ISSN 2618-1584 Vol. 3, Issue 6: 67-69, DOI: 10.25236/FMSR.2021.030612

Design of an Antibacterial Bio-adhesive Material with Silver Nanoparticles

Xingmei Jin

Northeastern University, 360 Huntington Ave, Boston, MA, USA
xmjin320@gmail.com

Abstract: *This paper proposes a possible antibacterial bio-adhesive. In the paper, a new bio-adhesive has been designed by combining nano-silver gel, which has a high antibacterial effect, with human fibrin adhesive to get a bio-adhesive material with antibacterial ability. Although the mechanical properties of the new adhesive need to be further measured, if the mechanical properties are as good as the currently used fibrin adhesives, it is worthwhile to continue development and research. By designing a new type of adhesive, this paper presents the potential for more widespread medical use of adhesives that can reduce the risk of bacterial infection at the incision site.*

Keywords: *biological adhesives, silver nanomaterials, fibrin adhesive, nano-silver gel*

1. Introduction

In surgery, whether treating skin wounds or transplanting organs, suture operations are required for vascular, organ, skin and other body parts. Surgical adhesives are extremely convenient methods for medical suturing because of their quickness and effectiveness [1]. In the past, chemical synthetic adhesives were often used in medical applications; however, it is now preferred to use biological adhesives that have a better biocompatibility. The risk of infections at the suture site is a serious problem. Those infections will not only increase patients pain but also cause other diseases in severe cases. So, among the conditions that should be met by the ideal medical adhesive material, the antibacterial ability is an indispensable part [2]. Current research efforts have focused on using silver nanomaterials [3] to achieve the antibacterial effect, marking a significant breakthrough in the medical field. Biological medical materials with silver nanoparticles can reduce inflammatory cells and greatly enhance the antimicrobial effect [3,4]. Fibrin sealant (FS) is derived from plasma and has good biocompatibility [5]. Therefore, at present, it is a typical biological adhesive glue in medical applications. In this research proposal, a new medical adhesive made of human fibrin adhesive with nano-silver gel, which has both biocompatibility and antibacterial properties will be examined. Such an antimicrobial adhesive can be widely used for trauma treatment as well as for vascular, visceral and hemostatic adhesion in surgery.

2. Background

Medical adhesives not only have the function of glue but also have special biomedical functions. Ideal bio-adhesives should be safe, non-toxic, biocompatible, antibacterial and have a good bonding strength and bonding speed [6]. Currently, a biological adhesive named fibrin adhesive is being used successfully for medical purposes. Compared with chemically-synthesized adhesive such as cyanoacrylate, it does not cause tissue rejection reactions, and also, it is completely biodegradable [5,6]. Fibrin adhesive imitates the final step of blood clotting and is made up of several components of human plasma [6,7]. The most basic fibrin adhesive consists of thrombin, fibrinogen, and a small amount of CaCl2. In the presence of Ca2+, thrombin activates fibrinogen to form a fibrin clot that binds firmly to the wound and serves to stop bleeding and promote tissue healing [7]. Scientists have done a large number of studies on antibacterial materials. Nano-silver is a new type of nanotechnology, with hundreds of times higher antibacterial effect than other inorganic antibacterial agents [3,8]. Additionally, it does not irritate skin or mucous membranes [8]. Because of its size in the nanoscale range, this brings about complete differences from the properties of metallic silver. The active group of nano-silver is charged silver ions [9]. It is known that silver ions can bind with sulfhydryl(-SH) of the proteins in an enzyme, which leads to the inactivation of the enzyme in the bacterial cell to kill the bacteria [4,9]. Some studies have shown that silver ions can also react with -NH and -COOH in bacteria to cause bacterial death [9]. Recently,

ISSN 2618-1584 Vol. 3, Issue 6: 67-69, DOI: 10.25236/FMSR.2021.030612

nano-silver antibacterial technology has been employed in various medical applications, such as surgical sutures, medical catheters, and dental antibacterial materials, among others [8-10].

3. Significance

Medical adhesives are extremely convenient for wound closure due to a rapid application, less wound on suture, less pain, and no seam removal [1]. Therefore, in the past few decades, there has been a tremendous effort by scientists to combat the significant limitations and drawbacks that these bio-adhesives still have. However, they are still not widely used now and only applicable to a few specific fields in the clinical setting [6]. One of the reasons is that surgical sites can be infected with various microorganisms both in vivo and on the skin. Additionally, it is known that sepsis due to bacterial infection often occurs after the patient has undergone surgery, which is associated with a high rate of mortality when accompanied by impairment of body organ function or septic shock [2]. Therefore, improving the antibacterial properties of bio-adhesive materials is an important part of optimizing biological adhesives. If the antibacterial bio-adhesive material can be successfully optimized by using nano-silver materials, the scope of application of biological adhesives will become widespread, and the side effects caused by bacterial infections will be reduced. From binding small skin wounds to use in surgical procedures, biological adhesives will bring a lot of convenience and efficiency for people.

4. Strategy

4.1. Prepare a lyophilized human fibrin adhesive for use in biomaterial

This experiment will use a human fibrin adhesive as a bio-adhesive material, to wait for combining with nano particulate silver gel. The lyophilized human fibrin adhesive is mainly composed of plasma from healthy humans. The plasma will be separated and purified for human fibrinogen and thrombin, respectively. Then those will be subjected to virus removal and inactivation treatment, and freeze-dried to make a lyophilized human fibrin adhesive.

4.2. Synthesize nano-silver gel and test antimicrobial properties

Nano-silver antibacterial material preparation methods include physical methods, chemical reduction methods, and microbial system preparation methods [11,12]. Sol-gel technology will be used to prepare nano-silver antibacterial gel. When selecting the matrix, it is necessary to consider the consistency of the matrix and ensure that no precipitation reaction occurs after the silver nanoparticles are included. In this experiment, Carbomer 940 will be chosen as the matrix. After Carbomer was fully swollen, triethanolamine and glycerol will be added. Then, nan-silver stock solution will be added and stirred uniformly to obtain nano-silver gel. The concentration of Carbomer 940, triethanolamine, and glycerol used in experiments will be determined by concentration gradient test and orthogonal test to optimize the concentration of nano-silver gel. In addition, the nano-silver gel's antibacterial ability can be tested by inhibition zone test using Escherichia coli and Staphylococcus aureus as representatives of Gram-negative and Gram-positive bacteria. The appearance of the inhibition zone indicates that the nano-silver gel has a bactericidal ability, and the size of the inhibition zone can be used to judge the level of antibacterial activity. Next, the minimum bactericidal concentration(MBC) of the nano-silver gel will be measured under different concentrations of nano-silver gels.

4.3. Combine human fibrin adhesive with nano-silver gel for fabrication of a new antibacterial biological adhesive material

Human fibrinogen dilutions and human thrombin dilutions will be placed under aseptic conditions using the lyophilized human fibrin adhesive, and the two solutions will be mixed to form a viscous adhesive solution. Then nano-silver gel will be combined with the adhesive solution.

1) Preparation of fibrinogen solution:

Lyophilized fibrinogen will be dissolved in sterile water. The vial will be placed in a warm water bath and gently shaken until the fibrinogen will be completely dissolved.

2) Preparation of thrombin solution:

Lyophilized human thrombin will be dissolved in calcium chloride solution at room temperature.

ISSN 2618-1584 Vol. 3, Issue 6: 67-69, DOI: 10.25236/FMSR.2021.030612

Gently shake the bottle to dissolve it.

3) Fabrication of a new antibacterial biological adhesive

Combine the human fibrin adhesive with nano-silver gel with the minimal bactericidal concentration which can be obtained from above test results.

4.4. In vitro cytotoxicity assay for combined gels

This experiment will use the MTT assay [13]. The combined gel will be introduced into human skin cells cultured in vitro. The survival and growth of skin cells will be detected. Furthermore, after successful in animal testing, the bio-adhesive can eventually be applied to clinical.

5. Conclusion

As biological adhesives bring many benefits to humans, more and more research is being done on optimizing bio-adhesive materials. If the nano-silver gel, which has a high antibacterial effect, can be combined with the human fibrin adhesive to prepare a bio-adhesive material with antibacterial ability, the wound can be treated more effectively. This new bio-adhesive can reduce the risk of bacterial and viral infections in the body and will be used more widely in medicine. Recently, scientists continue to optimize fibrin adhesives' weak tissue adhesion and high manufacturing costs [5]. With the development of genetic engineering and transgenic technology, the ideal biological adhesive will appear in the near future.

References

[1] Zi-da, C. H. E. N., Ling, L. I., & Han, Z. O. U. (2001). The Research Development of Medical Adhesives. Chemistry and Adhesion, 1, 007.

[2] Pelz, K., Todtmann, N., & Otten, J. E. (2015). Comparison of antibacterial-coated and non-coated suture material in intraoral surgery by isolation of adherent bacteria. Annals of Agricultural and Environmental Medicine, 22(3).

[3] Pattabi, R. M., & Pattabi, M. (2013). Antibacterial Applications of Silver Nanoparticles. In Materials Science Forum (Vol. 754, pp. 131-142). Trans Tech Publications.

[4] Sun, D., Yang, J., Li, J., Zhou, L., & Yu, J. (2009). Preparation and antibacterial capacity of artificial skin loaded with nanoparticles silver using bacterial cellulose. Journal of biomedical engineering, 26(5), 1034-1038.

[5] Cavichiolo, J. B., Buschle, M., & Carvalho, B. (2013). Comparison of fibrin adhesives prepared by 3 different methods. International archives of otorhinolaryngology, 17(1), 62-65.

[6] Sierra, D. H. (1993). Fibrin sealant adhesive systems: a review of their chemistry, material properties and clinical applications. Journal of Biomaterials Applications, 7(4), 309-352.

[7] Suga, Nakagawa, Soga, Takahashi, Abe, Deguchi, . . . Fukuda. (2004). Endoscopic Hemostasis Using Fibrin Adhesive to Treat Hemorrhage in the Upper Digestive System. Surgery Today, 34(11), 902-906.

[8] De Simone, S., Gallo, A. L., Paladini, F., Sannino, A., & Pollini, M. (2014). Development of silver nano-coatings on silk sutures as a novel approach against surgical infections. Journal of Materials Science: Materials in Medicine, 25(9), 2205-2214.

[9] Cheng, D., Yang, J., & Zhao, Y. (2004). Antibacterial materials of silver nanoparticles application in medical appliances and appliances for daily use. Chin Med Equip J, 4, 26-32.

[10] Lee, Y., Xu, C., Sebastin, M., Lee, A., Holwell, N., Xu, C., ... & Karp, J. M. (2015). Bioinspired nanoparticulate medical glues for minimally invasive tissue repair. Advanced healthcare materials, 4(16), 2587-2596.

[11] Rizzello, L., Cingolani, R., & Pompa, P. P. (2013). Nanotechnology tools for antibacterial materials. Nanomedicine, 8(5), 807-821.

[12] Cheng, X., Li, Y., Zhao, Z. (2013). Preparation of nanometer silver antibacterial gel. Chinese modern drug application, 7(14), 38-40.

[13] Shin, S. H., Ye, M. K., Kim, H. S., & Kang, H. S. (2007). The effects of nano-silver on the proliferation and cytokine expression by peripheral blood mononuclear cells. International immunopharmacology, 7(13), 1813-1818.