Surface Characterization of Biodegradable Magnesium-Calcium Orthopedic Implants by Low Plasticity Burnishing

Y.B. Guo, M. Salahshoor
Department of Mechanical Engineering, The University of Alabama, Tuscaloosa, Alabama 35487

Statement of Purpose: Current commercial permanent metallic implants, e.g. bone screws and plates, are made of titanium, stainless steel, and cobalt-chromium alloys. Current permanent metallic implants suffer two grand challenges, i.e., "stress shielding" and "surgical interventions". Previous in vivo studies have shown that magnesium-calcium (MgCa) alloys may be suitable as degradable biomaterial for use in orthopedic implants. The close Young's modulus between magnesium and cancellous bones has the potential to minimize stress shielding. However, the pressing issue of an MgCa implant is that it has very poor corrosion resistance in saline media such as in the environment of the human organism. It has been shown that the corrosion rate of MgCa implants may be controlled by adjusting surface integrity by a novel low plasticity burnishing (LPB) technique. However, biomechanics of the novel material during LPB process is poorly understood. This study focuses on surface characterization of MgCa biomaterial by burnishing.

Methods: The material used in this study is magnesium-calcium alloy with 0.8 weight percent calcium (MgCa0.8). This specific value is the solubility limit of calcium in magnesium which beyond that inter-metallic phase Mg_2Ca will form. This binary alloy is not commercialized and was lab made for research purposes. Researchers have found MgCa0.8 is very promising for biomedical applications through in-vitro and in-vivo tests.

As shown in Figure 1, the MgCa sample surface will be rolled by the smooth ceramic ball of 12.7 mm in diameter. This ceramic ball sits on a pressurized hydro cushion. The MgCa sample of 50 mm diameter is secured in the pocket of a resting plate which is positioned with four rods that maintain the rigs position and rigidity. The resting plate is free to move up and down as it rests on a load cell, allowing accurate measure of the applied burnishing load.

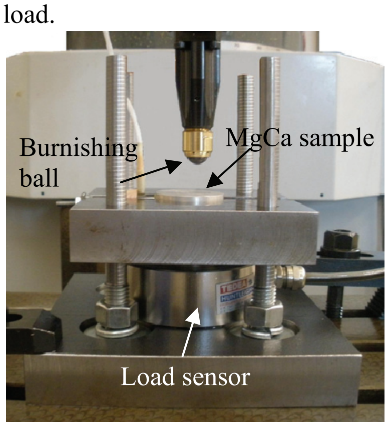

Figure 1. LPB Experimental Setup

Results: Optical images of five dents made under different pressures are shown in Figure 2. MgCa0.8 behaves very ductile in compression mode. The measured dent profiles of the dents are shown in Figure 3. The maximum measurable depth is 55 µm for 6 MPa hydraulic pressure. Dents made with higher pressures have depth beyond the profiler's limit which is 60 µm.

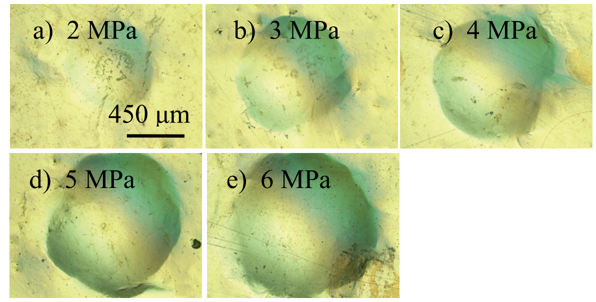

Figure 2. Dent Images at Different Burnishing Pressures

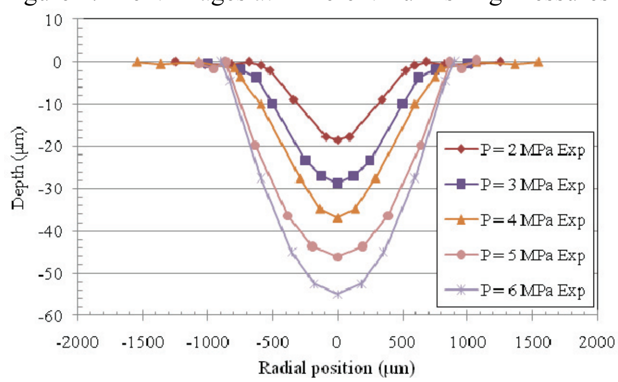

Figure 3. Dent Profiles at Different Burnishing Pressures

The theoretically calculated and experimentally measured indentation forces are shown in Figure 4. The actual indentation force is smaller than theoretical one. The amount of this discrepancy depends on the amount hydraulic pressure. This discrepancy is attributed to the pressure loss at LPB tool's tip which seems to be the right reason since by increasing hydraulic pressure this discrepancy increases. On average, experimental force is 23% lower than theoretical one.

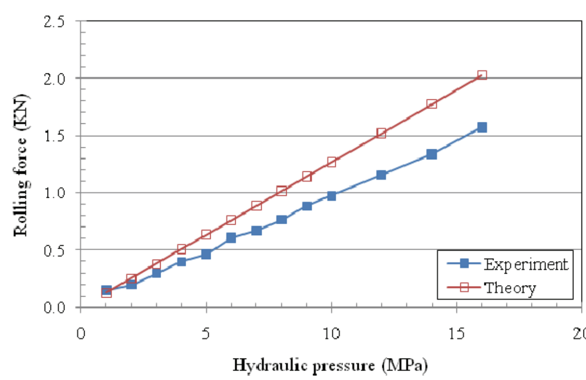

Figure 4. Experimental and Theoretical Burnishing Force

Conclusions: The experimental study on finish burnishing MgCa0.8 biodegradable orthopedic material has shown that plastic deformation increases with the burnishing pressure. The actual rolling force is lower than the calculated data based theoretical principals of hydrostatics and the discrepancy increases with increasing hydraulic pressure. It is expected that corrosion rate in human body fluids will be affected by surface integrity.