BEARING SURFACES

Metal versus polyethylene [UHMWPE] articulation was popularized by Charnley with excellent results since 1960. With more use of joint replacement in young active patients, it has been noted wear is an issue on long term follow up and this has led to development of alternative bearings.

TRIBOLOGY

Friction
Wear
Lubrication

JOINT FRICTION

Resistance to sliding motion is friction

If W=load; F Frictional force; u = coefficient of friction

Law of friction force [F] = u W

Ie., Friction is proportional to the load

It is independent of sliding speed

It is independent area of contact

Decreased by Lubrication by more than 10 folds than any best synthetic articulation

NORMAL FRICTION

Joint	0.005 to 0.025
Poly with Co-Cr, SS	0.05
Metal-metal	0.5

WEAR

Charnley Metal Vs poly wear
Wear 0.15 mm/yr.
Now 0.07 mm/yr

Wear = (K/H)FS

[K = wear coefficient; H = Material hardness ; F = Contact force ; S = Sliding distance]

Wear and the bearing surface

Cemented Hip:	Metal -poly	0.07 mm/yr
Uncemented Hip:	Poly-Metal	2 fold more wear
Metal on cross link		0.02 [3 fold less wear]
Ceramic- poly		0.02 [3 fold less wear]
Metal on Metal		0.001mm/yr
Ceramic on ceramic		0.001mm/yr

3 TYPES OF WEAR

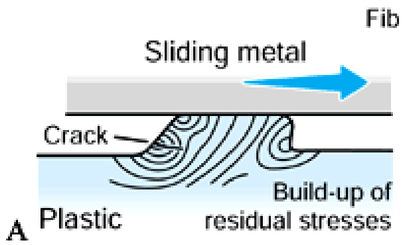
Abrasive wear [Commonest]
Adhesive wear
Third body wear
Delamination fatigue in TKA due to fatigue

A: Adhesive wear

Bonding of surface when they are pressed together under load

Material is pulled away from one to other surface

Usually from the weaker material by the harder material.

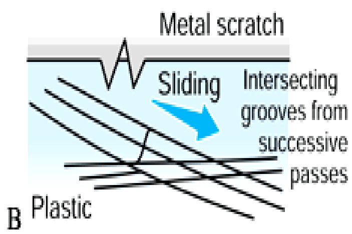


B: Abrasive wear

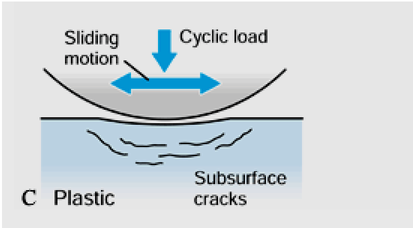
Rough surface slides over smooth leaving indentations

or grooves

Hard surface takes material from the soft [poly]



C: Delamination [Fatigue wear]

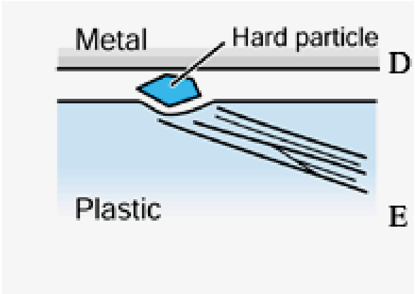


Subsurface stress concentrations

It is due to fatigue failure on repetitive cyclical loading.

Seen on non-conforming tibial trays

D: Three-body abrasive wear



Bone or cement particles between joint surfaces

Between joint surface can accelerate the wear

MODES OF WEAR FAILURE

Mode 1	Intended wears [adhesion and abrasive]
Mode II	The head wears through the poly and articulates with the metal shell
Mode III	Third body wear
Mode IV	Backside wear

Creep is a plastic deformation. Usually stabilises within a year

FACTORS FOR WEAR

A. CUP FACTORS

1. **Radiation treatment** Poly which is radiated without oxygen has better wear property.
2. **Type of poly:** Cross poly has better wear property than traditional poly
3. **Thickness of Poly** Hip should be more than 6 mm and in the knee more than 8mm

B. HEAD FACORS

1. Size of the head	Wear is optimal with size 28 mm of head Large head: increased volumetric wear Small head: increased linear wear

2. Bearing surfaces VS Poly

Poly against head	1. Ceramic	Best
	2. Chromium cobalt	Good
	3. Stainless steel	Fair
	4. Titanium head	Bad

C. STEM FACTORS

1. More wear with decreased stem offset
2. Good trunion means less wear
3. Cemented or not: Controversial

   Cementless cup been reported to wear 2 fold more than cemented.

PATIENT FACTORS

Young patients; Active patients mean more wear.

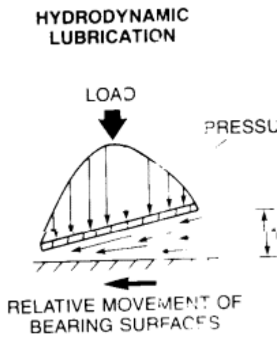
Wear debris less than 5 u can activate Macrophages. Activated macrophages releases mediators like IL-1, TNF -α and IL-6. These mediators stimulate osteoclastic resorption. This results in osteolysis.

LUBRICATION

1. FLUID FILM LUBRICATION

Involves a thin film of lubricant which increases the separation of the bearing surfaces.

Load on the bearing surfaces is supported by the pressure in the fluid film.



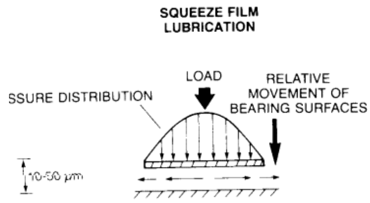
Two forms

Hydrodynamic lubrication

When rigid bearing surfaces which are not parallel

Squeeze film

Lubrication:Occurs when the bearing surfaces are moving perpendicularly towards each other. The viscosity of the fluid in the gap between the surfaces produces pressure which tends to force the lubricant out. This mechanism is capable of carrying high loads for short lengths of time. As the fluid is forced out, so the layer of fluid lubricant becomes thinner and the joint surfaces come into contact.



A number of different “lubrication” mechanisms known in engineering have been found to apply to human joints.

During a lightly loaded swing phase, synovial fluid is drawn in between the joint surfaces.

On applying a force at the start of stance, a fluid film is maintained by a squeeze film mechanism, whereby the large surface area and the viscosity of the fluid mean that leakage of the film occurs at a very low rate.

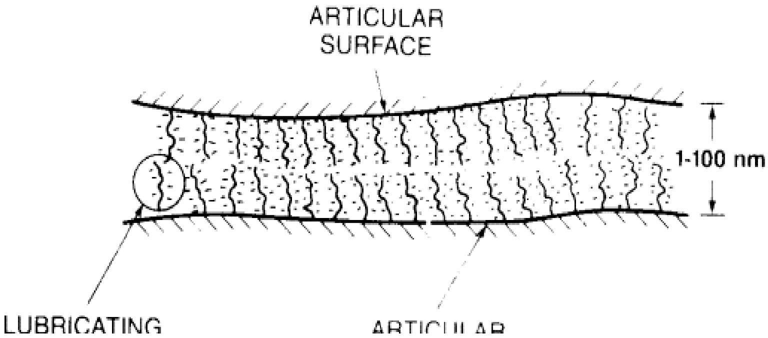
As movement begins, the film is further maintained or even enhanced by elastohydrodynamic lubrication, by which the area of contact is maintained due to the deformations of the bearing surfaces and fluid is pressurized as it is drawn into a thin converging wedge between the surfaces.

In addition, as the cartilage surfaces are deformed, fluid is exuded between the surfaces (this has been termed weeping lubrication and at the leading edge of the contact area. Fluid becomes trapped in small undulations in the cartilage surfaces, a mechanism called trapped pool lubrication and a higher concentration of hyaluronic acid can result in a more viscous layer of synovial fluid, by so-called boosted lubrication. The hyaluronic acid protein complex chemically binds to the cartilage surface so that even if sliding occurs when there is minimal film thickness**, boundary lubrication** is provided.

In metal-plastic artificial joints, fluid film lubrication mechanisms are ineffective because of the hardness of the materials and the limited surface areas, so that surface-to-surface rubbing takes place during sliding. At each step, it is estimated that millions of submicron-sized plastic particles are released into the joint. The effect of wear on particles and osteolysis of the bone around the interface, as well as the mechanical effects of the change in geometry, are major limiting factors in the durability of artificial joints.

Boundary lubrication.

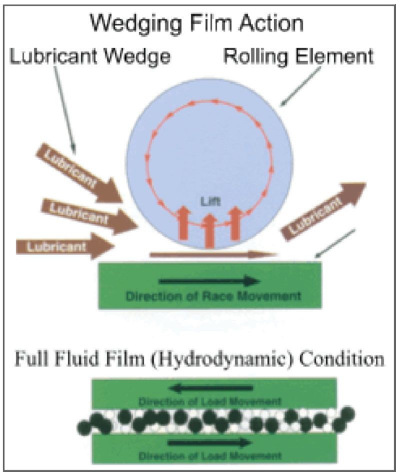
This involves adsorption of a single monolayer of lubricant on each surface.

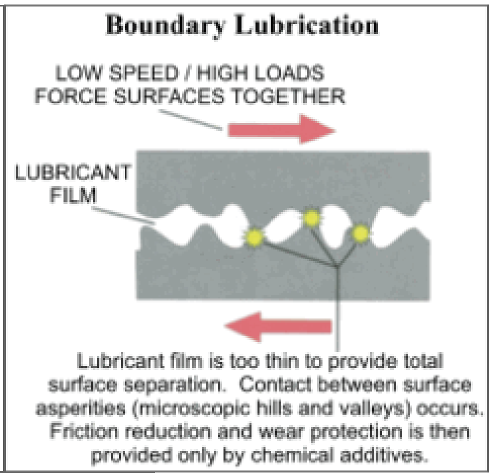


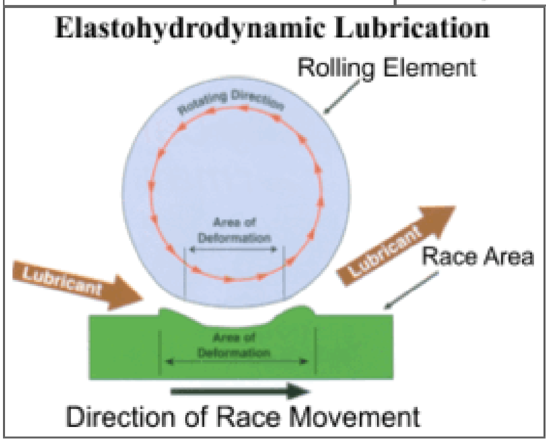
This type of lubrication prevents direct surface to surface contact at an articulation and therefore minimises wear of the articular surfaces.

Boundary lubrication is independent of the properties of the lubricating substance and the mechanical properties of the surfaces involved.

In synovial joints the glycoprotein, lubrican, which is found in synovial fluid is believed to be the adsorbed molecule. The thickness of this layer of adsorbed molecules is between 1 and 100 nanometres.


Wedging Film Action
Lubricant Wedge
Rolling Element
Lubricant
Lubricant
Lubricant
Lift
Lubricant
Direction of Race Movement
Full Fluid Film (Hydrodynamic) Condition
Direction of Load Movement
Direction of Load Movement


Boundary Lubrication
LOW SPEED / HIGH LOADS
FORCE SURFACES TOGETHER
LUBRICANT
FILM
Lubricant film is too thin to provide total surface separation. Contact between surface asperities (microscopic hills and valleys) occurs. Friction reduction and wear protection is then provided only by chemical additives.


Elastohydrodynamic Lubrication
Rolling Element
Rotating Direction
Area of Deformation
Lubricant
Lubricant
Race Area
Area of Deformation
Direction of Race Movement