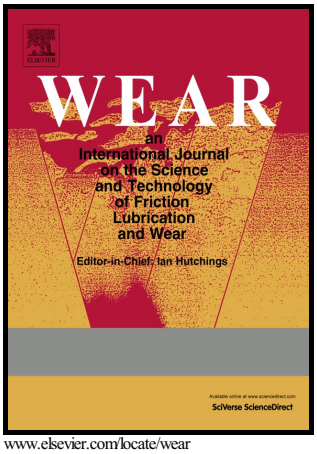

www.elsevier.com/locate/wear

Experimental study on friction and wear properties of interpenetrating polymer network alginate-polyacrylamide hydrogels for use in minimally-invasive joint implants

Mohammadreza Arjmandi, Maziar Ramezani, Ashveen Nand, Thomas Neitzert

PII: S0043-1648(18)30293-X
DOI: https://doi.org/10.1016/j.wear.2018.04.013
Reference: WEA102405

To appear in: *Wear*

Received date: 7 March 2018
Revised date: 20 April 2018
Accepted date: 22 April 2018

Cite this article as: Mohammadreza Arjmandi, Maziar Ramezani, Ashveen Nand and Thomas Neitzert, Experimental study on friction and wear properties of interpenetrating polymer network alginate-polyacrylamide hydrogels for use in minimally-invasive joint implants, *Wear,* https://doi.org/10.1016/j.wear.2018.04.013

Experimental study on friction and wear properties of interpenetrating polymer network alginate-polyacrylamide hydrogels for use in minimally-invasive joint implants

Mohammadreza Arjmandi[a]*, Maziar Ramezani[a], Ashveen Nand[b], and Thomas Neitzert[a]

[a]Department of Mechanical Engineering, Auckland University of Technology, Auckland,1010,New Zealand
[b]Health and Community, and Environmental and Animal Sciences Network, Unitec Institute of Technology, Auckland, 1025, New Zealand
*Corresponding author. *Email address:* mohammadreza.arjmandi@aut.ac.nz (M. Arjmandi)

Abstract

Alginate/Polyacrylamide (ALG/PAAm) hybrid hydrogel was suggested as an orthopedic prosthesis due to its biocompatibility and promising properties. Their friction and wear performances, however, have remained under-explored. In this study, indentation tests were conducted to obtain the mechanical properties of ALG/PAAm interpenetrating polymer networks, while the tribological response was evaluated by reciprocating sliding motion against alumina ceramic ball. The hydrogel samples were synthesized using two different ratios of crosslinking agent (X.A %) to study the effect of crosslinking on wear resistance of the material. Various loads and sliding speeds were considered to simulate human gait/running cycle, with and without presence of bovine serum as lubricant. Mass loss was quantified by gravimetric measurement of dried samples before and after each test, while the wear volume was measured by profilometry. An increase in the crosslinker concentration resulted in improvements of up to 21% the elastic modulus and 32% the hardness. A trend was observed in mass loss increase with higher loading regardless of crosslinker concentration. However, under higher sliding speed less material was removed due to wear. With lubrication and under the highest load, the minimum mean friction coefficient was obtained for samples with 0.06 X.A% (0.010 ± 2.6E-3) which is promising when compared to that of articular cartilage. Visual inspection of worn surfaces by electron microscopy revealed adhesion as the dominant wear mechanism. Overall, the hydrogels with higher crosslinking density were considered as a potential candidate, due to higher stiffness and better tribological performance under lubrication.

Keywords: Biomaterials, Tribology, Wear, Hydrogels, Cartilage replacement

1. Introduction

Articular cartilage, a smooth tissue covering the end of long bones in diarthrodial joints, plays a crucial role in load distribution and almost frictionless movement once the bones articulate. Unique biomechanical characteristics and multiphasic fiber-reinforced structure with anisotropic, viscoelastic, nonlinear and inhomogeneous material properties, are known to provide ultra- high wear resistance and damage tolerance that would lead to several decades of service life [1, 2]. The interstitial fluid pressurization is known as the main lubrication mechanism to reduce friction between cartilage mating pairs [3]. If the tissue loses its performance due to osteoarthritis (OA) disease or trauma, the damage would be permanent due to the avascular nature of cartilage. Unfortunately, the treatment methods are all temporary and eventually a total joint replacement would become inevitable. Due to the limited service life of the total joint replacement, and issues with probable implant failure and more invasive revision surgeries, this operation is more dedicated to the elderly. For younger patients with healthier cartilage, it was proposed to replace the cartilage lesions with synthetic biomaterials, which can mimic the native cartilage tissue, to postpone joint replacement and to preserve the healthy cartilage tissue, intact [4-7].

Hydrogels benefit from a three-dimensional network of hydrophilic polymers that can retain large volume of solvent (water) inside the macromolecular structures and are of great interest as cartilage replacement [8-11]. Characteristics such as tunable mechanical properties, a compliant structure which would enhance fluid film lubrication and friction reduction, the ability to be prepared as injectable material to fill defects of any shape, among others, have attracted other researchers to propose various hydrogels as the constituent of cartilage replacement. Their mechanical behavior is affected not only by the elasticity of the polymer network, but also the migration of solvent through the network, known as poroelasitc response. Due to the high water content, hydrogels in a swollen state lack sufficient mechanical properties required for load-bearing applications, therefore various methods were proposed to increase their mechanical strength, such as nanoparticle/fiber-reinforcements [1, 12], double network [13], annealing [14-16] and interpenetrating polymer network (IPN) hydrogels [17, 18]. The latter refers to a combination of two polymers where one polymer is crosslinked in the