ABSTRACT

SOUTH AFRICAN EXPERIENCE WITH CROSS- LINKED ULTRAHIGH MOLECULAR WEIGHT POLYETHYLENE IN TOTAL HIP ARTHROPLASTY

Student: **Josip Nenad Cakic**

Supervisor: **Prof. B. Sweet**

Co-Supervisor: **Prof. C.M. Schnitzler**

Department: **Department of Orthopedic Surgery**

Faculty of Medical Sciences

University of the Witwatersrand

Degree: **Doctor of Philosophy , PhD**

Keywords: **ultra-high molecular weight polyethylene**

total hip replacement

cross-linking

Total hip replacement (THR) is an effective method of treatment for patients with hip disability. The procedure is capable of providing long-term functional improvement with excellent control of pain and restoration of function. Sir J Charnley developed a concept of low friction arthroplasty, which was based on use of ultra-high molecular weight polyethylene acetabular and stainless steel femoral components. The components were attached to bone with the use of polymethylmethacrylate (PMMA) bone cement. This concept has been very successful, and is considered the gold standard of THR.

Aseptic loosening of the prosthetic components remains the single most important reason for failure of THRs. Wear to the ultra high molecular weight polyethylene (UHMWPE) acetabular cup is a well-known cause of osteolysis and aseptic loosening of the components. Thus, substantial improvement to the wear resistance of UHMWPE could extend the clinical life span of total hip replacements. In an attempt to reduce polyethylene wear and subsequent osteolysis, a method was developed in the early seventies in South Africa to improve polyethylene quality by means of gamma ray cross-linking. The acetabular cup was irradiated with 100 Kilogray in an acetylene environment, which was used as a cross-linking gas material, resulting in improvement of UHMWPE wear resistance.

Influenced by the world trend and with the advent of a ceramic bearing surface, the Project of cross-linking was, to a certain extent, forgotten. Patients followed up in the late 1990s, showed minimal or total absence of wear after 15 years or longer.

Based on my preliminary studies, and anticipating the world trend of acceptance of cross- link UHMWPE, the aim of this research is to consolidate the results from the largest long term group of patients with acetylene cross-link UHMWPE, to study polyethylene gamma irradiated in the presence of a cross-linking acetiylene gas and the effects of it, in vitro, using a hip simulator. I was planning to communicate with as many patients as possible from the group operated on from 1977 until 1983 in whom cross-link UHMWPE was used. This group of over thousand patients represents the largest group of patients with cross-linked UHMWPE acetabular components in the world, with the longest clinical follow up of over 20 years on average.

The first part of the research is a retrospective study:
The goal was to contact as many patients as possible who were operated on during the period 1977 to 1983 when cross-linked polyethylene was used. To qualified for the study each patient had to have an early postoperative and the latest follow up radiograph.

The radiological study consisted of the radiological measurement of wear. For this purpose the Hip Analysis Suite program was used. This is a software program designed by Dr John M. Martell from the University of Chicago, which is widely used and internationally accepted for
that purpose. Image analysis offers significant improvements in reproducibility and accuracy when compared to manual analysis.

The final results were compared with results of polyethylene wear in patients in whom conventional UHMWPE was used. For this comparison only patients with acetabular components made from the same UHMWPE material and from the same supplier were used. The conventional UHMWPE is a component of the gold standard of hip replacement surgery. World-wide published follow up studies of 15 years and longer using conventional UHMWPE were compared to the cross-link UHMWPE group.

If revision surgery was indicated for whatever reason in patients in with cross-linked UHMWPE acetabular components, the retrieved prosthesis was analyzed. The analysis consisted of examination of the articular surface of the cross-linked acetabular component for micro wear phenomena using a Scanning Electron Microscope (SEM). In order to perform an objective analysis of the retrieved components, two independent laboratories were used, namely:
Peterson Tribology Laboratory, Loma Linda University, California, and
Biomechanical Laboratory, Faculty of Engineering, University of Pretoria.

The analyses were possible thanks to collaboration with Dr Ian Clark from Peterson Tribology Laboratory and Dr NDL Burger in charge of the Biomechanical Laboratory at the Department of Engineering, University of Pretoria.

Concurrent with retrospective radiological analysis and SEM analysis of the retrievals, a prospective study of the new chemically cross-linked cups was also performed.

In the majority of patients with total hip replacement, walking is the activity that contributes most to wear. An average person takes around 5000 steps per day, which extrapolates to 1.8 million steps per year for a lower extremity, or 0.9 million steps per hip joint. The hip simulator was used to simulate the average annual cycles of walking, where one million cycles will correspond to one year of normal average walking per hip joint.

In hip joint simulation, appropriate load was used at constant value to simulate average body weight. Similarly, for objectivity and independency, part of the analysis was performed under the supervision of Dr Stephen Li in the Tribology Laboratory, Sarasota, Florida. By using independent Institutions I hoped to achieve the highest possible level of expertise and objectivity.

The contribution of South Africa to the method of cross-linking is important. This is a cheap and effective way to improve the quality of the polyethylene with minimal increase in the cost of the final implant. I believe that the South African method has proved itself to transform UHMWPE into a material with a highly acceptable level of reliability, and it is important to scientifically consolidate the available data for access to everyone.