SciMedCentral

JSM Dental Surgery

Short Communication

Magnesium Screws and Plates for Bone Augmentation: a New Concept in Dental Surgery

Olga WetterlövCharyeva*

Department of Prosthodontics, Malmö University, Sweden

***Corresponding author**

Olga WetterlövCharyeva, Department of Prosthodontics, Malmö University, Sweden, E mail: olga.charyeva@gmail.com

Submitted: 17 November 2016

Accepted: 09 February 2017

Published: 13 February 2017

Keywords

• Bone augmentation
• Magnesium screws
• Magnesium implants

Abstract

Objectives: This short review gives an overview of magnesium as a potential material for temporary metal screws and plates for maxillofacial applications.

Materials and Methods: PubMed was searched for magnesium as a biomaterial. Only in vivo studies and reviews were included.

Results: Until now, titanium screws and plates have been a golden standard in fixing augmented bone and bone grafts. However, a second operation for screw removal causes further damage to the tissues, increases infection risk, and increases patient suffering and costs. Magnesium is a biocompatible metal that resorbs in tissues without causing tissue damage, and it has better mechanical properties than titanium. Magnesium alloys are commercially available for orthopedic and cardiovascular uses, but not for maxillofacial applications.

Conclusion: Magnesium alloys have better properties than titanium and are beneficial in fixing bone grafts. Further development and implication of magnesium in the maxillofacial field would be beneficial for patients undergoing dental surgery.

INTRODUCTION

Metal screws and plates that fix the bone and then dissolve upon healing is a new concept in dentistry. Until now, titanium has been the metal of choice for fixing augmented bone. Although titanium plates, screws, and nets provide good stability for tissues during the healing phase, these materials have to be removed before further treatment with dental implants [1,2]. The second operation on screw and plate removal leads to new tissue damage, increased infection risks, and high patient costs and suffering.

The concept of biodegradation is already known in medical practice resorbable sutures are successfully used in surgery. Polymers and metals are bioresorbable materials that are suitable for bone augmentation. Polymers have low impact strength; low wear resistance, low capacity to absorb high-strain energy compared to metals Moravej and [3], and might provoke foreign body reactions [4]. The idea behind magnesium screws is to combine the degradability similar to polymers with good mechanical properties similar to or better than titanium.

Historically, the first metals to be used for medical applications were Ag-, Fe-, Au-, and Pt-based alloys in the late 18th century [5]. The discovery of elemental magnesium by Sir Humphrey Davy in 1808 led to the design of metallic biodegradable implants. The first implantation of magnesium wires as ligatures to stop bleeding vessels of human patients was performed [6]. Today, magnesium has been rediscovered in the medical field due to its fantastic properties.

MATERIALS AND METHODS

The PubMed database was searched for magnesium as a biomaterial. The search words were “magnesium biomaterial,” “magnesium in vivo,” “magnesium biodegradable,” and “magnesium implants.” Only *in vivo* studies and reviews from 2005 were selected. The aim was to get insight into magnesium’s properties, problems, and medical application areas. In total, 12 articles met the search criteria.

RESULTS

Properties of magnesium

It is crucial for metal alloys that are to be used for surgical applications be biocompatible and provide enough strength to the tissues. Magnesium is considered a suitable material for medical uses for a number of reasons. First, it is highly biocompatible [7]. Secondly, magnesium occurs naturally in our bodies: 50–60 % of this element is found in bone, and we get about 380–850 mg of magnesium daily from [8]. Foods rich in magnesium include cabbage, spinach, nuts, and grains. Magnesium deficiency can lead to serious problems, such as migraines and cardiovascular disorders [8]. Excess magnesium is removed by the kidneys

[8]. Thirdly, magnesium seems to have osseoinductive and osseoconductive properties [9]. Numerous publications show that magnesium stimulates bone attachment to implant surfaces compared to conventional materials [10,11]. Magnesium promotes formation of calcium phosphate, which is favorable for bone mineralization [12-14].

It has been shown that magnesium's mechanical properties are better than those of titanium [15]. Magnesium-based alloys are typically very light, since they are 1/3 less dense than titanium-based alloys [15]. Titanium alloys typically have a modulus of elasticity of around 115 GPa. In contrast, magnesium alloys' E-modulus is around 45 GPa, which is much closer to the bone's 3-20 GPa. This is much better matched to the bone and lessens the likelihood of stress shielding [15].

By-products of degradation

A major problem of magnesium is hydrogen gas formation as a by-product of degradation [16]. Four types of degradable magnesium-based materials were tested in the *in vivo* study of [12]: magnesium-hydroxyapatite, magnesium-calcium phosphate cement, alloy of 96 % magnesium and 4 % yttrium (W4), and 99.95 % pure magnesium. It has been shown that hydrogen bubbles push away osteoclasts and osteoblasts from the healing site, making it difficult to form osteoid on the material's surface [12]. However, hydrogen seems to appear within one week after implantation and then vanish after around two to three weeks, as shown in another *in vivo* experiment [13]. The rate of hydrogen gas production can be controlled by alloying magnesium with other metals. Alloying not only slows down the degradation rate but also increases mechanical properties. It is necessary for magnesium-based alloys to have a slow degradation rate so that the bone heals before the screw resorbs. Hard-tissue repair typically requires implantation of the fixture for a minimum of 12 weeks [17]. Thus, designing an alloy that has good mechanical properties over this critical 12-week period is of high importance.

Another method to slow down the degradation rate is purification. Studies have shown that purification of magnesium reduces the corrosion rate considerably; however, due to the low yield strength of pure magnesium [13], its application in medical appliances that require good load-bearing properties is rather limited.

Applications of magnesium

Two magnesium alloys are commercially available today for cardiovascular and orthopedic applications, WE43 and MgYREZr, respectively. However, no screws or plates are available for dentistry. MgYREZr is a modification of WE43, which, apart from magnesium, yttrium, and rare earth elements, also contains zirconium. The degradation time for MgYREZr is around 24 months [18]. These screws have shown positive results in the pilot study on 13 [2]. However, a limitation of this study is the relatively low statistical power.

DISCUSSION

Titanium-based implants are currently used in maxillofacial surgery for fixing augmented bone. Although they provide excellent stability, they may cause adverse tissue reactions, and additional surgery for implant removal may be necessary [1,2]. Alternatively, degradable polymers are mechanically weaker and might aggravate foreign body reactions [4]. The idea behind magnesium implants is to combine degradability similar to polymers with good mechanical properties similar to titanium.

The problem with magnesium is that it forms hydrogen gas in contact with fluids, which can interfere with tissue healing [17]. Thus, a slow degradation rate is required to achieve optimum healing [5]. The rate of hydrogen gas production can be controlled through several methods, the most common being alloying and purification [12,13]. Using these techniques can increase degradation times up to 24 months *in vivo* [16]. Even though slow degradation of magnesium is desired, degradation shorter than 24 months is essential for the dental and maxillofacial fields. For dental and maxillofacial medicine, six-month degradation would be optimum.

In our opinion, the potential application areas of magnesium in the maxillofacial field apart from bone augmentation procedures are screws and plates for fixation of traumatic orbital defects, treatment of zygomatic fractures, fixation of mandibular fractures, and fixation in orthognathic and pediatric craniofacial surgeries.

CONCLUSION

Although magnesium has excellent biomechanical properties, it is biocompatible and a perfect material for temporary bone fixation. It is currently used only in orthopedic and cardiovascular medicine. Development of optimal degradation times together with a screw and plate design specific for the dental field would begin a new era in maxillofacial surgery.

REFERENCES

1. Sumitomo N, Noritake K, Hattori T, Morikawa K, Niwa S, Sato K, et al. Experiment study on fracture fixation with low rigidity titanium alloy: plate fixation of tibia fracture model in rabbit. J Mater Sci Mater Med. 2008; 19: 1581-1586.

2. Waizy H, Seitz JM, Reifenrath J, Weizbauer A, Bach FW, Meyer-Lindenberg A, et al. Biodegradable magnesium implants for orthopedic applications. J Mater Sci. 2013; 48: 39-50.

3. Moravej M, Mantovani D. Biodegradable metals for cardiovascular stent application: interests and new opportunities. Int J of Mol Sc. 2011; 12: 4250-4270.

4. Bostman OM, Paivarinta U, Partio E, Manninen M, Vasenius J, Majola A, et al. The tissue-implant interface during degradation of absorbable polyglycolide fracture fixation screws in the rabbit femur. Clin Orthop Relat Res. 1992; 285: 263-272.

5. Bhat SV. Biomaterials. Kluwer Academic Publishers, Boston, MT, USA: 2002; 265.

6. Witte F. The history of biodegradable magnesium implants: a review. Acta Biomater. 2010; 6: 1680-1692.

7. Goyer RA, Klaassen CD, Clarkson TW. Toxicity of metals, Casarett and Doull's Toxicology: The Basic Science of Poisons. USA: McGraw-Hill Book Company Inc. 2001; 811-868.

8. Institute of Medicine Standing Committee on the Scientific Evaluation of Dietary Reference Intakes. Dietary Reference Intakes for Calcium, Phosphorous, Magnesium, Vitamin D, and Fluoride. Washington, DC: National Academy Press, *1997.*

9. Zijian Lia, Xunan Gua, Siquan Loub, Yufeng Zheng. The development of binaryMg-Caalloys for use as biodegradable materials within bone. Biomaterials 2008; 29: 1329-1344.

10. Castellani C, Lindtner RA, Hausbrandt P, Tschegg E, Stanzl-Tschegg SE, Zanoni G, et al. Bone-implant interface strength and osseointegration: bio-degradable magnesium alloy versus standard titanium control. Acta Biomater. 2011; 7: 432-440.

11. Cecchinato F, Karlsson J, Ferroni L, GardinC, Galli S, Wennerberg A, et al. Osteogenic potential of human adipose-derived stromal cells on 3-dimensional mesoporous TiO2 coating with magnesium impregnation. Mater Sci Eng C Mater Biol Appl. 2015; 52: 225-234.

12. Charyeva O, Thormann U, Schmidt S, Sommer U, Lips KS, Heimann L, et al. *In Vivo* Comparison of New Biodegradable Magnesium-Based Implants for Orthopaedic Uses. Bone & Joint J, Orthopaedic Proceedings Supplement. 2014; 96: 247.

13. Witte F, Kaese V, Haferkamp H, Switzer E, Meyer-Lindenberg A, Wirth CJ, et al. *In vivo* corrosion of four magnesium alloys and the associated bone response. Biomaterials. 2005; 26: 3557-35663.

14. Xu L, Yu G, Zhang E, Pan F, Yang K. *In vivo* corrosion behavior of Mg-Mn-Zn alloy for bone implant application. J Biomed Mater Res A. 2007; 83: 703-711.

15. Seal, C. K., K. Vince, and M. A. Hodgson. Biodegradable surgical implants based on magnesium alloys-A review of current research. IOP ConfSer: Mater Sci Eng. 2009; 4: 1.

16. Witte F, Hort N, Vogt C, Cohen S, Kainer KU, Willumeit R, et al. Degradable biomaterials based on magnesium corrosion. Curr Opin Solid State Mater Sci. 2008; 12: 63-72.

17. Staiger MP, Pietak AM, Huadmai J, Dias G. Magnesium and its alloys as orthopedic biomaterials: a review. Biomaterials. 2005; 27: 1728-1734.

18. MagneZix Compression Screw 3.2. Product Information.

Cite this article

WetterlövCharyeva O (2017) Magnesium Screws and Plates for Bone Augmentation: a New Concept in Dental Surgery. JSM Dent Surg 2(1): 1011.