BIOMATERIALS IN MEDICINE

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Abstract

The article is a minireview on the use of biomaterials in medicine. Biomaterials have a central role in biomedical industry, being required in a broad range of medical applications for the purpose of diagnosis, prevention and therapy. They are used in orthopedics, vascular therapy, trauma, esthetic surgery, ophthalmology, maxillo-facial surgery, cardiology, urology and neurology by being integrated in implants, devices, prosthesis and drug-delivery systems. The metallic alloys are considered dominant biomaterials The main metalic representatives are commercially pure titanium, titanium alloys (Ti-6AI-4V, Ti-6Al7Nb, Ti-5Al-2.5Fe), stainless steel (316 and 316 L), tantalum, Co-Cr-Mo alloys and Mg alloys. Bioceramics became a group of materials of great importance for maxillo-facial surgery and orthopedics. Polymeric materials have a growing medical importance. Due to their biocompatibility, similar resistance of cortical bone, good corrosion resistance in the physiological environment.

Keywords: *biomaterials in medicine, metalic alloys, bioceramics, polymers, biocompatibility*

Introduction

Biomaterials have a central role in biomedical industry, being required in a broad range of medical applications for the purpose of diagnosis, prevention and therapy. They have found application in orthopedics, vascular therapy, trauma, esthetic surgery, ophthalmology, maxillo-facial surgery, cardiology, urology and neurology by being integrated in implants, devices, prosthesis and drug-delivery systems.

Biomaterial science combines physics, chemistry, medicine and materials science with the main purpose of continuous development and translation of biomaterials to clinical use. As a result of ongoing research, there is currently a wide variety of biomaterial alternatives with medical applicability available on the market. Biomaterials may be natural or synthetic. They can be metallic materials ornon-metallic materialssuch as polymeric compounds, composite materialsor ceramic materials.

From a practical and medical point of view, the metallic materials are considered dominant biomaterials, but nowadays there is a significant growth of other new biomaterials who are gaining increasing attention in the medical field.

The main metallic representatives are commercially pure titanium, titanium alloys (Ti-6AI-4V, Ti-6Al7Nb, Ti-5Al-2.5Fe), stainless steel (316 and 316 L), tantalum, Co-Cr-Mo alloys and Mg alloys. Those have a wide use in surgery lines due to their inert behavior, good biocompatibility and osteointegration capacity, good mechanical properties and compatibility with MRI scanning and other medical imaging techniques by having non-magnetic properties, excellent corrosion resistance in the physiological environment given by the stability of the oxide layer formed on the surface of the implant material when it comes about Ti[(21)], Tantalum and Co-Cr-Mo alloys [(1,2)], which helps with the passivation of the implant, or biodegradation kinetic in case of of Mg alloys [(4,5,16,17,19,24,25)].

Porous tantalum implants are relatively new in orthopedics but along with the advantages from above, its high porosity and its functional and mechanical properties similar to bone tissue made porous tantalum a highly attractive biomaterial [(6,7,8,15,26,27)].

Bioceramics became a group of materials of great importance for maxillo-facial surgery and orthopedics, with three basic classes: inert ceramics (alumina, zirconia, carbon), bioactive ceramics (glass ceramics, bioglass) and biodegradable and resorbable ceramics (carbonate-apatite, hydroxyapatite, coral).

Inert ceramics are highly attractive as dental implants due to their good stability and esthetics, biocompatibility with paradontal tissues and compatibility with medical imaging techniques, minimal thermal and electrical conductivity and chemical inertness and they can be the first choice in patients with titanium allergy.

Bioglass and glass ceramics show good biocomptibility, lack of cytotoxic effects, superior mechanical properties and the ability of forming an active layer of hydroxiapatite at the bone-implant interface that stimulates osteogenesis(9,18), attributes that helped them find a place in dental and orthopedic surgery lines.

Biodegradable ceramics such as hydroxyapatite which is the essential mineral component of the bone tissue, are ceramic materials based on calcium phosphate with a porous structure and high degree of similarity with the bone, characteristics that gives them a special bone-bonding ability. This bone-binding ability manifests by releasing calcium and phosphate ions followed by absorption by adjacent bone tissue, interactions that stimulate positive biological reactions at the material-tissue interface such as bone ingrowth into the porous structure. The porosity can be tailored to accelerate the physical dissolution process and the biological process of cell attachment and osteoid deposition(10).

Polymeric materials have a growing medical importance. Due to their biocompatibility, similar resistance of cortical bone, good corrosion resistance in the physiological environment(11,12,22,23) and their versatility, they are creating excitement in the biomaterials field. They can be tailored to have specific mechanical and physical properties in order to comply with the implant applications. Three of the most representative polymeric materials are PEEK (polyetheretherketone), PLA (polylactic acid) and PGA (polyglycolic acid). They can be used as alternatives to titanium implants in orthopedics, cranioplasty, osteotomy, maxillo-facial reconstructions and spinal surgery.

Biomaterials are being widely used in medicine from a long period of time in the form of devices, drug delivery systems or implants (stents, ligaments, prosthesis, screws,vascular grafts, heart valves, rods, plates, etc.) to repair damaged tissue, help with tissue regeneration or to restore tissue function. Appropriate selection of biomaterials plays a key role in biological response and to clinical performance. A biomaterial must possess multiple properties in order to be eligible, such as: biocompatibility (”the ability of a material to perform with an appropriate host response in a specific application"(12)), biostability (chemical, biological and structural resistance), biofunctionality(13), high corrosion resistance, no cytotoxic effects, good mechanical properties and to respect functional tissue structure and pathobiology when used as implants.

Therefore, all biomaterial science efforts are and will be focused on continually improving biomaterials, tissue-implant interface through bulk and surface modification (physical and chemical approaches, design of a bioactive surface implant), in order to enhance their medical utility, positive biological response, implant integration and to achieve a successful clinical performance.

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References

1. Wang, N., Li, H., et al.: Study on the anticorrosion, biocompatibility, and osteoinductivity of tantalum decorated with tantalum oxide nanotube array films. In: ACS Applied Materials & Interfaces 4 (2012) No. 9, p. 4516- 4523.

2. Levine BR, Sporer S, Poggie RA, Della Valle CJ, Jacobs JJ. Experimental and clinical performance of porous tantalum in orthopedic surgery. Biomaterials. 2006;27:4671–81.
3. S. Shadanbaz and G. J. Dias, “Calcium phosphate coatings on magnesium alloys for biomedical applications: a review”, ActaBiomaterialia, vol. 8, no. 1, pp. 20–30, 2012.
4. D.Persaud-Sharma and A. McGoron, “Biodegradable magnesium alloys: a review of material development and applications,” Journal of Biomimetics, Biomaterials and Tissue Engineering, vol. 12, no. 1, pp. 25–39, 2011.
5. Hanzlik, J.A., Day, J.S., et al.: Bone ingrowth in well-fixed retrieved porous tantalum implants. In: The Journal of Arthroplasty 28 (2013), p. 922-927.
6. Shimko DA, Shimko VF, Sander EA, Dickson KF, Nauman EA. Effect of porosity on the fluid flow characteristics and mechanical properties of tantalum scaffolds. J Biomed Mater Res B Appl Biomater. 2005;73:315–24.
7. Cohen R. A porous tantalum trabecular metal: Basic science. Am J Orthop (Belle Mead NJ) 2002;31:216.
8. Loty C., Sautier J.M., Tan M.T., Oboeuf M., Jallot E., Boulekbache H., Greenspan D., Forest N. - Bioactive glass stimulates in vitro osteoblast differentiation and creates a favorable template for bone tissue formation, Journal of bone and mineral research, 2001; 16(2):231-9.
9. R. Sarkar, G. Banerjee, Ceramic Based Bio-Medical Implants.
10. Liao K. Performance characterization and modeling of a composite hip prosthesis. Exp Tech. 1994;18:33–38.
11. Moon SM, Ingalhalikar A, Highsmith JM, Vaccaro AR. Biomechanical rigidity of an allpolyetheretherketone anterior thoracolumbar spinal reconstruction construct: an in vitro corpectomy model. Spine J. 2009;9:330–335.
12. DF Williams, The Williams Dictionary of Biomaterials (Liverpool, UK: Liverpool Univ. Press, 1999), 40.
13. Courtesy R. Zenz, Conference on Biomaterials WS2008,For Genomics and Bioinformatics.
14. Kelsey DJ, Springer GS, Goodman SB. Composite implant for bone replacement. J Compos Mater. 1997;31:1593–1632.
15. Mozella, A.P., Olivero, R.R., et al.: Use of a trabecular metal cone made of tantalum, to treat bone defects during revision knee arthroplasty. In: RevistaBrasileira de Ortopedia (English Edition) 49 (2014), p. 245-251.
16. S. Zhang, X. Zhang, C. Zhao et al., “Research on an Mg-Zn alloy as a degradable biomaterial,” ActaBiomaterialia, vol. 6, no. 2, pp. 626–640, 2010.
17. H. Waizy, J.-M. Seitz, J. Reifenrath et al., “Biodegradable magnesium implants for orthopedic applications,” Journal of Materials Science, vol. 48, no. 1, pp. 39–50, 2013.
18. Andrade A.L., Valerio P., Goes A.M., de Fatima Leite M., Domingues R. Z. - Influence of morphology on in vitro compatibility of bioactive glasses, Journal of Non-Crystalline Solids, 2006; 352:3508–11.
19. Liu C, Ren Z, Xu Y, Pang S, Zhao X, Zhao Y: Biodegradable Magnesium Alloys Developed as Bone Repair Materials: A Review, March 2018.
20. S.M. Kurtz, J.N. Devin, PEEK Biomaterials in trauma, orthopaedic, and surgical implants, Biomaterials 28 (32) (2007) 4845–4869.
21. Wilson Wang șiChyeKhoonPoh – Titanium alloys in orthopaedics; 2013; DOI:10.5772/55353.
22. Yu S, HariramKithva P, Kumar R, Cheang P, AikKhor K. In vitro apatite formation and its growth kinetics on hydroxyapatite/ polyetheretherketone, biocomposites. Biomaterials. 2005;26(15):2343–2352;
23. Toth JM, Wang M, Estes BT, Scifert JL, Seim HB, 3rd, Turner AS. Polyetheretherketone as a biomaterial for spinal applications. Biomaterials. 2006;27(3):324–334.
24. A. C. Hänzi, I. Gerber, M. Schinhammer, J. F. Löffler, and P. J. Uggowitzer, “On the in vitro and in vivo degradation performance and biological response of new biodegradable Mg-Y-Zn alloys,” ActaBiomaterialia, vol. 6, no. 5, pp. 1824–1833, 2010.
25. W.J. Ciccone, et al., Bioabsorbable implants in orthopaedics: new developments and clinical applications, JAAOS 9 (5) (2001) 280–288.
26. Osseous integration in porous tantalum implants Christos G Paganias, George A Tsakotos, Stephanos D Koutsostathis, George A Macheras, 2012.
27. Wegrzyn, J., Kaufman, K.R., et al.: Performance of porous tantalum vs. titanium cup in total hip arthroplasty: randomized trial with minimum 10- year follow-up. In: The Journal of Arthroplasty 30 (2015), p. 1008-1013.