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INVESTIGATION OF NOVEL POLYMER WOUND HEALING MATERIAL

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Introductions. Nowadays, much attention is paid to purulent wounds, particularly trophic ulcers (TU), especially of venous origin, that occur against the background of varicose veins of the lower extremities and occur in 1-3% of the population industrialized countries.

One of the serious problems in wound healing is the infection of the damaged part of the skin with microorganisms such as bacteria. Infection delays skin repair and can lead to further problems [1]. In the care of wounds, it is important to control infections of the affected area.

In recent years, researchers have focused on the use of biodegradable polymers in various fields of application, such as the manufacture of synthetic bone material [2], bioresorbable materials for surgery [3], controlled drug delivery [4] and wound healing materials [5–7]. Many materials are known, both based on polymers and modified with various inorganic particles. Organometallic compounds present in body tissues in very low concentrations, including elements (Ag, Zn, Cu, Ti, Co, V, Cr,) play an important role in the synthesis of materials, drugs, biological systems and exhibit antimicrobial activity properties as a part of therapeutic means. Therefore, wound dressings with antimicrobial activity are useful in minimizing microbial wound infections.

Aim. This study consists of developing synthesis technology, creating laboratory samples, and studying the physicochemical properties of composite material based on a biopolymer matrix with zinc oxide particles and metal ions for the treatment of trophic ulcers.

Materials and Methods. Hydroxyapatite (HA) hydrogel and zinc oxide (ZnO) were prepared according to the previously described technologies ([8] and [2], respectively). The dried products were ground and passed through a sieve to obtain a fine powder of HA and ZnO with a particle size of ≤63 μm. In the first step, a mixture of HA and ZnO was added to a 2% sodium alginate solution (Alg) containing organic matter and dispersed by ultrasound. The resulting suspension was poured into a prepared plastic mould with a diameter of 20 cm. The samples were frozen and lyophilized at -53 °C for 24 hours. After lyophilization, the samples were chemically cross-linked in Chitosan solution (CS) for 1 day (the sample is named CScontr), and then in 0.25M solutions of compounds containing Ca, Zn, Cu, Ag ions. After washing, the samples were dried at room temperature until completely dry.

The degree of swelling (Sw, %) was calculated by the following equation [9].

$$Sw = (m_2 – m_1)/m_1 * 100$$

where m_1 is the initial mass of the sample, m_2 is the mass of the sample after swelling.

The ability of the samples to absorb liquid (Fluid handling (FH), g/g^{-1}) was determined according to the accepted standard BS EN 13726-1: 2002.26 by the formula:

$$FH = (WW - WD1) / WD1,$$

where WW is the sample mass after water adsorption, and WD1 is the mass of the initial dry sample.

The dehydration rate (DR, g / min*)* was calculated by the formula*:*

DR= (WW -WD2) / T,

where WD2 is the mass of the sample after second drying, and T=1440 minute.

Results and discussion. Composite material for the treatment of trophic ulcers and purulent wounds based on a porous alginate matrix containing HA and ZnO as adsorbent and antimicrobial components, respectively, was experimentally developed.

Studies of samples with different crosslinking metal ions (Ca^{2+}, Zn^{2+}, Cu^{2+}, Ag^{+}) and CS molecules have shown that the type of crosslinking agent influences polymer chains' mobility and flexibility, thus the degree of edema. According to the study results, the increase in the crosslinking effect and, as a consequence, the decrease in the degree of edema are demonstrated by metal ions and CS in the series: Ag <CS <Ca <Zn <Cu (Table 1).

Table 1

Experimental samples and Sw for 24 hours (PBS pH=4.33)

CScontr	Ca	Zn	Cu	Ag
614±22 %	555±14 %	114±8%	63±4%	715±35%

The dispersion characteristics of bandages indicate their mechanical properties in the conditions of interaction with the fluid during wound healing, and it is also very important when removing bandages from wounds. During the saline experiment, all samples tested remained intact despite swelling and were determined to be *non-dispersible*. Comparison of samples was performed with a commercial overlay for the treatment of wounds “Kaltostat” [6], which is based on alginate, and another one based on pectin, presented in [7] (Table 2 and 3).

The obtained data show that in comparison with the commercial “Kaltostat” dressing, our samples adsorb less liquid, but at the same time, the degree of their dehydration is ten times lower.

This means that the samples we synthesized provide a more humid and long-lasting environment than Kaltostat.

Table 2

Experimental samples and FH

CScontr	Ca	Zn	Cu	Ag	Other	
					[6]	[7]
3.59±0.3	1.62±0.02	1.03±0.01	0.78±0.01	7.91±0.4	18.4±1.3	3.23±0.13

Table 3

Experimental samples and DR (10^4 g * min^{-1})

CScontr	Ca	Zn	Cu	Ag	Other	
					[6]	[7]
13.47 ± 1.5	5.49 ± 0.4	6.74 ± 0.7	4.33 ± 0.3	2.59 ± 0.2	350	7.14 ±1.4

Conclusions. 1. A composite material for treating trophic ulcers and purulent wounds was created experimentally.

2. It is proved that the type of crosslinking agent (Ca^{2+}, Zn^{2+}, Cu^{2+}, Ag^{+}, CS molecules) plays an extraordinary role in influencing the mobility and flexibility of polymer chains and exudate. Ions and chitosan show an increase in the crosslinking effect and a decrease in the degree of swelling in the following series: Cu > Zn> Ca> CS> Ag.

3. All samples tested remain intact in saline and have been identified as non-dispersible.

4. The obtained values of swelling, Fluid handling and dehydration rate are those that meet the requirements for this class of biomaterials and are promising in the treatment of trophic ulcers and purulent wounds.

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