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Polymers in Clinical Practice: A Beginning of a Revolution

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Abstract

The science of polymer engineering has led to the development of a wide range of compounds which offer an extensive spectrum of physical and chemical properties rendering these compounds therapeutically useful. These compounds are now widely used in a variety of surgical settings thus providing superior surgical results without significant side effects. The paper reviews the basics of polymer compounds relevant to clinical practice.

Key words: *polymers, biodegradable, clinical applications.*

Introduction

Polymer compounds have been in use in clinical practise for over 30 years. Extensive research on polymer compounds with respect to biodegradation, inertness and strength has led to the evolution of more sophisticated polymer molecules. As a result, these newly developed polymer compounds have found their application in every branch of clinical practise.

Polymer Chemistry

Metals were widely used in clinical practise. However these caused significant amount of complications in the human body. The advent of polymer based materials has significantly revolutionised surgical practise. The isotonic saline environment of the human body happens to be extremely hostile to metals. However it is not usually associated with significant degradation of high molecular weight polymers. The degradation of the materials and the release of the degradation products may at times be dangerous for clinical use. The use of homo chain high molecular weight polymers which elicits minimal response has immensely helped in the evolution of biocompatible and biodegradable compounds.

Every branch of clinical practise demands a wide spectrum of physical and chemical properties of polymer compounds. Certain basic criteria need to be satisfied to render a polymer compound clinically viable. [1]These include

1. The mechanical properties with respect to strength should match the clinical need until healing of the surrounding tissues has taken place.
2. The compound should be inert and should not elicit a toxic reaction.
3. The degradation time should match the needs of the purpose.
4. The compound should be metabolised in the human body only after fulfilling its need.
5. It should be easily reproducible with an acceptable shelf life.
6. It should be easily sterilized without causing physical or chemical damage to the material.

Biodegradation

The physiological environment of the human body is isotonic saline environment. The fluid is complex as it contains a wide range of anions, cations and organic molecules as well. In addition to these molecules the metabolic processes in the cells may also significantly alter the internal environment. This complex environment plays a significant role in the degradation of polymers. Knowledge of the degradation process and the factors affecting it is of utmost importance while using such compounds as implants in the human body.

Susceptibility of polymers to degradation under physiological conditions is a complex process with a wide range of reaction kinetics. [1, 2] The process is generally divided into 2 types:

1. Those which involve absorption of some kind of energy to cause disruption of primary covalent bonds releasing free radicals. This in turn causes further propagation of molecular degradation by secondary reactions.

   The factors which affect this process include elevated temperatures, presence of oxygen to give thermal oxidation, electromagnetic radiation, and mechanical stress at elevated temperatures giving thermo-mechanical degradation and ultrasonic vibrations. The promising part of the whole process is that the human physiological environment does not have any of the aforementioned physical factors acting on the implanted polymer. As a result the implanted polymers remain stable without significant biodegradation, thus fulfilling the therapeutic purpose.
2. Various hydrolytic mechanisms wherein the depolymerisation process continues. Hydrolysis in the midst of an aqueous extra cellular fluid poses a great challenge to the chemical structure of the polymer

compound. The polymer structure has to be carefully designed to meet these chemical challenges. The polymer has to contain hydrolytically unstable bonds. For degradation to occur the polymer should be hydrophilic which will enable the medium producing hydrolysis to gain access to the susceptible bonds. This entire process of hydrolysis should take place within the physiological range of the human body pH which ranges from 7.36 to 7.44.

Biodegradable Polymers

The property of degradation of polymer compounds is instrumental in widening the applications in clinical practise. These compounds are of particular use during the course of surgical intervention. The use of biodegradable polymer obviates the need for removal when used as implants thus eliminating the need for a second surgery. The backbone of the polymer is hydrolytic instability. [3] Water penetrates the implant breaking the chemical bonds and converting long chains into shorter water soluble fragments. There is reduction in the molecular weight without much loss of physical strength. In addition to water penetration, surface erosion of the polymer also occurs leading to biodegradation. Polymer engineering has to tailor make the compound rendering it slow to degrade while transferring the stress at an appropriate rate to the surrounding tissues as they heal taking into consideration the chemical stability of the polymer compound, the nature of the device and the presence of additives, plasticizers and catalyst.

Another promising event in the same direction is the use of nanocomposites which contain biodegradable polymers and organically modified layered silicates which impart better mechanical and thermal properties enabling faster decomposition by virtue of a low degree of crystallinity and intercalation of initiators of polymer degradation into the interlayer space of the silicates. [1,3,4] As a result, macromolecules are broken down into oligomers which are eventually processed by bacteria. The final products of breakdown are carbon dioxide and water.

Clinical Application

1. Suture materials: eg; Polyglycolate, polylactate.
2. Drug carriers in controlled drug delivery systems.
3. Orthopaedic fixation devices.
4. Biodegradable vascular stents.
5. Biodegradable soft tissue anchoring devices.
6. Tissue scaffolds to enhance healing in wounds with extensive tissue loss.
7. Dental implants.

Conclusion

The growing field of biodegradable polymer technology has revolutionised treatments in various branches of medicine.

Developments of new molecules based on the clinical requirements and the properties of individual molecules is the biggest challenge for polymer engineers.

Understanding the intricacies of chemical and physical properties of polymer compounds is pivotal in the process of developing newer compounds with extensive therapeutic applications in medicine.

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