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BIOMATERIALS USED IN GASTROINTESTINAL ENDOSCOPY

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Abstract

Biomaterials play a critical role in gastrointestinal endoscopy, revolutionizing the diagnosis and treatment of digestive disorders by improving the performance and safety of medical devices. This review provides a detailed analysis of the types of biomaterials used, including metals, synthetic polymers, biodegradable materials, and composites, highlighting both their advantages and limitations. Biocompatibility, adaptability, and sustainability are key characteristics that underpin the success of biomaterials, but challenges such as high costs, biocompatibility complications, and environmental impact require innovative solutions. Future research also focuses on the development of smart and sustainable biomaterials to improve the accessibility and efficiency of endoscopic procedures. The results highlight the need for interdisciplinary collaboration to fully harness the potential of biomaterials in medical practice.

Keywords: biomaterials, gastrointestinal endoscopy, biocompatibility, biodegradable materials.

Introduction

Gastrointestinal endoscopy (GIS) is one of the most widely used medical techniques for diagnosing and treating gastrointestinal tract disorders. Endoscopic procedures allow direct visualization of the gastrointestinal mucosa, taking biopsies, and performing therapeutic interventions, all of which minimize the invasiveness and risks associated with classic surgeries. The continuous development of medical technology has led to the diversification of equipment and materials used in endoscopy, with biomaterials having a central role in optimizing clinical outcomes [1-3].

In recent decades, biomaterials have become indispensable in endoscopic practice. From the simple use of traditional metal materials for stents and instruments to the introduction of advanced biopolymers, endoscopy has benefited from innovations that have improved the durability, biocompatibility, and functionality of the devices used [1-3].

The use of modern biomaterials in EGI has a significant impact on the quality of healthcare. Devices made of advanced biomaterials allow for better adaptation to the patient's anatomy, minimizing the risk of discomfort or iatrogenic injury. For example, stents made of nitinol, a shape memory alloy, are preferred for their ability to expand and adapt precisely to the treatment area, thus reducing the risk of migration. In addition, biodegradable biomaterials, such as polymers, are used for temporary devices, eliminating the need for additional intervention to remove them [1-4].

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As the complexity of endoscopic procedures increases, the need for biomaterials with superior characteristics becomes evident. Traditional materials, such as stainless steel or other metals, are often limited by their rigidity and the risk of corrosion. Advanced biomaterials, such as collagen-based, biodegradable polymers, and ceramic materials, offer safer and more effective solutions to clinical challenges. They also reduce complications, such as perforations or inflammatory reactions, and improve the healing process of tissues [2-5].

This review aims to analyze the contribution of biomaterials in the field of gastrointestinal endoscopy, addressing both their advantages and disadvantages. Emphasis will be placed on the specific characteristics of the biomaterials currently in use, as well as their limitations, which require further research. The importance of identifying new biomaterials that meet increasingly complex medical requirements will also be discussed. This critical review, it is intended to highlight future research directions and the importance of interdisciplinary collaboration for the development of new biomaterial solutions in endoscopy.

Types of biomaterials used in gastrointestinal endoscopy

Biopolymers are among the most commonly used biomaterials in endoscopy, due to their biocompatibility and ability to adapt to biological structures. Examples such as collagen and chitosan are used in stent coatings, endoscopic dressings, or absorbable suture materials. Collagen, due to its natural tissue regeneration properties, is preferred in therapeutic applications, including in treatments for gastric ulcers or fistulas [3-6].

Metallic materials, such as nitinol and stainless steel, play a critical role in making stents and other devices used in endoscopy. Nitinol, a shape memory alloy, is ideal for esophageal and biliary stents due to its ability to expand at body temperature and provide stable fixation [3-6].

Ceramic materials and composites are mainly used for coatings that improve biocompatibility and corrosion protection. For example, endoscopic metal devices are often coated with ceramic layers to minimize interaction with tissues and reduce the risk of inflammatory reactions. In addition, composites, which combine organic and inorganic materials, offer superior mechanical strength and increased flexibility, being used in the making of catheters and other flexible devices [4-7].

Synthetic polymers such as polyurethane and silicone are widely used in endoscopy due to their flexibility and durability. Polyurethane is preferred for flexible tubes and catheters used in complex endoscopic procedures due to its ability to withstand repeated movements without damage. Silicone is frequently used for temporary devices such as drainage tubes due to its excellent biocompatibility and resistance to microbial adhesion (table 1), [4-8].

Table 1. Types of biomaterials used in gastrointestinal endoscopy (EGI) [3-9].

Type of biomaterial	Common examples	Key Properties	Applications in EGI	Advantages	Disadvantages
Metals and alloys	Nitinol, stainless steel	High mechanical strength Elasticity (nitinol)	Esophageal, biliary, and pancreatic stents Biopsy forceps	High durability Corrosion resistance	High costs Risk of stent migration
Synthetic polymers	Polyurethane, silicone	Flexibility Biocompatibility	Drainage tubes Endoscopic catheters Temporary	Low cost Easy handling	Potential allergic reactions Limited

Type of biomaterial	Common examples	Key Properties	Applications in EGI	Advantages	Disadvantages
			prostheses		durability
Biopolymers	Collagen, chitosan	Biodegradability Tissue regeneration capacity	Endoscopic dressings Absorbable suture material	Excellent biocompatibility Promotes healing	Low mechanical strength
Biodegradable materials	PLA, PGA	Controlled degradation in the body	Temporary stents Absorbable devices	Eliminates the need for additional interventions	Potentially irritating byproducts High costs
Ceramic materials	Zirconium oxide, silica	Corrosion resistance High biocompatibility	Coatings for stents Protection against bacterial migration	Minimizes inflammatory reactions	Fragility Difficult processing
Composite materials	Carbon fiber, hybrid materials	Combination of strength and flexibility	Flexible catheters Supporting devices	Superior mechanical performance	High costs Complex manufacturing process
Smart biomaterials	pH-sensitive hydrogels, nanomaterials	Responsive to external stimuli (temperature, pH)	Controlled drug delivery Adaptive stents	Personalized functionality Therapeutic efficiency	Early-stage research High costs

An emerging field in endoscopy is the use of biodegradable biomaterials such as polylactic acid (PLA) and polyglycolide (PGA). These materials are used for stents and other devices that require controlled degradation after they have performed their therapeutic function. Biodegradable biomaterials eliminate the need for an additional procedure for removal, reducing risks to the patient and costs associated with medical care [6-9].

The diversity of biomaterials used in endoscopy reflects the complexity and specificity of medical procedures in this field. Choosing the right material depends on many factors, including the therapeutic purpose, tissue compatibility, and the required duration of the device's function. As research advances, biomaterials will continue to evolve, opening up new possibilities for improving the quality of medical care and patient safety [7-10].

Types of materials used in gastrointestinal endoscopy

Metallic materials are essential in the realization of devices used in endoscopy, due to their strength and durability. Nitinol, a shape memory alloy, is commonly used for esophageal, biliary, and pancreatic stents due to its ability to return to its original shape in biological environments. Stainless steel is preferred for rigid instruments such as biopsy forceps, being valued for its corrosion resistance and affordable cost.

Synthetic polymers such as polyurethane, silicone, and polyethylene are widely used in endoscopic procedures due to their flexibility and biocompatibility. Silicone is often used in drainage tubes and endoscopic catheters, providing easy handling and a reduced risk of side effects. Polyurethane, due to its mechanical strength, is preferred for devices that require a long service life, such as stents[10-14].

Biodegradable materials, such as polylactic acid (PLA) and polyglycolide (PGA)--based polymers, are increasingly being used for temporary devices, such as stents that dissolve after a set period. These materials reduce the risk of complications associated with permanent devices and eliminate the need for additional removal interventions [10-14].

Endoscopy explores the use of composite materials and smart biomaterials, which can respond to stimuli such as temperature or pH. These materials allow for personalized functionality and better adaptation to clinical needs, showing promise for the future of endoscopic devices [10-15].

Modern biomaterials are designed to be highly biocompatible, minimizing the risk of side effects, such as inflammation or rejection by the body. This is essential in endoscopy, where devices come into direct contact with sensitive mucous membranes and tissues. The use of biocompatible biomaterials contributes to faster healing and reduces post-procedural complications [13-17].

The flexibility and customization of biomaterials allow for better adaptation to the specific clinical requirements of each patient. For example, stents made of nitinol can be shaped so that they extend and provide support in complex anatomical areas, such as the esophagus or bile ducts. At the same time, biodegradable biomaterials eliminate the need for additional interventions to remove devices, reducing stress for the patient [16-18].

Many biomaterials, including metal alloys and synthetic polymers, offer high mechanical strength, ensuring the durability of devices used in endoscopic procedures. These properties allow the repeated use of devices or the maintenance of their functionality for an extended period, even under difficult biological conditions [17-20].

Advanced biomaterials enable more efficient and high-performance endoscopic devices, such as flexible instruments and smart stents. These innovations help reduce procedure time, increase accuracy, and improve therapeutic outcomes. Biomaterials have revolutionized gastrointestinal endoscopy, providing safe, effective, and adaptable solutions for a wide range of clinical applications [18-22].

Conclusions

Biomaterials have transformed the field of gastrointestinal endoscopy, offering innovative solutions for the diagnosis and treatment of complex conditions of the digestive tract. They significantly improve the performance of medical devices, increasing patient safety and comfort, through features such as high biocompatibility, adaptability to human anatomy, and the ability to support healing processes.

Progress in the use of biodegradable and smart biomaterials opens up new perspectives in medical practice, eliminating the need for additional interventions and optimizing therapeutic outcomes.

However, there are notable limitations that cannot be ignored. The high costs, biocompatibility risks, premature degradation, and environmental impact of synthetic materials underline the need for continuous improvements. In this context, research becomes essential for the development of more accessible, sustainable, and sustainable biomaterials. Future innovations need to integrate technologies such as 3D printing, artificial intelligence, and nanotechnology to personalize and streamline endoscopic devices.

Biomaterials are a fundamental pillar of progress in gastrointestinal endoscopy, contributing to improving the quality of life of patients. However, their widespread adoption depends on striking a balance between technological performance, costs, and environmental impact. An interdisciplinary approach involving doctors, researchers, and engineers is vital to overcome current challenges and turn biomaterials into reference solutions for endoscopic practice.

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