7th World Tribology Congress, WTC 2022
July 10-15, 2022, Lyon, France

# Enhanced lubrication on articular cartilage surface through hyaluronic acid conjugated with dopamine as intra-articular injections

Ke Ren[1)], Hongping Wan[1)], Hans Kaper[1)] and Prashant K. Sharma[1)*]

[1)] Department of Biomedical Engineering, University Medical Center Groningen and University of Groningen, Groningen, The Netherlands.
*Corresponding author: p.k.sharma@umcg.nl

Viscosupplementation i.e. intra-articular administration of hyaluronic acid (HA) is widely applied for increased lubrication and pain relief for osteoarthritis patients. However in the clinical setting the pain relief of HA for patients is temporary due to its poor adhesion. Here, a surface binding dopamine modified HA (HADN) is proposed for reliable enhanced lubrication through enhancing viscosity and absorbing itself onto bovine cartilage surface. HADN solution in cartilage-glass model not only enhances viscosity under weeping condition but also increases boundary lubrication shown through coefficient of friction, roughness, and atomic force microscopy images.

**Keywords (from 3 to 5 max):** Lubrication, Cartilage, Boundary lubrication, Hyaluronic acid

## 1. Introduction

Osteoarthritis (OA) is the most prevalent autoimmune disease know to man affecting the articular joints of around 15% of the population worldwide [1]. Viscosupplementation of exogenous HA as intra-articular injections has been proposed as a symptomatic treatment method for OA and pain relief. However, the half-life of intra-articular HA is only a couple of days, nonetheless clinical effects have been shown to maintain over several months. This can possibly be explained by the fact that exogeneous HA has poor adhesion on cartilage surface. In this study, a novel cartilage-binding material based on hydrophilic polysaccharide hyaluronic acid conjugated with dopamine (HADN) was proposed for enhancing cartilage lubrication through not only enhancing viscosity but also absorbing itself onto lamina splendens under articular cartilage condition.

## 2. Methods

2.1. QCM test
Quartz crystal microbalance (QCM) was used for demonstrating the HADN absorption onto lamina splendens.

2.2. UMT-3 tribological test
Tribological tests were performed using a universal mechanical testing machine (UMT-3). The tests were at 33°C for 1 h at high pressure (40N, ~1MPa) to get weeping lubrication and at low pressure (4N, ~0.1MPa) to get boundary lubrication conditions. The sliding speed of 4 mm/s was chosen for mimicking human walking. In order to demonstrate the adsorption ability of HADN, the tribological testing was performed in two ways – Test 1 where the cartilage and glass surfaces were kept submerged in PBS, PBS+20 µg/ml HA or PBS+20µg/ml HADN while sliding and Test 2 where cartilage was pre-exposed to the three solutions for 4 h but the sliding against glass performed in PBS. Coefficient of friction (COF) was monitored as a lubrication analysis.

2.3. AFM morphological and roughness test
After tribological experiments. Cartilage wear was quantified by monitoring the roughness using AFM.

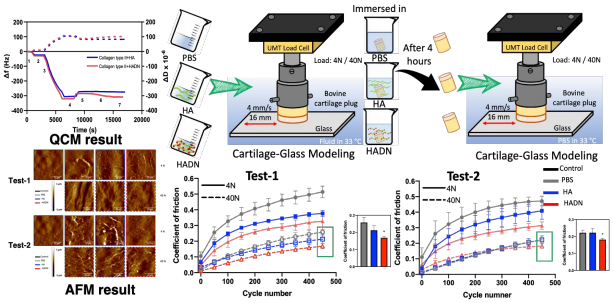


Figure 1: QCM result, cartilage-glass modeling setup, AFM images and COF result of test 1 and test 2.

Table 1: the frequency shift and the ratio of dissipation to frequency shift during the adsorption of HA and HADN on collagen layer.

| Substrate | -Δf (Hz) | | -ΔD/Δf x $10^{-6}$ (s) | |
|---|---|---|---|---|
| | HA | HADN | HA | HADN |
| Collagen-type II | 3.64±2.07 | 25.00±9.35 * | 0.09±0.07 | 0.42±0.18 * |

## 3. Discussion

According to QCM result, HADN adsorption on collagen type II was much higher (frequency shift, $\Delta f$=25 Hz) as compared to HA (3.64 Hz). HADN adsorption was also evident from the higher viscoelasticity ($\Delta D/\Delta f$=0.42x$10^{-6}$) compared with HA (0.09). This result demonstrated that HADN is able to absorb onto exposed cartilage which is devoid of the naturally occurring lamina splendens. Regarding to Tribological test, either test 1 or test 2, both revealed the HADN has much less COF under high and low pressures. Meanwhile, AFM image result shows that after rubbing under different situations, the surface of cartilage treated with HADN or immersed in HADN solution was a bit more intact than others.

## 4. References

[1] Poole, A. R. et al., "Type II collagen degradation and its regulation in articular cartilage in osteoarthritis," Ann. Rheum. Dis, 61, 2002, 78-81.