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Research Article

Modern Therapeutic Contact Lenses with a Nanomodified Surface, Offered to Shorten the Effective Rehabilitation Period of the Restoring the Anatomical Structures of the Anterior Segment of the Eye Ball and its Visual Functions.

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Abstract

To improve the results of ophthalmic surgical interventions, the tasks of which are increasingly complicated, for example, operations on the anterior segment of the eyeball, when it is necessary to improve the quality of not only medical instruments, but also to carry out successful rehabilitation, which is aimed to recovering the anatomical state of the tissues of the anterior segment of the eye, as well as visual functions in postoperative period. After completion of surgery on the anterior segment of the eyeball, therapeutic contact lenses (TCLs) are applied to the cornea to accelerate and correct the corneal healing process. Unfortunately, instead of specially manufactured TSLs, soft contact lenses (SCLs) are often used, since special production of TSLs practically does not exist. Ophthalmologists are well aware of eye diseases in SCL users, such complications are sometimes very severe and dangerous; most often they arising as a result of violations of the regime and hygiene of wearing SCLs, as well as due to allergic reactions to the polymer material of SCLs.

A huge number of different devices made of polymer materials are widely used in medicine and biology. These products are made from inexpensive polymer raw materials, while the finished polymer products must meet, first of all, certain medical requirements for polymer products. The use of disposable polymer products cannot completely solve the problems associated with the use of unsafe polymer products! The main requirements for polymer products used in medicine and biology are to ensure aseptic properties and, if necessary, biocompatibility between the physiological environment, living tissue and the surface of the polymer product, which can be achieved by treating the surface of polymer products. These requirements for the properties of polymer products can be successfully achieved by modifying the physicochemical properties of the surface of the polymer product by depositing the carbon-containing nanofilms (CCNFs), such as diamond-like films (α-C:H), on the polymer surface in the case of our research, for example. To achieve this goal, various devices made of polymer materials undergo a 2-stage processing of their polymer surface: 1. Nano structurization (SNS) of the polymer surface and at the subsequent 2nd stage, when the polymer surface is subjected to Nano modification (SNM). Those two-stage surface treatment of a polymer product, carried out with the aim of imparting such sought-after and attractive surface properties as biocompatibility and aseptic properties to the initially unsuitable porous surface of the untreated polymer surface. Thus, by treating the surface of a polymer, it is possible to impart new properties to the polymer surface: from acquiring completely new properties of the polymer surface to giving the treated polymer surface properties that are opposite to the properties of the original untreated surface.

The goal of our work was to create the first therapeutic contact lenses (TCLs) for use during the period of postoperative rehabilitation of the eye after operations on the anterior segment of the eyeball. Until now, as is known, conventional corrective SCLs are often used as TCLs. For the production of TSL, the same polymer materials are used as for the production of SCL: polyethylene terephthalate (PET), polytetrafluoroethylene (PTFE) and polyvinylidene fluoride (PVDF), the same SCL production line is used. The difference between the production of conventional STLs and TSLs is that during the production of TSLs at the final stage, to obtain finished TSLs, the surface of the lenses is subjected to additional processing, that is, nanomodification of their polymer surface, which is achieved by applying nanocomposites from directed ions of vapor-plasma mixtures or magnetron deposition of nanocomposites onto the treated surface. surface. surface. surface. surface of the polymer, forming carbon-containing nanofilms on the surface of the processed polymer product.

A new form of TCL was also developed and proposed, which differs from the shape of conventional TCLs in that their internal surface has the shape of an aspheric segment with an absolutely homogeneous smooth surface, where, for example, there are no dividing zones characteristic of TCLs: optical, transition, sliding zones, which makes the surface of the future TCL smooth and uniform, without irregularities, i.e. gives the TCL a shape that provides better contact with the surface of the cornea that has undergone surgery. The nanostructured surface of the TCL also eliminates the growth of fibrous tissue on the cornea under the TCL. In the observed eyes, the desired positive postoperative result of healing and restoration of the cornea was achieved in 100% of cases.

One of the important positive aspects of using the technology of nanomodification of the TCL polymer surface is also the possibility of simultaneous modification of the relief of the internal surface of the TCL and ensuring its sterility. The characteristic properties of the TCL surface provided by the use of SNS and SNM are also: lack of toxicity, biocompatibility of the TCL surface, certain adhesive and repulsive properties to certain living cells and elements, which were also assessed as certain attractive properties of Carbon-containing Nano film coatings. Such treatment of the polymer surface can be considered as a way to improve the quality and safety of polymer products with a nanomodified surface, which has the prospect of expanding their use in medicine and biology.

Abbrevations

TCL – Therapeutic Contact Lenses

SCL – Soft contact lenses

CCF – Carbon-Containing Film

PET – Polyethylene Terephthalate

PTFE – Polytetrafluoroethylene

PVDF – Polyvinylidene fluoride

NSS – Nano Structurization of the Surface

NMS – Nanomodification of the Surface

Introduction

As it is known, the human body is approximately 99% composed of only six elements: oxygen, hydrogen, nitrogen, carbon, calcium and phosphorus. Oxygen is the most abundant element in the human body and makes up about 65.0% of body weight. Most of it is in the form of water. Carbon is a substance with the largest number of allotropic modifications, which differ from each other most radically in their properties: from soft to hard, from opaque to transparent, from abrasive to lubricating, from inexpensive to expensive. Carbon is the second most abundant element in the human body, accounting for 18% of body weight. The role of carbon is primarily structural; this element forms the "base" of many organic molecules, which may explain the biocompatibility effect of carbon-containing nanofilms with biological tissues.

As already mentioned, in medicine and biology it is very common to use products made from cheaper and more accessible polymer materials, which is unsafe, since the chemically loose and porous structure of the polymer contributes to the natural formation of biofilms on its surface, which are dangerous for the development of microorganisms in them. In this regard, a separate nosological class of diseases was even identified: "infections developing from biofilm microorganisms." Biofilm pathogens are not sensitive to the action of powerful pharmacological agents: neither antibiotics nor sulphonamides. In addition, polymer films are successfully used in laboratories for cultivating microorganisms.

We have conducted research into the possibilities of using advances in nanotechnology to improve the surface quality of products made from polymeric materials for medical purposes, for example, by treating the surface of the polymer with carbon-containing nanofilms (CCNF) in order to provide a treated polymer surface with certain specified physical and chemical properties. This opened up the prospect of modifying the untreated surface of the polymer to ensure safety when the polymer surface comes into contact with the tissues of a living organism, to prevent the formation of a biofilm on the surface of the polymer, as well as to acquire the necessary properties of the treated surface, aseptic properties, biocompatibility in contact with biological media, with the prospect of obtaining a bio epitaxy effect. The ability to obtain attractive polymer surface properties by treating the polymer surface using nanotechnology created such a boom, for example in the field of transplantology and implant processing, that the first complications of such implantations soon appeared. For example, the implantation of silicone breast implants coated with nanofilms has led to the development of malignant processes. The fact is that the silicone in breast implants under nanofilms inside the body, with powerful blood and lymph circulation, decomposes at temperatures above the external temperature, releasing dangerous carcinogenic silicone oil. In ophthalmology, silicone-containing contact lenses are also used, which have not become as popular among SCL users, which we also took into account. Therefore, at the time of our scientific research and research, it was decided to use CCNF only for surface treatment of polymer products, mainly to provide the necessary conditions for aseptic storage, for example, containers for long-term and aseptic storage and transportation.

RF Patent (RU Patent dated June 28, 2017; RU 2690153 C2)

“A method for prolonged-term storage and transportation of allogeneic implants, storage and safe transportation of donor tissues using the example of aseptic storage and safe transportation of a donor cornea in a special polymer container, the surface of which is treated by means of nanomodification of the polymer surface.

The current level of development of ophthalmic surgery, especially microsurgery of the anterior segment of the eyeball, provides for the mandatory use of TCL in the postoperative rehabilitation period. However, instead of specially manufactured TCLs, random SCLs can sometimes be used, which in terms of shape, topography and surface quality do not correspond to the required characteristics of TCLs. TCLs can be obtained using technologies for appropriate treatment of the polymer surface of TCLs by applying carbon-containing nanofilms deposition to their polymer surface, which will be in contact with the postoperative surface of the cornea, within 1–2 days of the postoperative period.

The human body is approximately 99% composed of only six elements: oxygen, hydrogen, nitrogen, carbon, calcium and phosphorus. Oxygen is the most abundant element in the human body, making up approximately 65.0% of body weight. Most of it is in the form of water. Carbon is the next most abundant element in the human body, accounting for 18% of body weight. Its role is mainly structural; it forms the “backbone” of many organic molecules.

The use of products made from cheaper and more accessible polymer materials in medicine and biology is extremely common, which, however, is unsafe, since a biofilm easily forms on the chemically loose porous structure of the polymer surface, which is dangerous due to the development of dangerous microorganisms in the biofilm. In this regard, a separate nosological class of diseases was even identified - infections developing from biofilm pathogens. Biofilm microorganisms are especially dangerous because these pathogens are not sensitive to the action of potent antimicrobial agents: neither antibiotics nor sulphonamides. In addition, polymer films can be used for cultivating various microorganisms in laboratories.

In this regard, research is being conducted into the possibility of using the results of nanotechnology application to improve the surface quality of products made from polymeric materials for medical purposes, for example, by applying carbon-containing nanofilms (CCNF) to their surface. in order to obtain a treated surface of a polymer product with certain specified physical and chemical properties that guarantee the safe use of such polymer products with a nanomodified surface intended for direct contact with living tissues. Nanotechnologies for processing polymer surfaces using the CCNF deposition method are used to impart the necessary surface properties to the processed polymer surfaces, such as aseptic properties, biocompatibility in contact with living tissues, with the possible achievement of bio epitaxy effect in the future. The possibility of obtaining attractive polymer surface properties by treating the polymer surface using nanotechnology created such a boom, for example in the field of transplantology for the processing of implants, that the first complications of such implantations soon appeared. For example, implantation of silicone breast prostheses treated with nanofilms led to malignancy processes. Silicone breast prostheses under nanofilms, being inside the human body, with blood circulation, lymph circulation, with a temperature inside the body different from the external temperature, decompose, releasing dangerous carcinogenic silicone oil. So, it was decided to use CCNF only for surface treatment of polymer devices in order to impart properties such as asepsis and biocompatibility to the treated surfaces - qualities that are already a great achievement and gain for medicine and biology. After a thorough study of the materials proposed after Otto

Wichterle's discovery in 1968 of the proposed method for producing SCL, which can still be considered fundamental, the new methods proposed for the production of various SCL can only be considered modifications of Otto Wichterle's basic method. The current level of development of ophthalmic surgery, in particular microsurgery of the anterior segment of the eyeball, provides for the mandatory use of TCL in the postoperative rehabilitation period. However, instead of specially manufactured TCLs, random SCLs can sometimes be used, which in terms of shape, topography and surface quality cannot meet the required characteristics of due TCLs. TCLs can be obtained through the use of technologies for appropriate processing of the polymer surface of TCLs by applying carbon-containing nanofilms deposition to their polymer surface. TCL is intended for contact with the post operated surface of the cornea for 1-2-3 days after surgery.

Therefore, the TCL must have certain parameters and surface quality obtained using the appropriate technology for processing its polymer surface, which determine the proper characteristics of the TCL surface in direct contact with the post operated surface of the cornea. That is why the TCL must have certain parameters and surface quality, be manufactured using technology for processing the polymer surface of the product in order to obtain the necessary characteristics of the TCL surface, such as:

Smooth and uniform shape of the aspherical segment, absence of irregularities, for example, transition from the optical zone to the sliding zone, etc.;

A certain form of curvature of the entire surface of the TCL, which must be at least 164 degrees, it is this surface contour that ensures the physiological processes of migration of corneal cells to restore corneal tissue;

Nanomodification of the surface of the resulting TCL eliminates the formation of biofilm on its treated polymer surface.

Materials and Methods

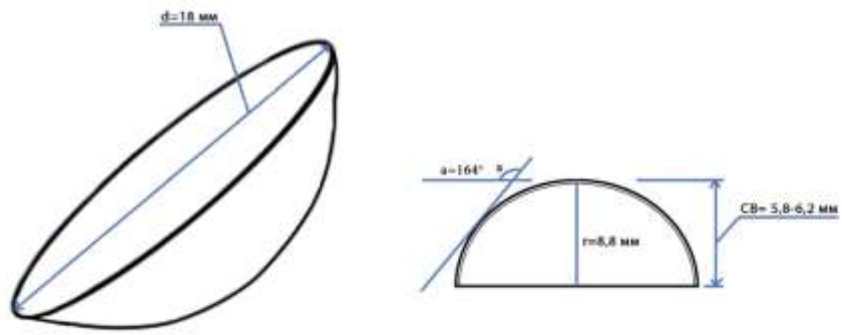

Fig.1. TCL. schematic illustration

A certain form of curvature of the TCL surface, which should be at least 164 degrees, it is this surface contour that provides the physiological processes of migration of corneal cells to restore corneal tissue. TCL, made of polymer, shaped to correspond to a corneoscleral SCL, with parameters: diameter 18 mm, thickness 0.3 mm, radius of curvature 8.8 in the center, sagittal height 5.8-6.2 mm, uniformly aspherical shape, with an outer angle of the aspherical segment of the TCL surface of at least 164 degrees over the entire surface of the TCL.

TCLs are produced on a conventional SCL production line. In terms of shape, the obtained SCLs correspond to corneoscleral SCLs made using various polymers with high adhesion on their surface of carbon-containing nanofilms: polyethylene terephthalate (PET), polytetrafluoroethylene (PTFE), polyvinylidene fluoride (PVDF), The PCL is made in the form of aspherical segment with the following dimensions: diameter 18 mm, thickness 0.3 mm, radius of curvature in the centre 8.8 mm, height of the spherical segment 5.8-6.2 mm. The resulting TCL must also have an aspherical shape with an external angle over the entire surface of at least 164 degrees; this form of surface curvature ensures the processes of physiological migration of corneal cells. It is necessary to strictly observe the shape and topography of the TCL surface, which should ensure the preservation of the physiological processes of the corneal tissues when using these TCLs. At the final stage, to obtain the proper TCL, the surface of the obtained TCL is treated with NSS, and then with NMS using known methods of polymer surface treatment nanotechnology by applying a carbon containing nanofilm deposition to the TCL surface in a special chamber. Surface treatment of high molecular weight polymeric materials is carried out on traditional equipment with planetary plates designed to process the surface. Earlier, the surface is structured using ion flows of reactive and/or inert gases of processing to obtain a developed surface (NSS), which is then nanomodified (NMS), containing nanotubes, which can be combined (single-layer, multilayer, monophase. The homogeneity of the obtained films was 95%. By varying surface treatment methods (chemical, physical, electrochemical, surface nanomodification methods), it is possible to obtain combined carbon-containing nanofilms with specified parameters, and hence with certain surface characteristics, such as inertness, atomic structure, charge on the surface, etc. These properties of surface characteristics make it possible to obtain certain surface properties, such as aseptic, bactericidal properties, biocompatibility of the nanomodified polymer surface with living tissues. Thus, the chemical resistance and specified characteristics of the nanomodified surface ensure the safety of the underlying living tissues when in contact with them. Materials with NSS and subsequent NMS represent a separate class of synthetic nanomodified materials. Such coatings are highly demanded for surface treatment of implants, since artificial substitutes in contact with tissue fluid require special surface treatment to improve biocompatibility. (1, 2, 3). Nano structurization of the surface of polymers was obtained by treating their surface with ions of reactive and noble gases and their mixtures (CF_4, Ar, O_2). Modification was carried out by two methods: deposition of CF_4 from directed ion-plasma flows of hydrocarbon vapour's 5–120 nm thick and magnetron sputtering of highly dispersed films.

Fig.2. TCL.

The surface charge characteristics of the treated CCF may promote adhesive properties or repel chemicals, proteins, cells from the interface through the generated active functional groups. Pretreatment of the polymer surface, for example, allows for covalent immobilization of cell-binding peptides derived from extracellular matrix proteins: fibrinogen, fibronectin, laminin and grafted peptides can provide an adequate matrix for subsequent cell migration.

The properties provided by CCF sputtering: lack of toxicity, biocompatibility, and obtaining a dispersed surface make it possible to obtain effective TCL. Mandatory properties provided by CCF application: lack of toxicity, biocompatibility, dispersed surface, can provide an opportunity for the creation of artificial substitutes and their successful application.

Results

Study of antimicrobial activity. The surface structure was studied using a FemtoScan atomic force microscope with a maximum scanning area of 10x10 µm. For each surface of the sample, photographs were taken at different points. After obtaining the relevant results of toxicity studies of HC-treated PET, PTFE, PVDF (results of studies, antimicrobial activity is described in detail), polymers with deposition bands α-C:H (100 nm) were selected as starting materials. Experimental studies of polymers with CP formed by ion-plasma methods have shown that the degree of surface dispersion and its microrelief, as well as methods for its modification, determine its surface properties and efficiency, in particular, antimicrobial activity (4). Gram-positive Staphylococcus aureus ATCC 29213 and Gram-negative Pseudomonas aeruginosa ATCC 27853 were used to study antimicrobial activity. To do this, 3-4 colonies of microorganisms cultured after 18-20 hours are suspended in 3 ml of saline. The suspension had a turbidity of 0.5 on the McFarland scale (1.5 x 108 cfu/ml). The base suspension was then diluted by diluting the serum with saline to a concentration of 15 cfu/ml. Samples of HSS polymers were cut into fragments with a size of 15x15 µm. A fragment of the substrate was placed in a test tube with a liquid nutrient medium to control the sterility of the coatings. Muller Hinton Bovril was used as the culture medium. From each test tube with different concentrations, 25 µl of the suspension was taken with a pipette and applied to individual fragments of the polymer substrate with GSS to control the growth of the culture. Such infected fragments were incubated in a humid environment with a thermostat at 37°C for 2 hours. After incubation, all fragments were placed in test tubes with 4 ml of nutrient medium and incubated again in a thermostat at 37°C for 48 hours. Antibacterial activity was assessed by the appearance of visible growth in test tubes with nutrient media after 48 hours

After obtaining the results of studies on the non-toxicity of PET, PTFE, PVDF samples treated with CCF, the treatment of the HSS polymer surface under the influence of UV radiation using ion plasma processes was developed to obtain the desired properties of the treated surface (4). This surface modification, which can be achieved in the process of plasma film deposition, is the result of the action of photons and active particles in the plasma, which react with surfaces at a certain depth without changing the bulk properties of the substrate material. Parameters such as gas types, processing power, processing time and operating pressure may vary. The process of ion-plasma deposition of CCF can change the surface energy. A certain film deposition can change almost any substrate geometry. The most important feature is the ability of CCF deposition applied to the surface of the polymer to function, which cannot be provided by chemical surface treatment. In all experiments, as well as control samples for growing cultures, control of the sterility of the samples was also provided. Experimental results of the study of antimicrobial activity are presented in table (1). In test tubes with polymer samples without coatings of hydrocarbons, the growth of microorganisms was observed in all dilutions, which indicated a high turbidity of the media. The lack of antimicrobial activity of CCF against Pseudomonas aeruginosa in some samples can be explained by the fact that this microorganism is more resistant to various aggressive factors compared to Staphylococcus aureus. Of greater interest are the results showing the antimicrobial activity of CCF coatings against Pseudomonas aeruginosa in samples 11-16. Sample 15 inhibited growth even at a microbial concentration of 104 cfu/ml (cfu/ml is colony-forming unit per milliliter). A colony-forming unit is where a colony of microbes grow on a petri dish, from one single microbe. Of greatest interest are samples 14 and 15, in which the growth of both types of microorganisms is suppressed. Analysis of the table. (1) showed that the maximum antibacterial activity of HC was observed in samples with the maximum relief (the ratio of the real surface to the geometric one was about ~100). Comparison of the results of the surface charge study and careful analysis of the data in Table (1) shows that the interaction between NSS and microorganisms may depend on two mechanisms. One of them is associated with electrostatic interaction, and a sample of this type is shown in Fig. 1, where the real surface is increased by a factor of 5-8, and the charge is 1-5 μC/m2. The second mechanism is associated with the dispersion parameters of the NSS, a sample of this type is shown in Fig. 2, where the value of the real surface is increased by about 100 times.

№	Polymer/ deposition Conditions	Indicator m/o	Innoculation dose (cfu/ml)				
			10^5	10^4	10^3	10^2	10
1	PTFE: 1. treated CF_4 2. α-C:H (50 nm)	Ps. aerug.	+	+	+	+	±
		S. aureus	+	+	±	–	–
2	PTFE, smooth 1. α-C:H (50 nm)	Ps. aerug.	+	+	+	+	+
		S. aureus	+	+	+	+	+
3	PTFE: 1. treated CF_4 2. α-C:H (100 nm)	Ps. aerug.	+	+	+	±	±
		S. aureus	+	+	–	–	–
4	PTFE, smooth	Ps. aerug.	+	+	+	+	+

	1.α-C:H (100 nm)	S. aureus	+	+	+	–	–
5	PET: 1. treated CF_4 2. α-C:H (50 nm)	Ps. aerug.	+	+	+	+	+
		S. aureus	+	+	+	+	+
6	PET, smooth 1. α-C:H (50 nm)	Ps. aerug.	+	+	+	+	+
		S. aureus	+	+	+	+	+
7	PET: 1.treated CF_4 2. α-C:H (100 nm)	Ps. aerug.	+	+	+	+	+
		S. aureus	+	+	+	–	–
8	PET, smooth 1.α-C:H (100 nm)	Ps. aerug.	+	+	+	+	+
		S. aureus	+	+	+	+	–
9	PVDF: 1. treated CF_4 2. α-C:H (50 nm)	Ps. aerug.	+	+	+	+	±
		S. aureus	+	–	–	–	–
10	PVDF, smooth 1. α-C:H (50 nm)	Ps. aerug.	+	+	+	+	+
		S. aureus	+	–	–	–	–
11	PVDF: 1.treated CF_4 2. α-C:H (100 nm)	Ps. aerug.	+	+	+	–	–
		S. aureus	+	–	–	–	–
12	PVDF, smooth 1. α-C:H (100 nm)	Ps. aerug.	+	+	±	–	–
		S. aureus	+	–	–	–	–
13	PTFE(relief): 1. treated CF_4 2. α-C:H (100 nm)	Ps. aerug.	+	+	±	–	–
14	PTFE(relief), 1. α-C:H (100 nm)	Ps. aerug	+	+	–	–	–
15	PVDF(relief): 1. treated CF_4 2. α-C:H (100 nm)	Ps. aerug.	+	–	–	–	–
16	PVDF(relief), 1. α-C:H (100 nm)	Ps. aerug.	+	±	–	–	–

Discussion and Conclusions

Nanotechnology is a relatively new area of science and practice, successfully developing and used in the creation of innovative materials by changing and creating new characteristics of the surface of materials, providing the possibility of obtaining materials with new modified surface characteristics, thereby expanding the horizons of obtaining and using new materials with specified polymer surface properties. Such advanced nanotechnology capabilities offer the prospect of a new approach to solving some important medical problems by programming specific physical and chemical characteristics of the nanomodified surface (NMS) of the processed material, designed to impart certain target properties to the surface of the processed polymer. for example, ensuring aseptic surface properties that prevent the risk of biofilm formation on the surfaces of various medical materials (probes, catheters, etc.). In the early 1990s, there was a boom with the idea of recycling many products and devices made from low-cost polymer material into medical devices by coating their polymer surfaces with nanocomposite films. For example, the processing of suture material. The use of such suture material in experimental studies has shown that the use of such surgical suture material ensures wound healing through primary wound healing. This is truly an achievement in the field of polymer surface treatment. But there have been other proposals for the use of surface treatments, such as silicone breast prostheses. In this case, it was soon discovered that the silicone under the film (CCNF) was degrading, releasing toxic silicone oil. Subsequently, in particular, statistical data were presented on the incidence of malignant neoplasms in such patients when using CCNF-coated silicone prostheses. Thus, it has become clear that at the current level of technological capabilities, nanomodification of polymer surfaces and the use of surface treatment are not possible for all materials. Only with a more in-depth study of technologies for nanomodification of surfaces of materials other than polymers, which are now quite well studied, is it necessary to conduct detailed and thorough studies of the possibility of treating surfaces of other materials and, if necessary, their feasibility.

To further develop this direction in the field of polymer surface treatment, the production of various polymer containers designed for aseptic storage and safe transportation of various implants and donor tissues that require guaranteed safe storage for a certain time is becoming very popular. For example, the storage of some implants and donor tissue can be achieved quite securely and simply by simply wrapping the preservation items in a CCNF-treated polyethylene sheet. Proper storage of donor implants in a special container, for example, a donor cornea, is presented and described in the Russian Federation Patent (RU Patent dated June 28, 2017; RU 2690153 C2). A. Musina (author)

“A method for long-term storage and transportation of allogeneic implants, storage and safe transportation of donor tissues using the example of aseptic storage and safe transportation of a donor cornea in a special polymer container, the surface of which is treated with nanomodification of the polymer surface.”

All these proposals are supported by patents for inventions.

The chemical and physical properties of NMCs can contribute to the ability of adhesiveness or repulsion, the transfer of chemical compounds, proteins, cells from the interface through the active functional groups of nanostructured surfaces. The physicochemical properties of the NMS with a preliminary surface of the NSS polymer surface under various surface treatment modes are further determined by the composition, atomic structure and surface charge of the treated surface and can affect the underlying corneal tissue through the NMS TCL, to maintain the polarization of cell membranes and influence the behavior of corneal cells, that is, on the condition of the tissue of the living cornea. This phenomenon can be successfully used both to restore the structure of the cornea and to control the correct path of its regeneration. Epithelial and stromal cells of the cornea, having different natures, change their shape and functional activity in terms of the characteristics of the extracellular matrix, biochemical properties and geometric configuration of the resulting NMJs. This may provide opportunities to regulate and accelerate the restoration of living tissues, in our case, the restoration of the cornea after eye surgery.

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7 th Euro BioMat 2021 Presentations:

7. The relief of surface migration determines the structure and behavior for each moving living cell

8. THE EYE DIAPHRAGM LOSS COMPENSATION BY MEANS OF ARTIFICIAL IRIS USE

9. The allogeneic transplants preservation

10. Dissertation "Ensuring prolonged aseptic storage and transportation of the high-quality donor cornea", 2006