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 \( W = \text{load} \); \( F \) Frictional force; \( u \) = coefficient of friction

Law of friction force \( F = uW \)

I.e., 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

<table>
<thead>
<tr>
<th>Joint</th>
<th>0.005 to 0.025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poly with Co-Cr, SS</td>
<td>0.05</td>
</tr>
<tr>
<td>Metal-metal</td>
<td>0.5</td>
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</tbody>
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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 FACTORS

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.
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.

![Image of boundary lubrication](image)

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

Direction of Race 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

Direction of Race Movement