Efficacy of high-purity magnesium for biodegradable implants

Ryo Maekawa[1], Yoshinobu Oka[1], Hiroaki Wada[1], Wook-Cheol Kim[2], Yoshinori Sakanoue[3], Tomoaki Murata[4], Yusuke Kobayashi[4], Natthiwan Dodyim[4], Tetsuo Aida[5], Sadami Tsutsumi[6], Kenji Takahashi[1]
[1]Kyoto Prefectural University of Medicine, Kyoto, Japan, [2] Uji Takeda Hospital, Kyoto, Japan,
[3] Kyoto Prefectural Technology Center for Small and Medium Enterprises, Kyoto, Japan,
[4] NITTOSEIKO Co., Ltd, Kyoto, Japan, [5] Toyama University, Toyama, Japan, [6] Kyoto University, Kyoto, Japan
Email of Presenting Author: maka@koto.kpu-m.ac.jp

Disclosures: Ryo Maekawa (N), Yoshinobu Oka (N), Hiroaki Wada(N), Wook-Cheol Kim(N), Yoshinori Sakanoue(N), Tomoaki Murata(N), Yusuke Kobayashi(N), Natthiwan Dodyim(N), Tetsuo Aida(N), Sadami Tsutsumi(N), Kenji Takahashi(N)

INTRODUCTION: Metal implants for bone fixation often require removal, which is invasive and socioeconomically problematic. Current biodegradable implants are not ideal in terms of degradation rate and strength. This study aimed to develop ideal biodegradable implants using high-purity magnesium.

METHODS: Five groups of commercially-available high-purity Mg ingots were used (A: extrusion and drawing, B: extrusion and machining, C: extrusion and drawing, D, E: extrusion only). The corrosion tests were performed per JIS T0304. Samples were immersed in a modified simulated body fluid. The average weight of the samples was calculated at 1,3,7,14,31,56, and 84 days after immersion. Transmission X-ray imaging was used to observe their internal structure. Strength testing was performed by tensile and hardness tests. Metal crystal evaluation was observed using electron backscatter diffraction (EBSD) to evaluate crystal grains on the surface. Statistical analysis was conducted using the Wilcoxon matched-pairs signed ranks test.

RESULTS: In corrosion tests, Group E (control) was completely degraded at 25 days. The weight of Group C decreased and degradation started after 14 days; Groups A and B started after 56 days. At the end of the test (84 days), 90.9% of samples from Group A, 75.3% of samples from Group B, and 41.0% of samples from Group C remained. From the transmission X-ray images, Groups A and B were stable in appearance and internal structure. Most of Group C failed structurally. The decrease of tensile strength of the metal was not significant in the case of Groups A and B, but it was significant in the case of Group C. For the samples from Groups A, B, and C, the change of hardness was not significant, respectively. In the crystal evaluation, differences in grain size were observed. Perpendicular plane to the C axis of each hexagonal crystal and parallel planes were frequently observed on the material surfaces.

DISCUSSION and CONCLUSION: Magnesium as a biodegradable implant is promising because of its similarity to the elastic modulus of bone, high biocompatibility, and reduces toxicity concerns. However, Mg implants, especially pure Mg, degrade too quickly in aqueous solution and the body, and lose strength before tissue restoration. The degradation rate of Mg implants has been controlled by alloying, but there are concerns of allying element toxicity. Our high-purity Mg material was demonstrated to slow the Mg degradation rate to 2〜3 months and maintain strength by controlling the metal structure.

SIGNIFICANCE/CLINICAL RELEVANCE: This magnesium material will reduce concerns about toxicity due to impurities during dissolution and eliminate the need for surgical removal.

Figure 1. Magnesium after refining

Figure 2. Photographs of the Mg samples A, B, C

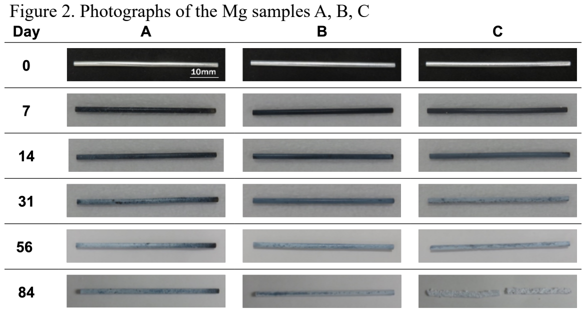

Figure 3. Weight change and residue of Mg samples and controls