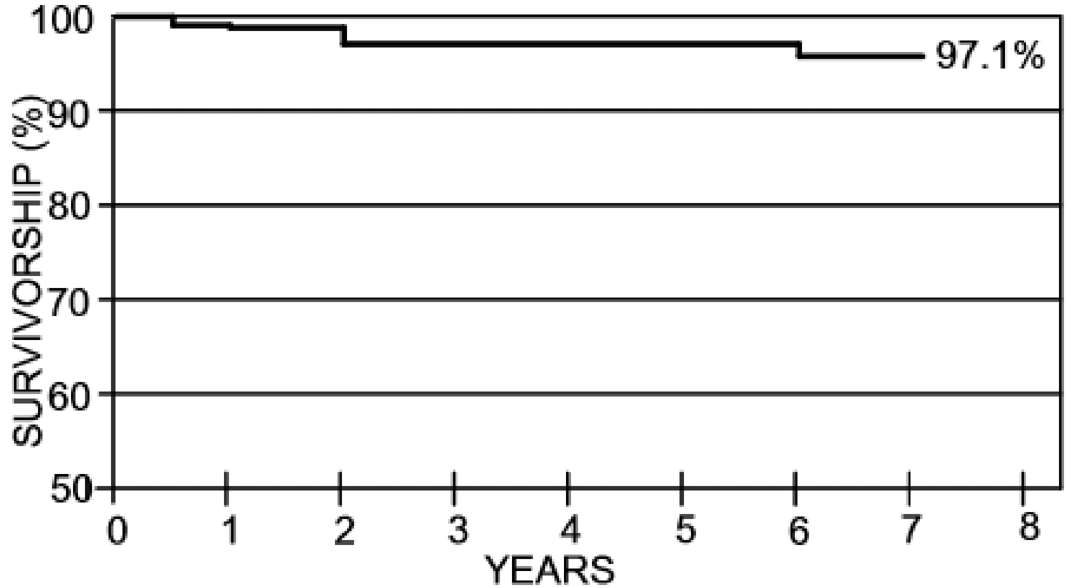


Fig. 6.51 Survivorship of 1140 New Jersey LCS Knees [109].

The Fourth Generation, *1998 - 2009*

The B-P Mark V total Knee Replacement:

- Experience with the previous
- Improved availability of materials
- Manufacturing process

↓

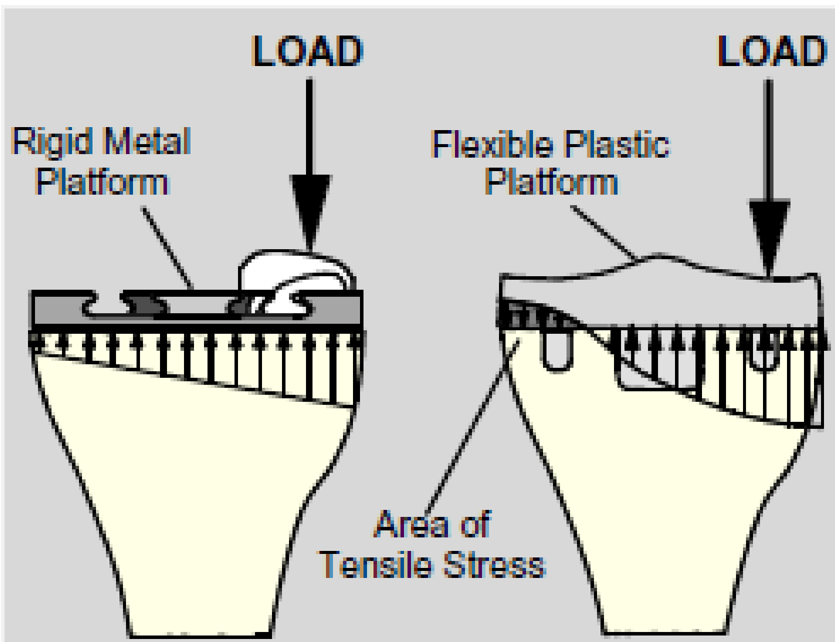
provided information to allow further development and refinement of the LCS, or Buechel - Pappas Mark II mobile bearing knee replacement:

- Metallic components made of wrought Ti alloy, coated with TiN ceramic
- Peak contact stress is about half of successful previous

Design of the B-P Knee Replacement (Buechel and Pappas)

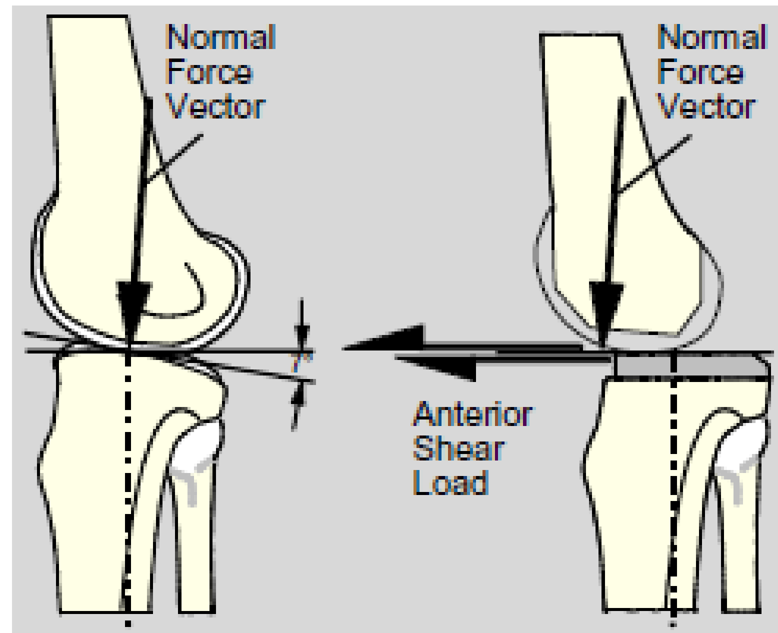
Tibial Components

a) Metallic Tray Reinforcement



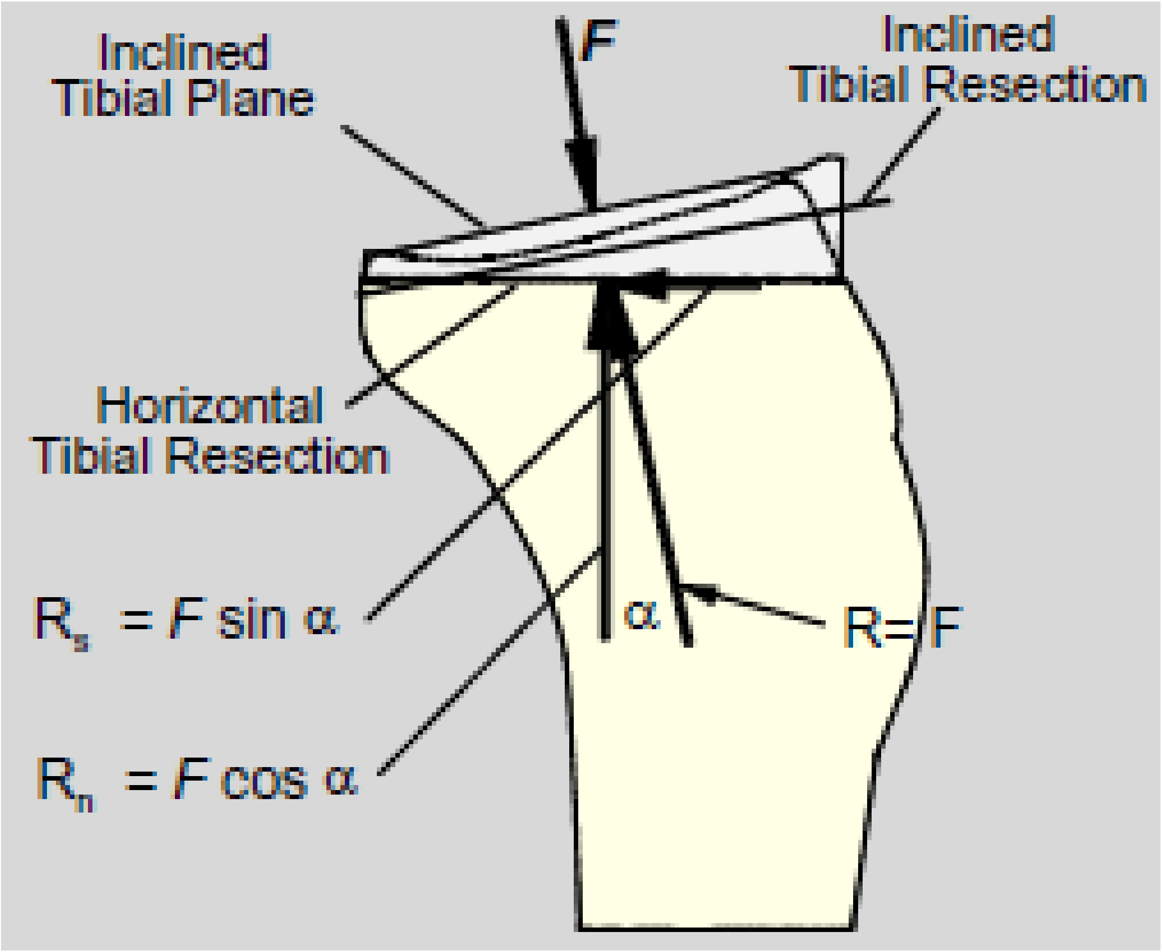
Reinforcing Effect of Metal Platform.

b) Effect of Tibial Plane Inclination



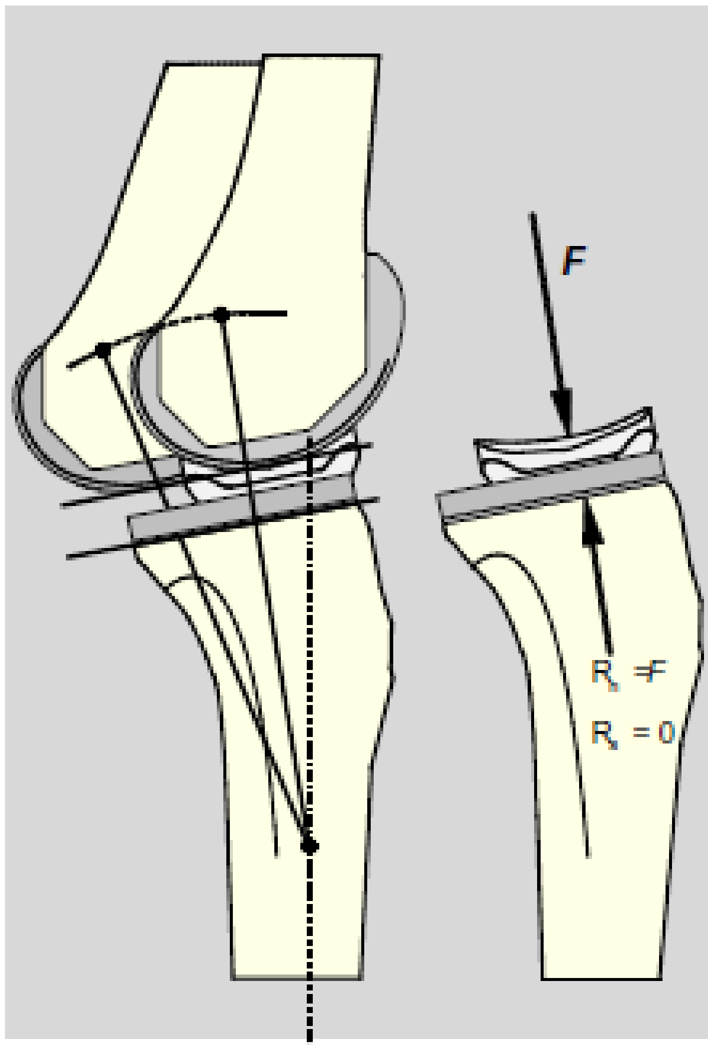
Added Joint Forces Resulting from Perpendicular Tibial Platform Placement

b) Effects of Tibial Plane Inclination

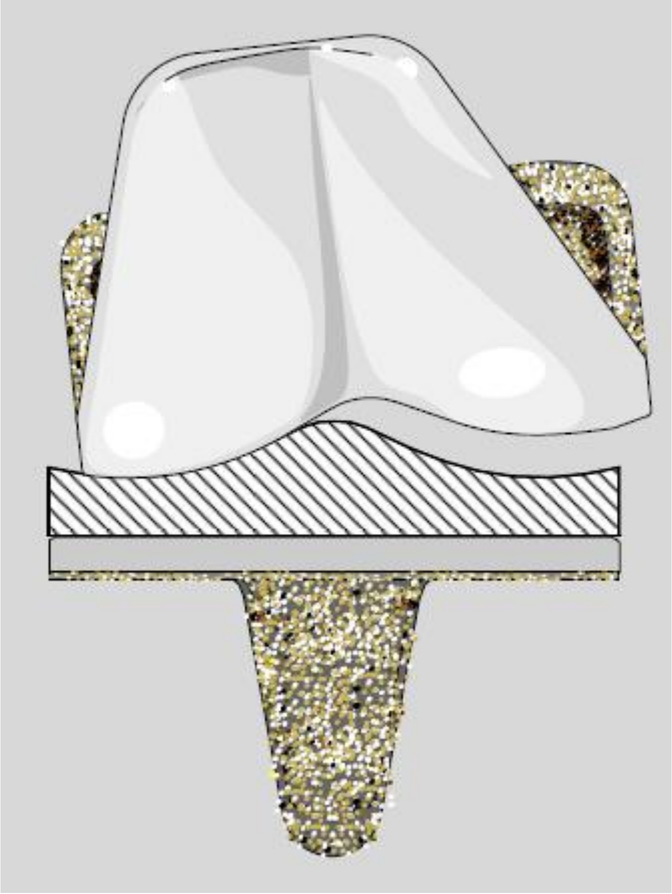


Interface Shear Resulting from a Perpendicular Resection

Elimination of A-P Shear and Uniform Prosthetic Gap Results from Use of Inclined Femoral and Tibial Resections.

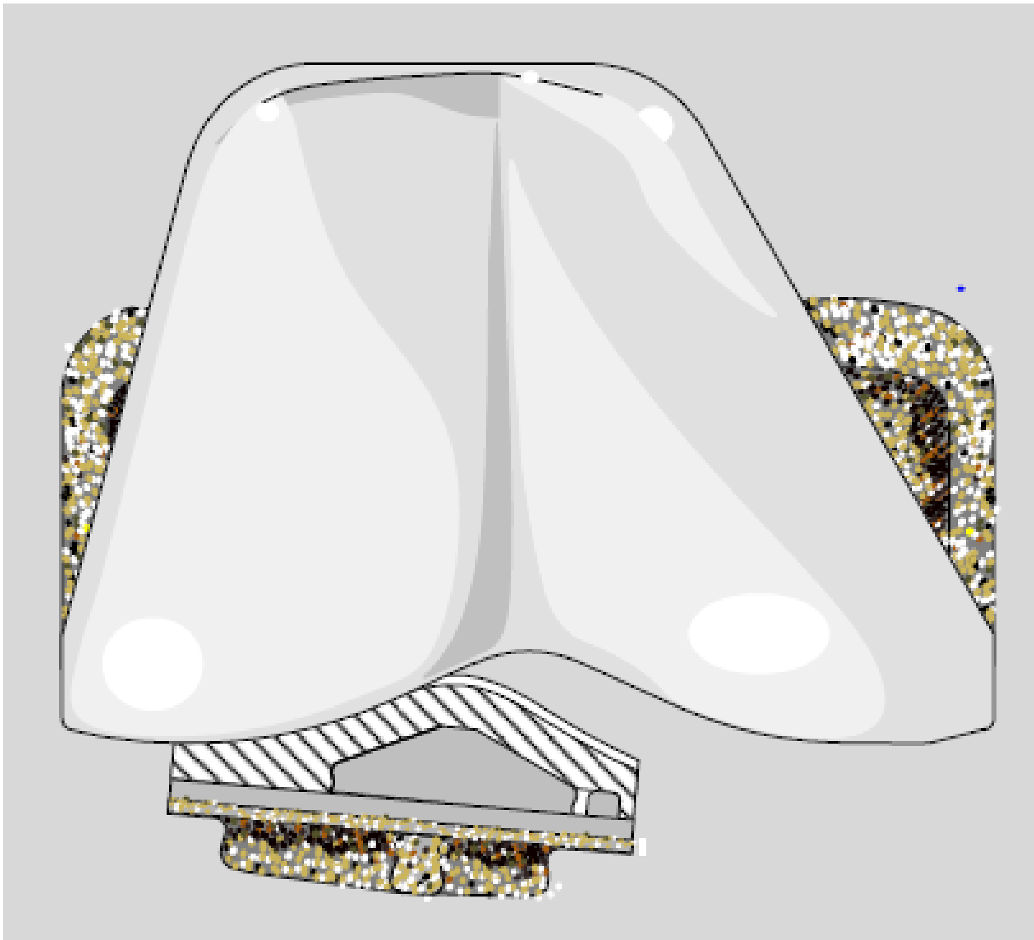


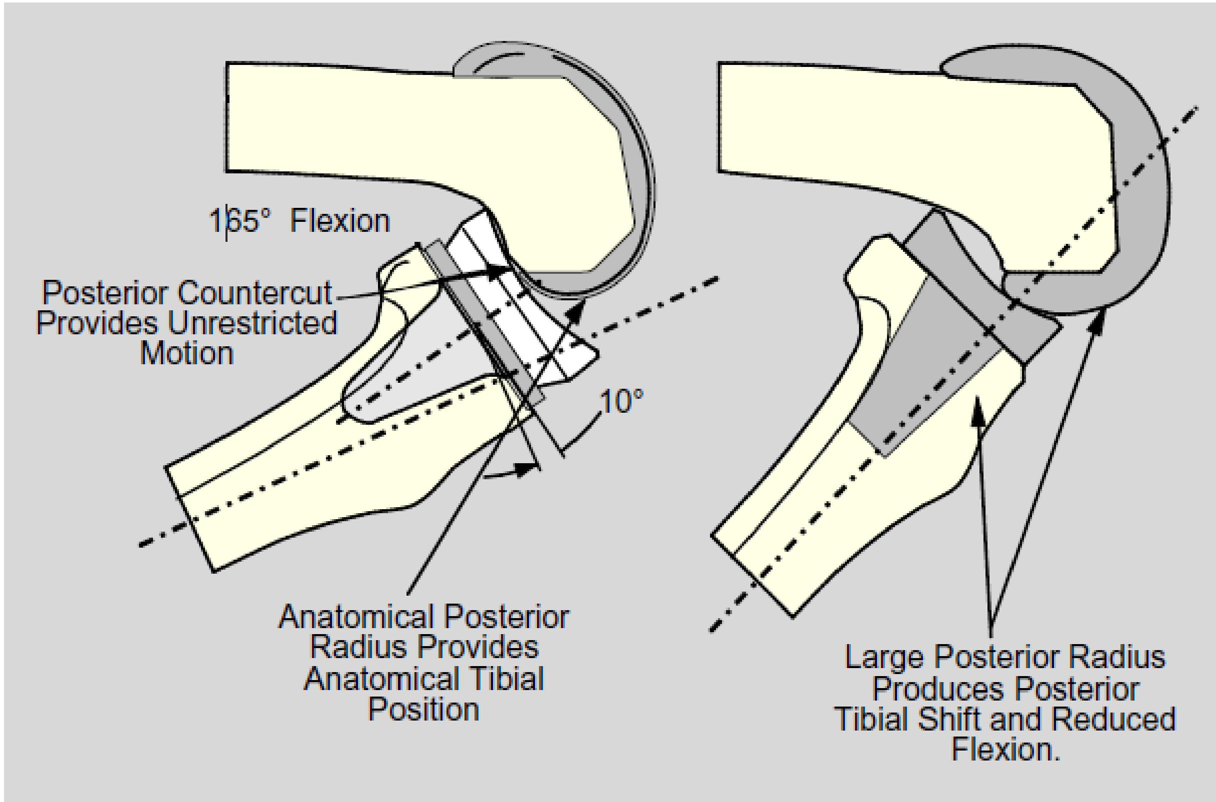
Femoral component



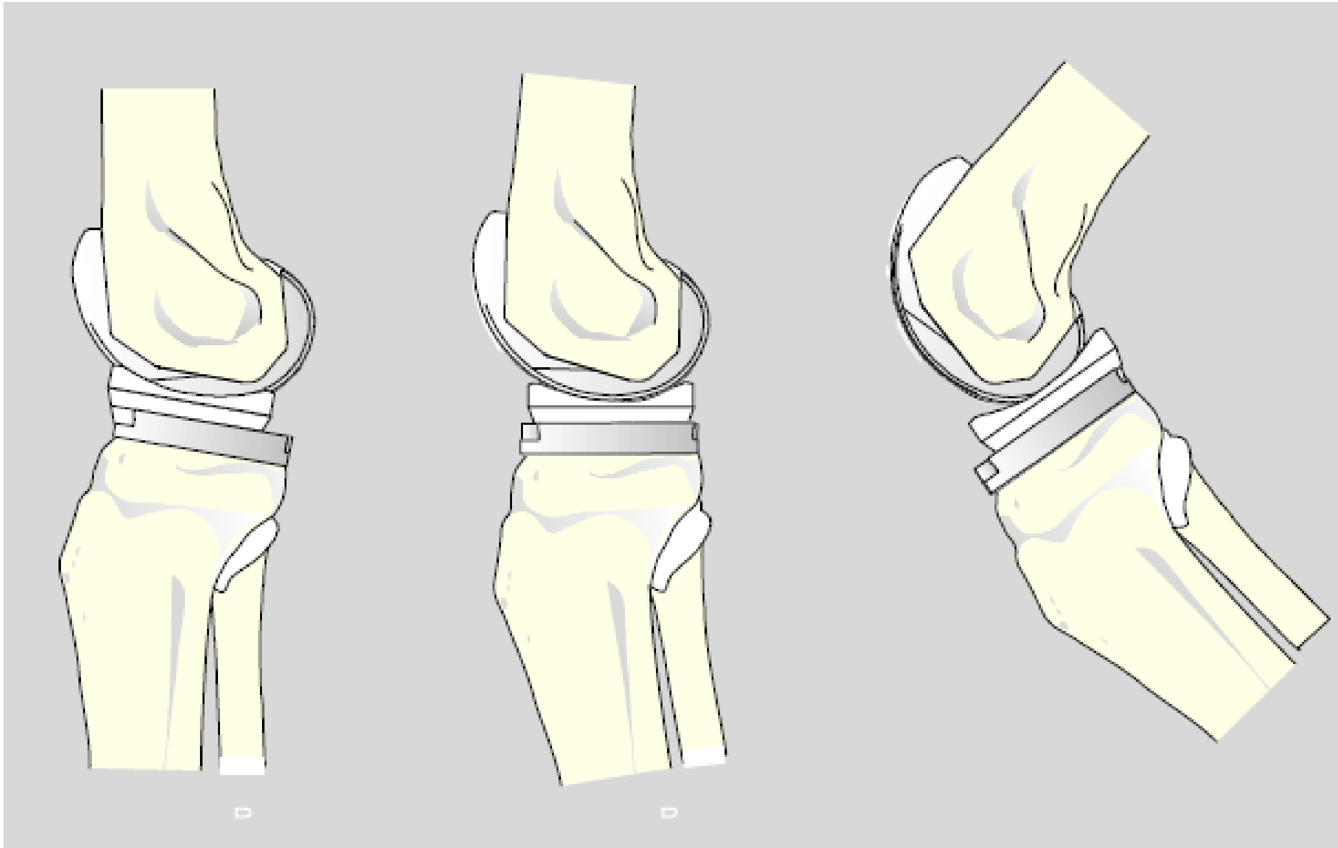
A reduced posterior radius of curvature for the femoral
Condyles enables Varus-Valgus Tilt without Loss of Congruent Contact.

Femoral component: Articular Surface –Patellar tilt without loss of contact



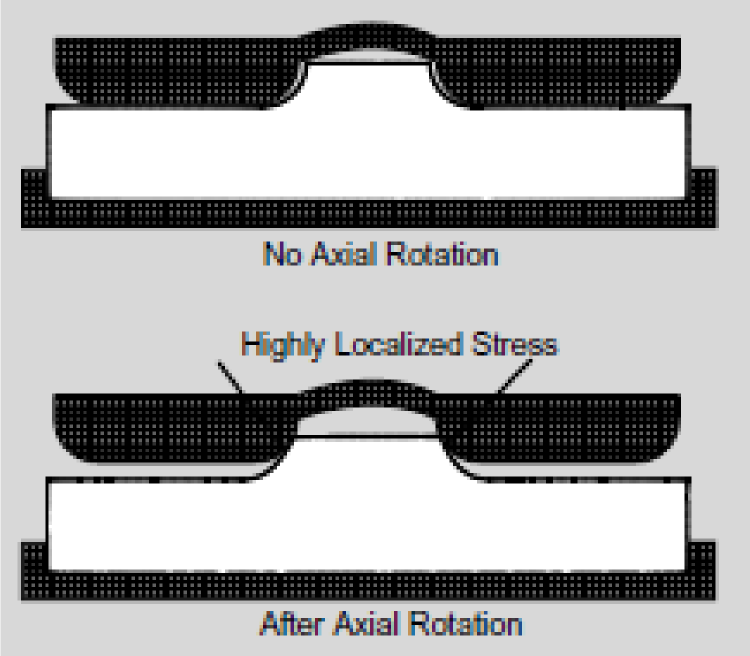


Added Flexion Resulting from Smaller Posterior Femoral Condylar Radius



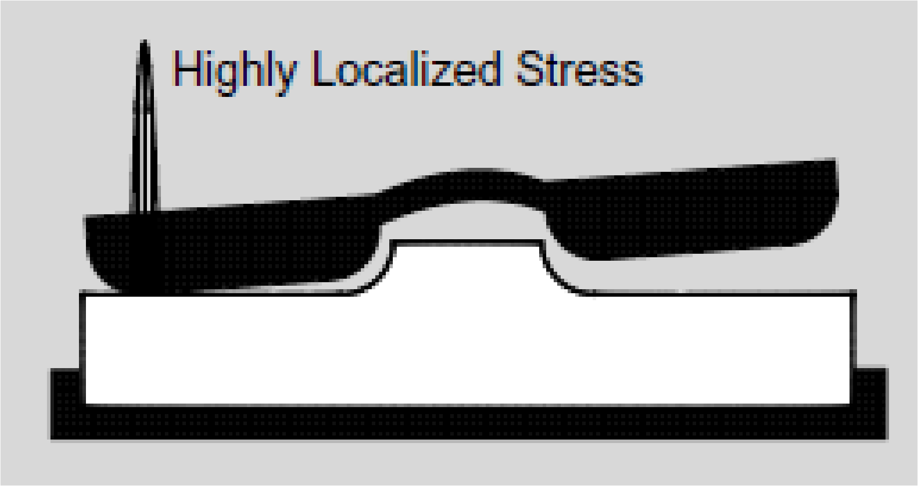
Roll Back Accommodated by Meniscal Bearing Motion

Provision for Adequate Axial Rotation



Increased Contact Stress During Axial Rotation

Provision for Abduction



Edge Loading During Abduction in Flat on Flat Design

The Future

Clinical experience and evaluation of the design concepts and materials currently employed in joint replacement devices will provide information needed to refine or abandon existing designs and to develop new ones.

The principal means for design improvement, probably will come from the development of new materials rather than new design concepts.

During the last quarter century, after the development of mobile bearing knees, there has been little improvement is knee joint replacement design. The Oxford knee is basically the same as it was a quarter century ago. The B-P design variants are only slightly improved in that time. Posterior stabilization seems unsound based on engineering principles and clinical experience.

The primary improvements have come from the introduction of ceramic coated titanium alloys and the possible improvement of UHMWPe.

Probably the greatest impact may come in surgical technique, rather than implant design. The application of computer technology to surgery has great potential in producing greatly improved prosthetic alignment, an important, if not critical, need for improved knee joint replacement performance.

Recent introduction of a “gender specific” femoral component