TEMPOROMANDIBULAR JOINT ARTHROPLASTY:
USING METAL-ON-METAL AND ACRYLIC-ON-METAL CONFIGURATIONS

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ABSTRACT
In the long-term performance of the temporomandibular joint (TMJ) implant, wear and durability must be considered. Thus retrieved and laboratory test implants were examined both optically and in a scanning electron microscope (SEM). In laboratory testing, the volumetric wear of metal-on-metal was about an order of magnitude less than that of metal-on-acrylic TMJ implants. This metal-on-metal wear was also about 1/60 of that reported in the literature for a laboratory test of (UHMWPE) polyethylene-on-metal TMJ implants. The retrieved TMJ implants showed some abrasive wear occurred during multi-directional articulation with smaller wear zones for the metal-on-metal compared to the metal-on-acrylic configuration. Further efforts to characterize and minimize wear were recommended as prudent in the continuing development of TMJ arthroplasty.

In TMJ laboratory wear testing, the protocol for mass loss measurements must be improved to yield realistic and repeatable mass loss values. In laboratory wear testing, multi-directional motion must be imposed in the surface articulations.

Further examination of retrieved TMJ implants is required, particularly in-situ for more than 10 years. The retrieval process should include study of tissue samples collected from surrounding tissues so that both the wear particles and the response to wear particles can be studied. New approaches in design and materials should be explored to further reduce wear.

INTRODUCTION
The metal-on-metal temporomandibular joint (TMJ) implant is not a new concept to the oral and maxillofacial surgeon. In the early 1970’s, Kiehn et al reported on the clinical use of a Christensen Fossa-Eminence component mated with a Cargill-Hahn condyle component. Both of these were made of cast cobalt-chromium-molybdenum (Co-Cr-Mo) metal alloy (Vitallium®). They reported a short-term follow-up of 27 cases, which were rated as successful through reduction of pain and increase in the range of motion and jaw opening. \(^1\)

The acrylic-on-metal TMJ implant also has a long history of application in oral and maxillofacial surgery. \(^2\) In addition, acrylic (PMMA or polymethylmethacrylate) was used for the articular surface of a femoral head implant for hip hemiarthroplasty by Judet and Judet in the early 1950’s. \(^4\) Mechanical failure of the Judet hip prosthesis forced discontinuance of the device after a decade of use. \(^5\) For acrylic-on-metal TMJ implants, the relevant issues in long term performance are the wear and tissue response to wear particles.

Other polymeric materials have been used for TMJ implants with very poor results. Oral maxillofacial surgeons are familiar with the pain, foreign body reaction, and bone loss caused by particles generated from Proplast-Teflon and Silastic materials that were used in TMJ implants. \(^6\)

The purpose of the present study is to examine the wear of both metal-on-metal and acrylic-on-metal Christensen TMJ implants. This study includes the comparison of retrieval implants (up to 11 years) with laboratory wear test implants. The assessment includes the measurement of changes in the macrogeometry with a three dimensional profiling system and the examination of the microgeometry with a SEM. The focus of the present study is to begin to characterize wear behavior of these two implant systems and thus, eventually evaluate the risk of clinical complications associated with wear particle release into surrounding tissues. The aim of the overall development program is to provide a well-engineered TMJ implant system with minimal risk of either short or long-term complications.

NOMENCLATURE
The average wear of Co-Cr-Mo metal-on-metal TMJ implants in laboratory tests for 2 million cycles was 0.197 mm\(^3\)/ million cycles. When compared with wear in laboratory testing of other TMJ implants with different material combinations, the metal-on-metal had the lowest wear.

The average wear of acrylic-on-metal TMJ implants in laboratory tests for 2 million cycles in a simulator apparatus was 1.64 mm\(^3\)/ million cycles. (Approximately 8 times metal-on-metal) This was almost exclusively on acrylic condylar heads.

Examination of the wear tested acrylic and metal components optically and in the SEM showed single wear zones with parallel surface scratches oriented in the uniaxial direction of motion imposed by the wear test apparatus. These scratches seemed deeper and more numerous on the metal-on-metal implant surfaces. In both implant types, the mechanism of wear appeared to be abrasion with additional “third body” abrasion by carbides detached from the metal surfaces.

Examination of retrieved metal-on-metal TMJ implants, optically and in the SEM, showed evidence of abrasive wear, in particular “third body” abrasion by detached surface carbides. Two wear zones and random oriented scratches were on each.

Upon optical and SEM examination of retrieved acrylic-on-metal TMJ implants, there was almost zero wear of the metal fossa component. There was a single large saddle-shaped wear zone on the acrylic condylar head, with randomly oriented scratches. Evidence was found for abrasive wear with additional “third body” abrasion caused by carbides detached.
from the metal fossa surface. The randomly oriented surface scratches of the retrieved implants indicated that multidirectional motion occurs in the articulation of TMJ implants in vivo.

The laboratory wear test apparatus did not represent all of the features of the TMJ implants in vivo with regards to the kinematic detail and contact mechanics, but the results could still provide useful information on TMJ implant performance. For example, the abrasive wear occurring in both material combinations and the amount of wear in the metal-on-metal TMJ implants was comparable to that reported for laboratory testing of metal-on-metal hip implants in the orthopedic literature. Furthermore, the lowest wear in laboratory testing occurred for the metal-on-metal implants, compared with the acrylic-on-metal or polyethylene-on-metal implants. The same ranking of wear performance is expected to occur in vivo.

Use of metal-on-metal as an articulating surface for load bearing joints has been criticized in the literature. It was stated that a metal-on-metal combination of materials would produce “galling” and lead to catastrophic failures. While galling may occur in some softer metal materials, such as the stainless steel or titanium alloys, harder cobalt-based alloys are known to be very wear resistant materials in their industrial applications.

It is true that the wear test in this study produced a rough, dull surface with parallel scratches over the wear zone due to uniaxial reciprocating motion. However, the surface profile measurements indicated low material loss occurred – leading one to believe that minimal wear debris was produced. The retrieval implants exhibited a “smooth and shiny” wear zone surface to the naked eye, much different in appearance from the laboratory wear test surfaces. The multi-directional motions of the mating Co-Cr-Mo components in vivo, along with an abrasive slurry of small carbides, must be the mechanism to produce these “lapped and highly polished” wear zone surfaces.

The wear was not sufficient to suggest any risk of device failures in either the laboratory tested or the retrieved implants. Thus, the statements predicting catastrophic failure of metal-on-metal implants, made of Co-Cr-Mo, are not justified.

Retrieved and laboratory tested acrylic-on-metal implants have shown higher wear than metal-on-metal implants in both the laboratory wear tests and implant retrievals. Although a correspondingly larger volume of acrylic wear in particulate form is generated in vivo, no report of deleterious foreign body reaction in surrounding tissue has been found in the oral maxillofacial literature. Some long-term retrievals (20 to 40 years) of orthopedic Judet hip implants showed high acrylic wear, yet no significant adverse tissue reaction.

Wear particle-induced osteolysis is a new issue that must be considered in the development of implants for load bearing joints. Osteolysis development is dependent upon (1) volume of particles accumulated, (2) particle size and shape, and (3) the threshold levels of particles that surrounding tissues, within an individual patient, can tolerate. The influence of these factors on osteolysis involving cell phagocytosis of particles through the release of tissue destructive biological substances, is the focus of current implant research. New designs are being explored to reduce the volume of particles.

This research includes improving the material composition and manufacturing methods of the Co-Cr-Mo alloys to reduce wear. Research centers have looked at various heat treatments, the alloy composition in the generation of microstructure carbides, and the “sliding contact” microstructure deformation processes with twinning and stacking fault energies, as an explanation for the superior wear resistance of Co-Cr-Mo.

New methods of decreasing wear, such as coating Co-Cr-Mo with various diamond-like carbon (DLC) coatings, have demonstrated improved wear resistance with effective corrosion resistance and biocompatibility. Adhesion of the coating to the substrate is critical and is in on-going research.

Both laboratory testing and retrieval analysis of the metal-on-metal Christensen TMJ System show that the use of these implants for combating temporomandibular joint disease is a viable option for the oral and maxillofacial surgeon.

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REFERENCES