A HIP REPLACEMENT FOR A LIFETIME:
ALTERNATIVE BEARING SURFACES

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INTRODUCTION: TWO MECHANISMS OF HIP REPLACEMENT FAILURE

THE PROBLEM: THE TWO MODES OF FAILURE OF THE ARTIFICIAL HIP

Total hip replacement surgery (THR) has become a highly successful reconstructive surgical procedure. Many thousands of patients benefit from the procedure annually. Of the commonly replaced joints, the hip is perhaps the one that “feels the most normal”. Though in experienced centers the risk of surgical complications is low, problems do exist. One of the major problems now being addressed is the limited life span of an artificial hip. THR implants historically have failed by one of two mechanisms. These failure modes include 1) implant loosening from the bone and 2) wearing out of the polyethylene (plastic) cup.

PREVENTION OF IMPLANT (CEMENT) LOOSENING

In early days of hip replacement surgery all implants were cemented. Cement fixation typically would last 10 to 15 years (less in a younger more active patient). Implant fixation failure would then gradually occur as the cement began to crack and loosen. Over time the problem of cement loosening has largely been eliminated by the development of cementless implants. Cementless implant fixation has now become safe and effective for use in most hips thus largely eliminating the problem of late implant loosening. In certain clinical situations such as in the very elderly or in patients with extreme osteoporosis cementing may still be the optimal fixation option.

PREVENTION OF POLYETHYLENE WEAR

Historically the artificial hip has consisted of a cobalt-chrome metal ball (titanium is not used as it scratches when used as an articulating surface) articulating with a high density polyethylene (plastic) socket. The problem with this metal on plastic articulation has been that the metal ball is harder than the plastic socket causing the plastic to gradually “wear away”. The result is that small plastic wear particles are released into the joint. Often these plastic particles set up an inflammatory reaction causing cysts to develop in the bone and contribute to loosening of the implants. This cascade of events typically would occur over 10 to 15 years but were observed to occur at an accelerated pace and over a shorter time period in younger more active patients. Thus the search was on to eliminate the plastic and develop a new more wear resistant articulating surface.

Recently advances have produced three new alternatives to the conventional metal ball on plastic cup articulation. These include 1) a new “cross-linked” plastic that is more resistant to wear 2) the use of a ceramic on ceramic ball and socket articulation 3) the use of a highly polished metal on metal ball and socket articulation. Each of these alternatives has certain advantages and disadvantages.

Figure 1. Metal on polyethylene articular bearing surface. It consists of a metal ball articulating with the polyethylene (plastic) cup which itself is fixed into a metal shell.

NEW ALTERNATIVE BEARING OPTIONS

OPTION 1: CROSSLINKED POLYETHYLENE - THE NEW PLASTIC

Recent research has demonstrated that by chemically altering the polyethylene "plastic" liner of the cup it can be made stronger so as to better resist the typical wear patterns to which it is exposed. The most common method of achieving this change is to expose the poly to a low dose of radiation. The irradiation of the plastic increases the bonding, called cross-linking, between polyethylene molecules. Data thus far confirms that this new "cross-linked" poly wears much more slowly than that of previous generations.

Advantages of the new cross-linked polyethylene include its relatively low cost (little more than conventional polyethylene), ease in manufacturing, and surgeon familiarity with successfully using the design.

Disadvantages include the fact that there is no long term data yet available confirming the theoretical increased longevity of this new form of polyethylene. Cross-linking is a relatively new technology that thus far has only been proved in the laboratory setting (clinical studies are currently underway and results thus far are encouraging). And, though wear theoretically is diminished by the use of cross-linked poly, it is not eliminated. Wear and polyethylene particle debris generation still does occur, just at a slower rate.

OPTION 2: CERAMIC ON CERAMIC BEARING SURFACE

In an effort to eliminate the wear problems of polyethylene entirely, research has been directed at the use of other alternatives. One of these has been in the use of ceramics. Ceramics have been utilized in hip replacement surgery for decades in Europe. Early implants failed not because of the use of ceramic in their composition, but instead due to poor implant design. Research has now produced improved ceramic on ceramic hip replacement designs that have just recently been approved by the FDA for use in this country.

Ceramic's prime advantage includes its minimal wear characteristics and the human body's excellent tolerance and low reactivity to it. In other words, ceramics do not wear appreciably and the human body tolerates them well.

Disadvantages exist, however. Ceramics are a form of glass and are somewhat brittle. If improperly designed, manufactured, or handled there is risk of the ceramic implant breaking. There is theoretic concern that as years pass, fracture of the ceramic implant might become an increasingly common problem. Revising a fractured ceramic implant is difficult due to the presence of many tiny "glass" fragments. And ceramic failures cannot be revised to another ceramic implant. Any revision requires a return to a metal on poly articulation.

A second major disadvantage in the use of ceramics is that due to current implant design constraints concerning femoral head size and socket depth, ceramic hip replacements will not be as stable as other alternatives. Thus there will a greater risk of hip dislocation after surgery. This is a significant drawback to the routine use of a ceramic on ceramic hip implant.

Figure 2. Ceramic on ceramic articular bearing surface. The ceramic femoral head articulates with the ceramic liner of the cup. The ceramic cup liner fits tightly into the metal shell of the cup.

OPTION 3: METAL ON METAL BEARING SURFACE

Another alternative to the traditional metal on polyethylene articular bearing surface is that of the metal on metal hip. This construct entails use of a highly polished metal ball articulating with a similarly polished metal socket. As previously noted, cobalt-chrome is the metal alloy utilized as titanium is not sufficiently scratch resistant. As with ceramics, the metal on metal design has been in use for decades in Europe. And as with ceramics, early failures were related to poor implant designs and not to the metal on metal bearing surface. Similar to the status of ceramic implants, the FDA has only recently released new improved metal on metal designs for implantation in this country.

Advantages of the metal on metal articulation over the other alternatives are several. Most importantly is the fact that almost no wear occurs. Of all alternatives, metal on metal is clearly the most durable. The issue of potential implant fracture that is of concern with the use of ceramics is non existent with the use of metal on metal implant designs.

Secondly, there are fewer design constraints with metal on metal hips as opposed to that found with ceramics designs. As a result, in metal on metal designs the femoral head (ball) can be made much larger and the socket thinner than with ceramics. The importance of the issue of head size is in its relationship to hip stability. The larger the diameter of the femoral head the more stable the hip and the less the risk of hip dislocation. Thus because of the larger femoral head size of the metal on metal designs (potentially almost twice as large as with ceramic implants) the THR can be made much more stable with less risk of dislocation.

The major disadvantage in the use of metal on metal hip articulations is the generation of metal ions that occur due to the friction of the metal head rotating in the metal socket. These metal ions are picked up by the hip's blood supply and carried throughout the body by the red blood cells. The ions are then excreted via the kidneys. Epidemiologic studies have looked exhaustively at several decades of data from European patients who have undergone metal on metal hip replacements and at newer data generated in clinical tests performed in this country over the last several years. No adverse health affects due to the presence of the circulating metal ions has been discovered. The risk of several specific health issues were examined in depth and not found to occur at any increased frequency. This included no statistical increased risk of any type of cancer (including leukemia, lymphoma and other cancers of the blood cell producing bone marrow) or kidney damage. Nor was any increased risk of neurologic disorders such as Alzheimer's discovered. At this point there has been no data to suggest that patients with a metal on metal hip articulation are at any increased risk of these or any other health conditions. Thus the FDA has determined that metal on metal hip designs are safe and have approved them for use.

Figure 3. Metal on metal articular bearing surface. Note that the large femoral head is nearly as great in diameter as that of the normal bony hip. This large diameter increases hip stability reducing the risk of dislocation. A typical ceramic head is just over half this size.

CONCLUSION: WHAT IS THE BEST HIP REPLACEMENT

CURRENT ALTERNAIVES

At this time there is no universal consensus among experts as to the best articular bearing surface for routine use. The four alternatives of 1) conventional metal ball on polyethylene cup articulation 2) metal head on the new cross-linked polyethylene cup 3) ceramic on ceramic articulation and 4) metal on metal each have drawbacks. With conventional polyethylene, wear over time is a certainty. With new cross-linked polyethylene wear appears to be slowed, but still present. In addition cross-linked polyethylene is new to clinical use and the apparent advantages over the previous polyethylene generation have yet to be clinically proved. Ceramics, while exhibiting almost no wear and being very well tolerated by the human body, are brittle and there is concern regarding the theoretical risk of implant fracture. In addition due to implant design constraints there is a greater risk of hip dislocation with use of ceramic on ceramic implants. Metal on metal articulations appear to solve the problems of the above alternatives. However the metal ions that are generated by these implants have created concerns regarding the potential for the development of secondary health problems. Despite extensive research no associated adverse health affects have been discovered to date due to the presence of these metal ions.

Trying to sort out for the individual patient which alternative is best is difficult. For patients over 70 to 75 years of age perhaps the safest alternative is the use of a metal on conventional polyethylene bearing surface due to its long successful tract record. Slightly younger patients nearer the 65 year old age range may be candidates for use of the new cross-linked poly. Healthy patients under 65 years of age and most patients under the age of 60 may be candidates for metal on metal systems.

THE FUTURE OF HIP REPLACEMENT BEARING SURFACES

Clearly the “perfect” hip has yet to be developed. Research is ongoing into newer still alternatives. Some work is being done on a ceramic femoral head articulation with an all metal cup. Problems of joint stability might remain a problem with these implants. And the risk of ceramic fracture also would still be present. Another avenue of research is examining the potential use of a diamond on diamond bearing surface which could possibly solve all of the various problems of current bearing surface alternatives. As the medical economic situation tightens this alternative may well be cost prohibitive. Suffice it to say that with the baby boom generation aging and the need for hip replacement surgery increasing, social and economic forces will continue to drive research efforts to improve the implant bearing surface into an ever more durable construct. And in the upcoming years if further follow up reveals that metal on metal bearing hip replacements are indeed as safe as is currently believed and the metal ions are a non issue as is suggested by current data, we may already have “the hip replacement for a lifetime”.