Osteochondral Replacement Therapy with Synthetic Plugs is Ineffective at **Repairing Cartilage Injuries**

Neal Mugve, Robert Erck, PhD, **Steven C. Chudik, MD**

OTRF, Hinsdale Orthopaedic Associates, Loyola University Chicago Stritch School of Medicine, Argonne National Laboratory, Energy Systems Division

Introduction

The search to find an ideal replacement therapy for articular cartilage remains a challenge to medical researchers. Following injury, the cartilage surface continues to wear, ultimately leading to functional limitations, pain, and possibly arthritis. While significant advances have been made in replacement therapy, current methods still fail to completely or consistently restore normal articular cartilage function. As a result, research to develop a therapy that mimics normal biological articular cartilage function is essential if we hope to prevent joint problems after cartilage damage.

Articular cartilage is unique in that it maintains an incredibly low coefficient of friction against cartilage countersurfaces, which occurs in healthy articular joints. When injury or damage occurs, this natural system is upset such that further wear and damage ultimately occurs within the joint. Our study focuses on the use of novel, synthetic plugs to replace these cartilage defects. We believe that if we are able to maintain a relatively low coefficient of friction using transplantable synthetic materials, then these plugs could serve as a sustainable long-term option for damaged articular cartilage replacement. Using preliminary studies and protocols developed to measure cartilage damage and wear, we can study the effect of osteochondral transplantation with commonly used synthetic materials against healthy, native cartilage.

Objectives

The objective of our study was to compare different synthetic materials in a cartilage repair model to see which one exhibited the most ideal tribological properties and minimized wear of the opposing native cartilage surface. We also wanted to elucidate mechanisms (i.e. shearing and sliding forces) responsible for articular cartilage wear against these materials in order to develop optimal repair strategies and wear prevention.

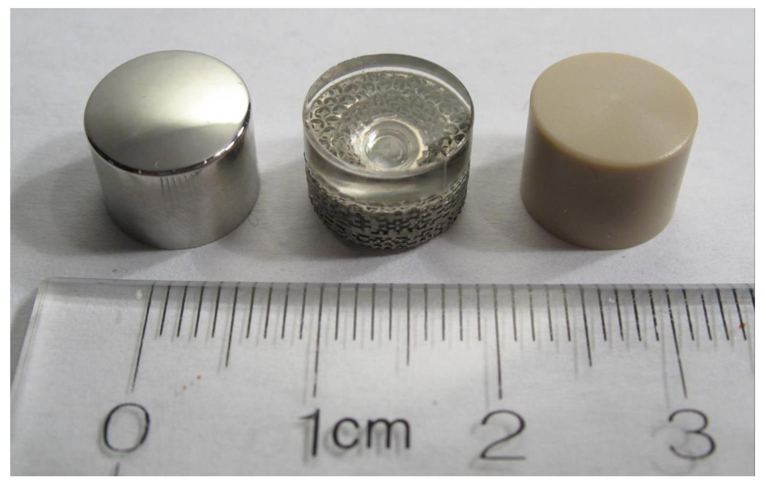
Methods

Three synthetic materials, polyurethane, cobalt chrome, and PEEK, were evaluated. Plugs of the artificial material 1 cm diameter by 1 cm deep were implanted into bovine medial femoral condyles. The corresponding medial tibial plateau cartilage was used as the countersurface. Contact pressure between the two surfaces was measured using pressure mapping film immediately before and after each trial. A reciprocating modified pin-on-disc test apparatus measured and recorded friction coefficients instantaneously throughout the trial length. Trials were set to run for 1-hour under predetermined physiological conditions. Images were obtained pre- and post-trial using digital photography and microscopy to qualify results. Two-tailed t-tests were used to compare differences in friction coefficients between native cartilage trials and each of the three synthetic implant trials.

Trial Conditions

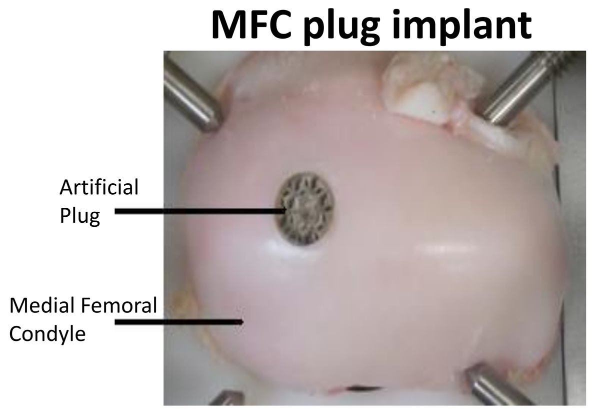
Parameter	Time
Time	60 min
Stroke Length	2 cm
Frequency	1 Hz
Force	250 N
Temperature	37º C

Synthetic Plugs

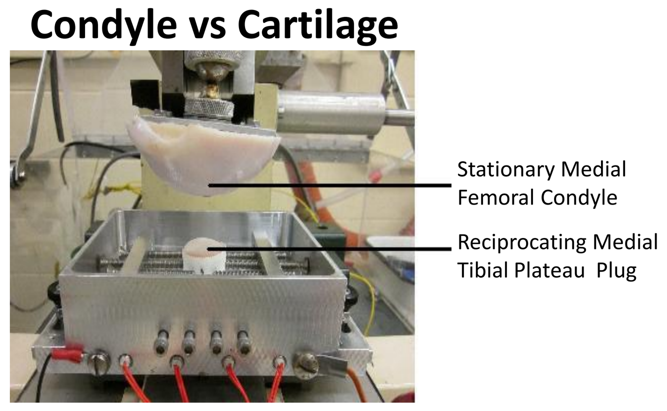


Synthetic test plugs (L to R) cobalt chrome, polyurethane and PEEK were tested to find a replacement for worn or damaged articular cartilage.

MFC plug implant



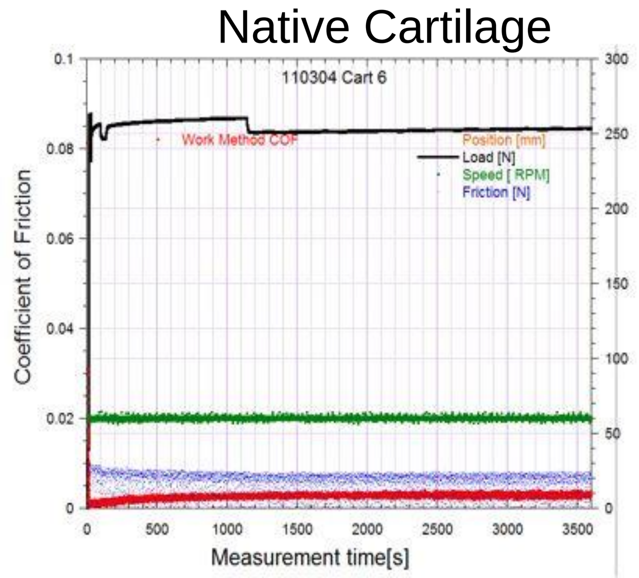
Condyle vs Cartilage



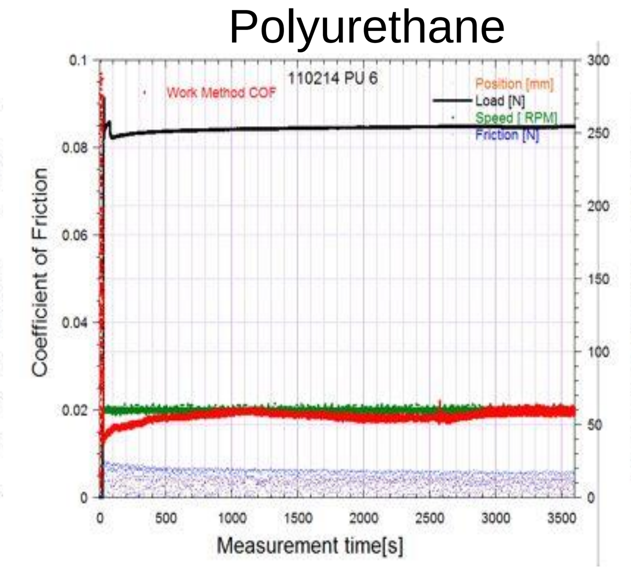
Results

Friction Results

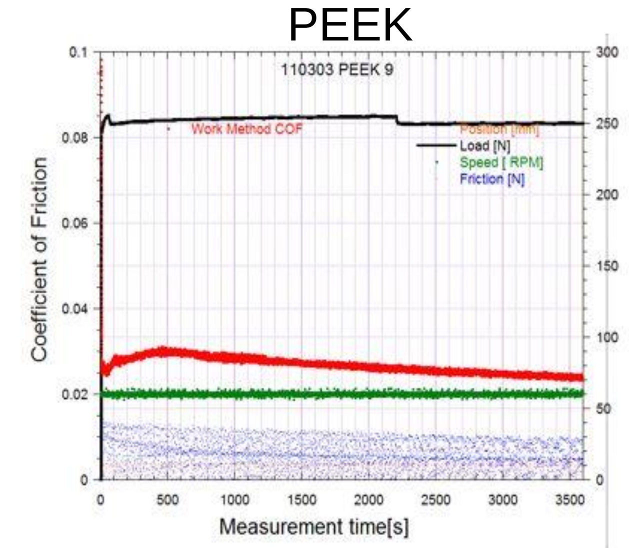
Native Cartilage



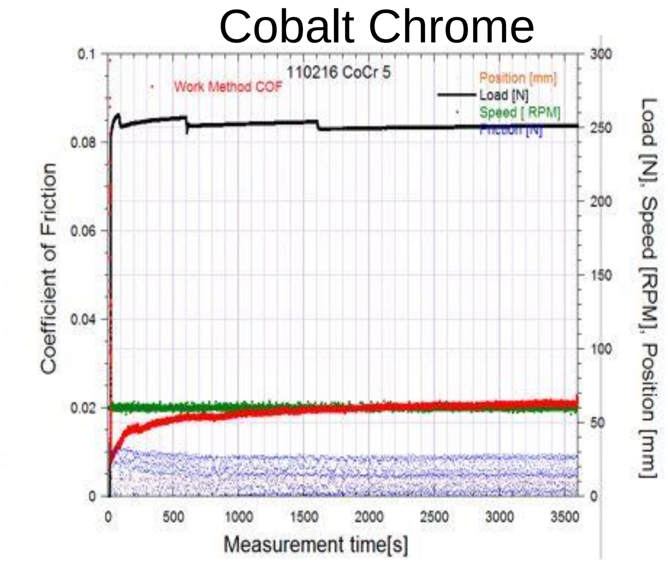
Polyurethane



PEEK



Cobalt Chrome



	Coefficient of Friction (x10^{-3})			Pressure (MPa)	
Material	600s	1800s	3000s	Pre	Post
Cartilage	4.5 ± 2.3	6.3 ± 2.9	6.8 ± 3.4	3.60 ± 0.72	2.89 ± 0.40
PU	18.4 ± 4.9	20.0 ± 3.9	20.6 ± 2.9	3.34 ± 0.34	2.88 ± 0.46
PEEK	31.6 ± 11.7	27.4 ± 8.7	25.3 ± 7.6	4.31 ± 1.00	3.50 ± 0.51
CoCr	18.9 ± 7.6	21.1 ± 7.6	21.8 ± 7.9	5.05 ± 0.61	3.96 ± 0.70

PU, PEEK, and CoCr plugs all had significantly higher coefficients of friction on average when compared to cartilage (p>0.001 for all materials). Values were typically 3-4 fold higher for the transplant plugs than the native MFC cartilage against MTP cartilage.

Wear Results

Native

Polyurethane

PEEK

Cobalt

Unlike the cartilage controls, damage was clearly evident on the cartilage surfaces exposed to the PU, PEEK, and CoCr plugs. PEEK was consistently most severe, followed by CoCr, with some samples being worn completely to underlying bone. Cross sectional images of the wear paths confirmed loss of cartilage thickness and integrity.

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Conclusion

The synthetic surface materials tested were not able to replicate the unique tribological properties of native cartilage, and thus are inefficient at replacing cartilage defects. While normal cartilage produces negligible wear and has an inherently low coefficient of friction, the implanted materials resulted in statistically significant higher coefficients of friction and markedly increased cartilage wear. When the friction coefficients of the materials were compared to each other, only PU vs. PEEK was significant (p<0.05). While PU produced the least visible cartilage damage among the three, there was a clear loss of cartilage in all transplant trials. Further investigation is warranted to elucidate defects or flaws in the transplant system, or new techniques should be developed in hopes of finding an appropriate method to repair degenerative articular cartilage defects.

Orthopaedic Surgery & Sports Medicine Teaching & Research Foundation

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