HOSTED BY

ELSEVIER

Available online at www.sciencedirect.com

ScienceDirect

Progress in Natural Science: Materials International 24 (2014) 446–451

Progress in Natural Science Materials International

www.elsevier.com/locate/pnsmi
www.sciencedirect.com

Original Research

Study on vertical mandibular distraction osteogenesis using magnesium alloy on canine

Chengyue Wang[a,*], Shufeng Wang[b], Yusheng Yao[c], Fuzhai Cui[d]

[a]*Department of Stomatology, Centeral Hospital of Jinzhou, Clinical Hospital of Liaoning Medical College, Section 2, 51 Shanghai Road, Guta District, Jinzhou 121000, China*

[b]*Stomatological Hospital of Xuzhou, Huaihai West Road, Quanshan District, Xuzhou 221000, China*

[c]*Stomatological Hospital of Liaoning Medical College, Section 2, 49 Shanghai Road, Guta District, Jinzhou 121000, China*

[d]*Department of Materials Science & Engineering, Tsinghua University, Haidian District, Beijing 100084, China*

Received 2 July 2014; accepted 1 September 2014
Available online 4 November 2014

Abstract

The bone formation feasibility by a novel magnesium alloy device was evaluated using a canine vertical mandibular distraction osteogenesis (DO) model. Osteotomies were performed in the area where last 3 star's teeth of left mandibular were pulled out before 3 months. Both AZ31 magnesium alloy ($n=6$) and 316L stainless steel ($n=6$) distraction devices were implanted. The distraction osteogenesis was carried out with a latency of 5 days after mandibular osteotomy. Distraction proceeded at a rate of 0.3 mm/8 h for 7 days and followed by 4 weeks of consolidations. The evaluations were conducted by scanning electron microscopy (SEM) and histological examinations. There were osteoblasts and trabecular bones formations manifestly in both groups. There was no significant difference in the bone mineral density between the two groups. The surface of the magnesium alloy was much more cracked and uneven, resulting from the surface pitting corrosion. The crew nails were closely combined with the surrounding bone tissue. AZ31 magnesium alloy exhibited a certain degradation rate in mandibular and did not post a negative effect on the kidney and liver. The observations in magnesium alloys group is consistent with the stainless steel group.

Keywords: Magnesium alloy; Distraction osteogenesis; Degradability; Bone formation; Canine

1. Introduction

Long before, many scholars made a lot of researches in the field of magnesium alloy. Earlier studies have shown that magnesium-based materials were non-toxic and promoted the bone healing. With deep research and development of magnesium alloy, the corrosion resistance and mechanical properties of magnesium alloys have been gradually improved. Researchers began to make further studies on magnesium and its alloys as implant materials [1,2]. In 2014, Lensing et al. [3] tested a bio-absorbable magnesium alloy serving as total ossicular replacement prostheses. The results showed that the magnesium alloy was corroded too fast, so that a complete bone reconstruction could not be established in time. So magnesium coating of biological materials is more favorable to the integration of biomaterials and bone tissue.

At present, biodegradable magnesium alloys, a new class of degradable biomaterials, are promising candidates for medical applications and therefore have attracted much attention in recent years [4]. Magnesium based materials is a hot point in the field of metallic biomaterials. Studies of magnesium based biomaterials are focused on increasing both corrosion resistance and biocompatibility of the materials. The low corrosion resistance of magnesium, a major limitation for its use in musculoskeletal surgeries, has been much improved by appropriate alloying design as well as surface treatments. However, there is still a large distance to practical application, which needs further research and exploration. On the one hand, we need to adjust the alloy composition to improve the corrosion resistance of magnesium alloys, to remove harmful impurities such as iron, copper and

*Corresponding author. Tel.: +86 133 2218 3877.
E-mail addresses: wchy1758@sohu.com (C. Wang), wsf_20052005@163.com (S. Wang), yyswgj2008@163.com (Y. Yao), cuifz@mail.tsinghua.edu.cn (F. Cui).

http://dx.doi.org/10.1016/j.pnsc.2014.09.006
1002-0071/

nickel to increase the purity of alloy, and to make extrusion or proper heat treatment to refine the grain size in the perspective of magnesium alloys. We can use rapid solidification to obtain finer grain size, even to produce nano-sized grain magnesium alloy, and thus the mechanical properties and corrosion resistance are greatly increased. The technique of rapid solidification can also get unique amorphous magnesium alloy with better mechanical properties and corrosion resistance [5]. On the other hand, we can improve the corrosion resistance with surface treatment on magnesium alloys, such as ion implantation, laser surface treatment, thermal diffusion, alkali heat treatment, surface coating, etc [6]. The surface roughness and rejection degree of magnesium alloys have a great influence on formation of fresh bone tissues when magnesium alloys are implanted into the body. Therefore, the preparation of new type of magnesium based materials can be more easily accepted.

In this paper, both biodegradable AZ31 magnesium alloy and stainless steel were used to make the distractors for the experimental study on a canine model. The similarities of both mandibular anatomy and masticatory mechanics between a dog and human would make this species particularly suitable for investigation.

2. Experimental

2.1. Materials

A total of 12 hybrid dogs were used for both the magnesium alloy group (experimental) and the stainless steel group (control), designated by Experimental group: #1–6, and Control group: #7–12. All the dogs were about 8–12 months old and 6–10 kg in weight. Adequate measures were taken to minimize the pain or discomfort to the experimental animals, and the experiments were conducted in accordance with the International Standards on Animal Welfare and the Ethical Standards of the Committee on Animal Experimentation of our institution. All the hybrid dogs were provided by the Animal Center of Liaoning Medical College, Jinzhou, China.

AZ31 magnesium alloy with nominal composition of Mg–3Al–1Zn in wt% and 316L stainless steel for the present study were provided by Institute of Metal Research, Chinese Academy of Sciences. The processed tractors are shown in Fig. 1.

2.2. Experimental procedures

Animals were anesthetized with hydrochloric acid Sarah polybenzoxazines injection (0.1 ml/kg). The infection prophylaxis was provided with 4 wu/kg penicillin preoperatively and 3 days postoperatively. Three left mandibular molars were pulled out from the animals, and then the site was disinfected and sutured. Animals were fed in the Animal Center of Liaoning Medical College and observed for eating and drinking.

After three months, animals were generally anesthetized with hydrochloric acid Sarah polybenzoxazines injection (0.1 ml/kg). Infection prophylaxis was provided with 4 wu/kg penicillin preoperatively and 3 days postoperatively. A 3-cm long incision

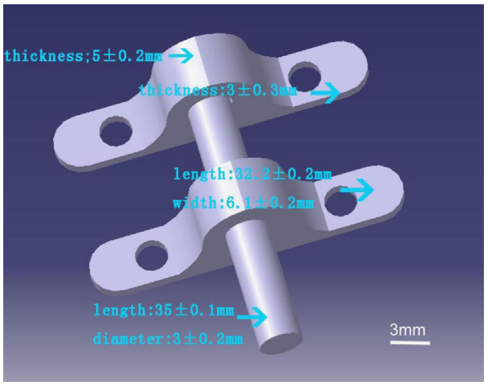

Fig. 1. Drawing of distractors.

was performed along the inferior border of the left mandible. The skin and subcutaneous tissue were dissected to disclose the medial masseter sling, which was sectioned using the scalpels. Using a blunt spatula, both muscles were then detached to expose both the internal and external aspects of the mandibular body. Firstly, an osteotomy line was vertically made in the position of lacking teeth on the left mandibular body. Using a cylindrical bur, four holes of 2.5 mm in diameter were drilled through cortical layers of the mandible. An up bone segment of 3 cm × 1 cm was made in the marked site. The mandible was made with osteotomy by a fissured bur with copious sterile saline irrigation. Then, the self-designed AZ31 magnesium alloy and 316L stainless steel distractors (0.3 mm of traction every 1 clockwise lap) were adapted by four mini-screws (2.5 mm in diameter × 10 mm in length) which were placed across both cortices. The distraction device was placed to test proper positioning and ensure it to be exerted without tension on the fracture ends. Secondly, the vertical heights of the fixed plate of distractors in the position of traction rods were measured by a Vernier Gauge. The surgical site was washed by normal saline containing penicillin. At last, the wound was closed in layers. Animals were fed in a single cage and observed for eating and drinking. Five days post surgery, the distraction was performed by a speed of 0.3 mm/8 h for 1 week. Fig. 2 shows part of the operation process.

After 4 weeks of consolidation, the dogs were sacrificed under general anesthesia. The stability of the screw nails were measured by a Periotest Mobility instrument. The vertical heights of the fixed plate of distractors of two groups were measured again at the same position in surgery by Vernier Gauge. Magnesium alloy distractors were washed with PBS, dehydrated with gradient ethanol solvent, and dried for 6 h. Then the weights of magnesium alloy distractors were measured on an electronic scale.

Mandibular bone pieces including prowled cracks in two groups were prepared, labeled and placed in 10% formalin solution for histological and morphological examinations. Bone pieces were divided into two parts. The specimens of bone were processed for demineralization in an EDTA (15%) at room temperature for 40 days, and then dehydrated in an ethanol series (70–90%) in an automated processor. The specimens were cleaned with xylenol, impregnated with melted paraffin wax, embedded in paraffin wax and sectioned by a microtome to sections of 5-μm in thickness. Sections of liver and kidney were stained by Hematoxylin-Eosin