Review Article

Bioabsorbable Implant Materials: A Review

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Received: 05-08-2013

Revised: 26-09-2013

Accepted: 02-10-2013

Abstract:
The use of bioabsorbable materials has become commonplace in surgery. These devices have expanded the armamentarium of the surgeon and the worldwide market is expanding rapidly. Despite the popularity of these implants, reports of complications continue to appear in the literature. The purpose of this review is to compare the polymers and to discuss properties of the polymers used as implant materials.

Keywords: Bioabsorbable, Implants, Polymers

This article may be cited as: Garg P, Ashutosh, Nagarth H, Pahuja M, Goyal S, Kaur RK, Singh S. Bioabsorbable Implant Materials: A Review. J Adv Med Dent Scie 2013;1(2):83-85.

Introduction

Implant design is integral to successful surgical intervention. Ever-changing methods of fixation and materials are studied and used to help attain improved results while limiting adverse outcomes. The development of bioabsorbable implants is an important aspect of this dynamic field of implant design. There are many options available to the surgeon who is interested in using bioabsorbable materials.[1] Bioabsorbable polymers are becoming more popular as implant materials. These implants have several leverages over the traditional metallic implants including reduced stress shielding since the implants bear less load initially and gradually transfer the load as they degrade.[2] This article reviews the three most common materials used in bioabsorbable implants in orthopaedic surgery: polyglycolic acid, polylactic acid, and polydioxanone.

Comparison of Metal Implants and Bioabsorbable Implants

Although metal implants have shown undoubted success when used for internal fixation of bones or soft tissue, these implants do have some problems. Metal implants are stiff and are permanent in nature. Thus, they tend to unload the tissues by load bearing and may necessitate removal because of the need for future surgery, migration of the implants over time, or irritation of the overlying tissues. Metal implants also interfere with radiologic imaging of the underlying skeleton. Bioabsorbable implants show promise with regards to these points in that they will degrade over time and gradually allow loading of the bone and soft tissues. They do not interfere with future surgery because they have been absorbed or can be drilled through. Furthermore, they do not require removal and are radiolucent on roentgenograms. We are currently seeing an increase in the development of these devices and find them as fixation rods, plates, pins, screws, suture anchors, and sutures.[1]

Properties

These materials are polymers, meaning they are composed of covalently bonded monomers to create macromolecules.[1,3] Polymers can be made of a repeating single monomer (homopolymer) or a combination of 2 or more types of monomers (copolymer). Moreover, these copolymers can have a random arrangement of its monomers (random copolymer) or they can have long segments of monomers alternating with other segments (block copolymer).[1,4] Polymer chains can be linear, branched, or cross-linked with other chains. The polymer chains can be organized in either an amorphous or a crystalline state. More typically, these materials are made up of both amorphous and crystalline regions. This “semicrystalline” structure affects the strength and absorption of these implants.[1,4] A more crystalline structure leads to a stronger construct because of more order within the microstructure and less slippage between neighboring chains. This slippage of the chains is time dependent under load; thus, they are viscoelastic structures. Polymers are also affected by temperature. Above a specific temperature (glass transition temperature [Tg]) the polymers soften and become flexible. It is thus important to have bioabsorbable polymers that have a Tg above body temperature.[1,3] The molecules behavior is further governed by orientation, geometric isomerism, conformation, and configuration.[1,5] PLA exists as either L-PLA (mostly crystalline) or DL-PLA (mostly amorphous). PGA exists in only 1 form. Homopolymer PGA has greater strength than PLA.9 PDS is a colorless, crystalline polymer. PDS is produced through melt extrusion of granules through a dye and then completed by heat treating the polymer.[1] Inherent in the name, bioabsorbable implants should effectively degrade and eventually be resorbed or excreted. This occurs first through a loss of molecular weight, loss of strength, and then a loss of material over time.[1]

The type of implant, method of manufacture, method of sterilization, and site of implantation all affect the degradation of the implant and the resulting biological response, making it difficult to make generalizations on the cause and possible solution for the foreign body response.[2] Resorption of polymers generally occurs in two phases.[6] In the first phase, the polymer chains are broken down through hydrolysis. In this phase, the molecular weight drops first, followed by mechanical strength loss, and finally by a loss of mass.[7] In the second phase, the implant loses its form and breaks physically into particles, which are attacked by macrophages. Depending on the size of the particulates, they are phagocytosed and the byproducts are excreted by the kidneys and lungs. The corresponding biological response to the degrading polymer is thought to happen as a result of either a buildup of acidic degradation products or as a response to the particulates of the polymer.[8] The timing of the foreign-body response is thought to be related to the final stage of polymer degradation.[2]

PGA is broken down into glycine. Glycine is either excreted in the urine or converted into carbon dioxide and water through the citric acid cycle. Lactic acid, a normal human metabolic byproduct, is the breakdown product of PLA and it also is converted to water and carbon dioxide in the citric acid cycle. PDS is either broken down into glycoxylate and excreted in the urine or converted into glycine then carbon dioxide and water through the same mechanism as PGA. The time it takes for degradation to occur is related to the copolymer's porosity, crystallinity, and molecular weight.[1,9]

These 3 copolymers can have a variety of mechanical properties based on their crystallinity, viscosity, and molecular weight. The manufacturing process affects these mechanical properties. The flexural strength, tensile strength, and tensile modulus have been tested on all of the available materials. Compared with stainless steel, these properties are poor. To improve the mechanical properties of bioabsorbable implants, fiber-reinforced implants have been designed. These materials have much higher tensile strength because of the orientation of fiber molecules. And, when the fibers are combined with a matrix of the same polymer (self-reinforcement), the mechanical properties improve substantially. In fact, initially, the bending strength of self-reinforced PGA is stronger than stainless steel but quickly decreases with degradation.[1,10]

Conclusion

Bioabsorbable implants are widely used in orthopedic surgery today and the worldwide market is expanding rapidly. These devices have expanded the armamentarium of the surgeon. Despite the popularity of these implants, reports of complications continue to appear in the literature.[1,2]

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Source of support: Nil

Conflict of interest: None declared