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Characteristics of Wound Dressings and Dressings Based on Natural and Synthetic Polymers (Review Article)

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Abstract
The article describes natural and synthetic polymeric materials used as the basis for the production of wound dressings. Methods for obtaining, stabilizing and sterilizing ready-made wound coverings, as well as the results of studies of antimicrobial and wound healing properties are considered.

Keywords: Wound dressings, cellulose, alginate, chitosan, polyvinyl alcohol, hydrogel, biocompatibility.

The aim of the study is to review the literature data covering the development and application of a new generation of dressings made on the basis of natural and synthetic polymers.

Materials and Methods

The materials of the study were reliable literature data, including articles, patents containing information about the range of modern wound dressings, the composition of biologically active substances and the prospects for use in medicine. The study was conducted using information retrieval and library databases. The research used informational, analytical and descriptive methods.

Introduction

Dressings of the new generation are characterized by great diversity, differ significantly from existing analogues in composition, design and properties. Dressings are used in everyday life to protect the wound from secondary damage and infection, as well as in special medical institutions during operations to stop bleeding and drain the surgical field [1].

At the same time, a number of requirements are imposed on dressings, such as sterility, atraumaticity, elasticity, and the absence of toxic and local irritating effects. Another qualitative characteristic is the possibility of non-contact control of the wound. Modern systematization of dressings of a new generation is carried out according to

various characteristic features [2]. Dressings such as gauze, mesh, knitwear are made from natural materials and are fibers, threads, fabrics made from wood and cotton. Synthetic polymers can be used to produce nonwoven materials such as films, sponges, hydrocolloids, gels, and pastes [3, 4]. The variety of modern polymeric materials expands the physicochemical characteristics, variety and effectiveness of dressings.The first and largest group consists of wound dressings based on cellulose and its derivatives. This is due to the presence of a variety of raw materials and technological processes. To obtain wounded coatings from cellulose, the method of chemical modification of the polymer and the introduction of functional groups are used. The drug components can then be absorbed onto the coating. after chemical modification, cellulose can acquire its own physiological activity, which allows it to be used as a medicinal form without the addition of medicinal substances. Wound cellulose-based coatings have high adhesive properties, the physical and mechanical properties of dressings make it possible to sterilize the finished product. The use of viscose fiber, partially hydrolyzed with cellulose, makes it possible to increase the sorption properties of the wound dressing by 90% compared to the original fiber, which helps to reduce wound contamination. However, in the treatment of purulent wounds, the use of woven covering materials leads to occlusion and the development of pathogenic microflora.

Therefore, many studies are devoted to the modification of traditional dressings based on cellulose gauze in order to eliminate existing shortcomings and impart new properties. There are many data in the literature on the cellulose derivative of carboxymethyl cellulose containing functional groups of the acid type. Carboxymethylcellulose is able to bind peptides and thus inhibit elastase activity. Monocarboxycellulose derivatives are used in the production of hemostatic wound dressings [5].By repeated impregnation of monocarboxycellulose material with soluble lincomycin, the so-called film with lincomycin was obtained, which is approved for use and is intended for the prevention and treatment of hyoid-inflammatory processes of various localization and origin, especially in the presence of diffuse tissue bleeding [6]. Carboxymethylated cellulose was impregnated with a solution of furagin or chlorhexidine bigluconate, followed by treatment with an alcoholic solution of menthol to impart antimicrobial properties [7].

Oxidized medical gauze dialdehyde cellulose was used for covalent binding of lysozyme [8]. Also, a pronounced antimicrobial effect can be achieved when using quaternary ammonium base catamine-AB, including preliminary activation of cellulose tissue or gauze with sodium dichloroisocyanurate or hydrogen peroxide [9, pp. 113-114]. Another important criterion is biocompatibility, while not causing an irritating effect and not having a toxic effect. Wound dressings based on alginate are characterized by good biocompatibility and have a stimulating effect on regeneration processes [10, 11]. Alginates are used as gelling agents; the degree of their structuring

can be controlled by the introduction of cations, such as calcium. This principle underlies the creation of many wounded coatings in the form of sponges and fibers.

To ensure the elasticity of the wound cover, polyethylene oxide is introduced into its composition. Also, to give additional antimicrobial properties, antimicrobial substances such as furatsilin, solufur, iodopyrone, catapol, dioxidin or estonia can be included [12, p.328]. The prolongation of the therapeutic effect of alginate materials is achieved in different ways, but is limited by the low solubility of the drug in water. Non-woven alginate wipes obtained from alginate materials are recommended for use in surgery as a homeostatic material [13].Another natural polymer used as a base or component in wound dressings is collagen. The main disadvantage of using native collagen is its almost complete solubility in various solvents [14]. Sponges are the main type of collagen-based wound coverings. The solubility and density of sponges is determined by the technology of their production, in particular, by freeze-drying. For stability, the sponges can be additionally structured in formaldehyde vapor [15]. The use of collagen makes it possible to obtain multilayer membranes. The sponge layer immediately adjacent to the wound is saturated with the antibiotic. Under Invitro conditions, the antibiotic is released from the coating within 3 days. In "artificial skin", the antibiotic is introduced not into the collagen sponge adjacent to the wound, but into the outer silicone layer by incorporating poly-L-lactide microspheres containing the medicinal substance into its structure. Polymers of a different chemical nature, such as chitosan, can also be used as part of collagen coatings. The structure of the collagen sponge is dispersed by a powdered sorbent made from natural or synthetic polymers (dextran, carboxymethylcellulose, chitosan, partially cross-linked polyvinyl alcohol), or inorganic compounds. The sponge may contain an antimicrobial and/or anesthetic agent. furagin. Such a coating provides drainage of the wound and retains its shape, however, the authors note that lysis of the layer adjacent to the wound and adhesion create difficulties in dressing. Other biopolymers are also used as the basis or constituent components of wound dressings: hyaluronate, its mixture with gelatin, or a mixture of gelatin with collagen, chitosan, alginate, which is crosslinked to increase resistance to the action of collagenase in vitro. The coatings may contain gentamicin sulfate, silver sulfadiazine, or another biologically active substance such as a growth factor. As already noted, the principle of multi-layering is actively used in the design of wound coverings.

In this case, polymeric materials of different chemical nature and physical form are combined, as this allows their properties to be fully used. Usually the layer adjacent to the wound is atraumatic, it provides maximum outflow of the separated and its retention in the sorbent layer.

The simplest variant of such means are dressings, which are a set of materials, where the first layer is a polyester mesh or medical gauze, and the sorption layer is a non-woven fabric. As a rule, one of the dressing layers contains an antimicrobial substance,

the amount and rate of desorption of which is regulated by varying the structure of the drug substance, the type of fibrous material, and the chemical bond between the active component and the material. To increase atraumaticity, a wax coating and an ointment with a medicinal substance (Voscopran dressings) are applied to the mesh base. In another type of multi-layer dressings, the layers cannot be separated, since one of them is the carrier of a multi-layer polymer layer, partially penetrating into the first. The polymer layer turns into a gel upon contact with the wound. This principle is used to create biologically active dressings with collagen, polysaccharide, or other coatings (Coletex, Activetex) [16, 2]. Approved therapeutic dressings contain furagin or chlorhexidine bigluconate, dimethyl sulfoxide, metronidazole, mexidol, etc. [16, 2]. Textile-based dressings with a polymer coating are characterized by the absence of a pronounced two-layer structure. Treatment of the matrix with a polymer composition gives it increased wettability and provides a prolonged therapeutic effect for 2-3 days. It should be noted that at present, wound dressings based on composite materials prevail among other analogues. In the form of gels, films, plates, powders, they are obtained from a mixture of polymers, sometimes with different thermodynamic compatibility. The advantage of such materials is the possibility of changing the composition and structure in a wide range which allows you to control the properties of the polymer matrix and the level of biological activity.Hydrogel coatings in the form of dense gel plates with a protective layer or amorphous gel are applied to the wound and covered with a napkin on top. When using non-drying hydrogel coatings, healing is faster, dressings are easier to perform, and the coating itself is easily removed without damage from the regenerated surface [17]. To achieve a greater effect, hydrogel dressings are saturated with antimicrobial substances. It is recommended to use a number of dosage forms with an antiseptic or antibiotic approved for use (“Appolo”).

This method created wound dressings based on hydrogel, which contains a cross-linked copolymer of N,N-methylenebisacrylamide, acrylamide and/or sodium acrylamide, as well as polyvinylpyrrolidone and plasticizers - glycerol and propanediol [4]. For greater stability, mesh, medical gauze, or other natural or synthetic materials can be used as a carrier for the gel. A hydrogel composition for wound healing, made from a mixture of polystyrene-polyethylenebutylene block copolymer and petroleum jelly, is also proposed to be applied to gauze when used. The composition may contain a biologically active component from a number of anti-inflammatory, painkillers, antibiotics, antifungal, antibacterial, antiseptics, anesthetics, growth factors. The action of the bioactive polyvinyl alcohol gel coating is based on the principle of activating a polymer containing a chemically bound antibiotic only in the case of infection of the wound. Gentamicin is linked to polyvinyl alcohol by a peptide bond containing an a-D-Phe-Pro-Arg fragment. Because

hydrogels are structured polymeric compositions, then diffusion restrictions may occur during desorption from the polymeric carrier of medicinal substances.

At present, the kinetics of the release of substances of various chemical nature (hydrophilic, hydrophobic, proteins) from a hydrogel obtained on the basis of a composition of human serum albumin and polyethylene glycol has been studied. It has been established that the half-life of theophylline from such a carrier is 0.8 hours, and that of lysozyme is 4.2 hours. Desorption of the active substance from a matrix containing more than 96% water can be controlled by changing its porosity and thickness.Means for the treatment of wounds in the form of polymer compositions based on a mixture of polysaccharides have been developed. They include a water-soluble cellulose derivative (methylcellulose or carboxymethylcellulose, or a mixture thereof), alginic acid and at least one other polysaccharide from the group: carrageenan, pectin, fucoidin, zosterol, gum arabic, xanthangam, tragacanth.

The composition forms an elastic, vapor-permeable coating on the wound that does not require additional fixation. Antiseptics (miramistin, chlorhexidine), antibiotics (lincomycin, gentamicin) and other substances are used as an antimicrobial substance. Rubber latex may be included in the bandage.Among the draining sorbents used at the stage of wound dehydration and converted into a gel, are products made from copolymers of vinyl acetate and vinyl glutarate in the form of a powder with a particle size of 10–1500 μm (sorbents “Diovin”, “Anilodiovin”) with additives of antimicrobial (dioxidine) or another medicinal substance (anilocaine) [4]. Along with hydrophilic coatings, hydrophobic coatings are also being developed, in particular, polyurethane or polysiloxane coatings [9, pp 128-. 129]. Unfortunately, in [9, pp. 128-129] are not given kinetic characteristics of drug desorption, which is of great interest due to the hydrophobicity of the polymer matrix. A number of studies have shown that hydrophobic materials are inferior in many characteristics to materials made from hydrophilic polymers. So, in a comparative study of collagen and polyurethane films, there was no discomfort and faster wound healing (for 5 days) when using collagen coatings. Therefore, polyurethane is combined with hydrophilic polymers, for example, a collagen or fibrin layer is created. In a separate group, wound dressings based on chitin derivatives, in particular chitosan, can be distinguished. The uniqueness of chitosan as a carrier of medicinal substances lies in its chemical nature - a cationic biodegradable polymer with its own physiological activity. The physical form of chitosan dressings is very different: fibrous, in the form of films, a spongy asymmetric membrane. Most coatings do not contain medicinal substances.To improve the physical and mechanical properties of chitosan coatings, polymers of a different chemical nature are introduced into their composition. Chitosan film with antimicrobial action may contain up to 20% of another hydrophilic polymer (for example, polyvinyl alcohol, gelatin, collagen, polyacrylic acid, polymethacrylic acid), which increases the strength of the film and its adhesion. Wound dressings based on a

complex of chitosan and alginate have been obtained, both in the form of a film and in the form of a sponge impregnated with silver sulfodiazine. By combining chitosan materials of various physical forms, two-layer coatings were obtained. Non-adherent wound dressing consists of two layers, the top layer is carboxymethyl chitin hydrogel, the lower layer is a biomaterial impregnated with an antimicrobial substance.In the creation of various forms of biologically active dressings, a synthetic polymer, polyvinyl alcohol, is widely used, which has high biocompatibility and hydrophilicity. The advantage of such polymers is plasticity, which provides good dressing modeling on the wound surface. In the event that the films are transparent, it is possible to exercise visual control over the condition of the wound. Non-woven knitted tampons and dressing tapes are made from the obtained fibers. Features of the chemical structure and supramolecular structure of biopolymers (polysaccharides, proteins) provide ample opportunities for new design solutions for wound dressings.Cross-linking reagents in the composition of polymer matrices are used to achieve various goals. Additives of sodium tetraborate in a polyvinyl alcohol film containing chlorhexidine bigluconate and lysozyme provide optimal characteristics of the degree of absorption (up to 2 g/g), strength in a humid environment, and desorption of medicinal substances [18]. Such a film coating has limited vapor permeability, and exudate is removed through perforations, thereby maintaining optimal humidity. It should be noted that the dressing contains a very high total content of medicinal substances, which may be due to both the low solubility of dioxidine and the strong fixation of other antimicrobial substances, and increased water absorption.

On the basis of the Biokol collagen film, multilayer materials have been developed that are used to treat burns and trophic ulcers. The polymer matrix is the carrier of a layer of fibroblasts or two-cell layers of keratinocytes and fibroblasts [19, p. 64-65].

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