13 Materials selection

13.1 What are the criteria for the selection of materials for a hip joint stem, head and cup?

(a) Stem and Head
There are many factors that come into play in deciding which material to use. The first and foremost criterion is biocompatibility. If a material is biocompatible, there will be no discoloration, irritation, infection or inflammation of the tissue in contact with the material. Eg: Ti-6Al-4V and Vitallium. Another criterion for material selection is the similarity of mechanical properties between bone and the material.
Another property to consider during material selection is corrosion resistance. The body fluid consists of an aerated and warm solution containing approximately 1 wt% NaCl in addition to other salts and organic compounds in relatively minor concentrations.

(b) Cup
The acetabulum cup usually consists of two types of materials. The base of the acetabulum is a metal, usually the same material as used in the femoral stem and head. This material is chosen with consideration to aniodic/cathodic corrosion with the femoral stem implant.
The other material needed in the acetabulum is usually ultra high molecular weight polyethylene (UHMWPE). The UHMWPE needs to have a very low coefficient of friction and a high resistance to wear. The UHMWPE must have a very low wear rate to avoid loss of material and to increase the life of the implant. The small particles from the loss of material could cause a reaction of the tissues.

13.2 Please explain how the process for the hip stem shaping is selected.

Generally processes of biocompatible materials machining involve **conventional machining operations** (turning, milling, drilling), forming operations (cold and hot forming, hydroforming, forging) and **alternative machining operations** (laser cutting, water-jet cutting, direct metal laser sintering, targeted metal deposition technology).
Implants are made in 3 basic ways:

(a) can be machine milled or drilled into a desired shape.

(b) can be cast, which means that the implant is formed from molten metal that is poured into a mold.

(c) can be forged, which means that the implant is shaped into its final form with the use of forces such as bending or hammering.

Development of hip implants is a multi-stage design and manufacturing process primarily based on computer aided design (CAD), computer simulations, machinability of certificated biomaterials, in-vitro biofunctionality and in-vivo tests.

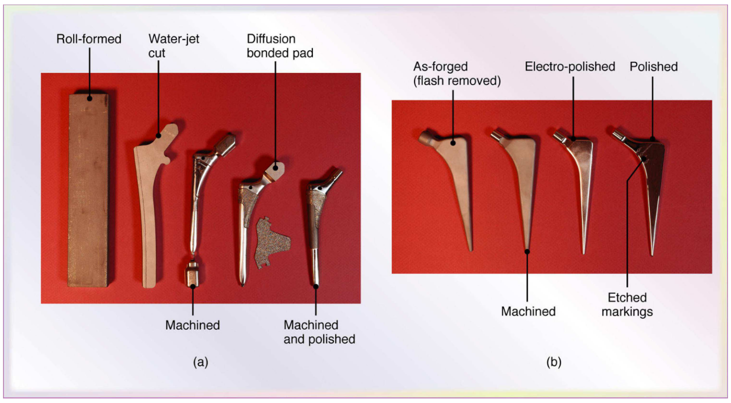

Figure 1: (a) Manufacturing steps in the production of a roll-formed and machined total hip replacement stem; (b) Manufacturing steps in the production of a forged stem. Hip stems can also be produced by investment casting, metal injection molding, insert injection molding, and assorted other processes. (Source: Courtesy of Zimmer)

13.3 Please explain how the shape of the hip stem can be optimized.

Shape of the the hip stem plays a crucial role in the initial stability and durability of the implant. The main considerations in the optimization of shape of the hip stem are:

(a) To avoid stem subsidence

(b) To minimize normal contact stress on bone-stem interface

(c) To minimize relative displacement

(d) To minimize stress-shielding effect

(e) To minimize stress-concentration

(f) Optimal load-transfer

Tips of hip stems are points (regions) of high stress concentration. The stiffness of the distal portion of the stem can be optimized reduce the high stress. The rotational stability of the stem is defined by the shape of the stem. Rectangular cross-sections and wedge designs offer excellent rotational and axial stability.