УДК 616.71-089.227.84-77 DOI: 10.21823/2311-2905-2019-25-2-121-122

Comment on the Article "Coatings Based on Two-Dimensionally Ordered Linear Chain Carbon for Protection of Titanium Implants from Microbial Colonization"

S.A. Bozhkova

Vreden Russian Research Institute of Traumatology and Orthopedics, St. Petersburg, Russian Federation

Surgeries aimed to restore bone integrity using various types of permanent or temporary implants have long proved their effectiveness. However, development of implant associated infection is one of the severest complications after such procedures, pathogeneses of which is driven to the major extent by the formation of microbial biofilm on the foreign body surface. Implant surface is the key factor for bacterial colonization and subsequent biofilm formation [1]. The study of Koseki et al. (2014) demonstrated reduced *S. epidermidis* biofilm formation on the cobalt chromium molybdenum alloy (CoCrMo), which the authors attributed to a higher hydrophobic properties of the alloy [2]. Another group of researchers observed reduced metabolic activity of *Candida albicans* on polycarbonate and stainless steel in contrast to Teflon [3]. It was experimentally proven that the overall bacterial adhesion and biofilm formation is reduced by low rigidity of the nanostructure [4], presence of nanoscale protrusions and recesses in contrast to smooth surfaces [5]. Besides, calcium-containing oxide coatings on the titanium surface reduce bacterial colonization as compared to titanium without calcium coating [6].

In the present research the authors examined antimicrobial activity and cytotoxicity of titanium samples with innovative silver and nitrogen alloyed coatings based on two-dimensionally ordered linear chain carbon in comparison with samples without coating and with unalloyed coating. Bactericidal properties of test samples against gram-positive (*Staphylococcus aureus* and *Enterococcus faecalis*) and gram-negative (*Pseudomonas aeruginosa*) agents were evaluated. Presented results demonstrate that silver alloyed carbon coatings exhibit bactericidal activity against all tested bacteria strains irrespectively of their antibiotic sensitivity, allow to prevent formation of microbial biofilms on coated surfaces and demonstrated no cytotoxicity.

At the present stage antibacterial implant coatings used in orthopaedics can be divided into three groups [7]:

1. *Passive processing/modification of the surface.* Surfaces that prevent adhesion without releasing antibacterial agents.

2. *Active processing/modification of the surface.* Surfaces that release antibacterial agents.

• *Comment on the Article*

Tapalski D.V., Nikolaev N.S., Ovsyankin A.V., Kochakov V.D., Golovina E.A., Matveenkov M.V., Sukhorukova M.V., Kozlov R.S. [Coatings Based on Two-Dimensionally Ordered Linear Chain Carbon for Protection of Titanium Implants from Microbial Colonization]. *Travmatologiya i ortopediya Rossii* [Traumatology and Orthopedics of Russia]. 2019;25(2):111-120. (In Russian). DOI: 10.21823/2311-2905-2019-25-2-111-120.

Cite as: Bozhkova S.A. [Comment to the Article "Coatings Based on Two-Dimensionally Ordered Linear Chain Carbon for Protection of Titanium Implants from Microbial Colonization"]. Travmatologiya i ortopediya Rossii [Traumatology and Orthopedics of Russia]. 2019;25(2):121-122. (In Russian). DOI: 10.21823/2311-2905-2019-25-2-121-122.

Svetlana A. Bozhkova; e-mail: clinpharm-rniito@yandex.ru

3. *Perioperative antibacterial carriers or coatings*. Carriers and coatings with antibacterial properties that are applied during surgery and are either biodegradable or not.

According to the above classification the experimental samples studied in the present paper can be attributed to group 2 while antibacterial activity for extended time is determined by presence of silver. The most notable advantage of silver coated surfaces is the ability to continuously release active agents in the peri-implant area for a significant period of time, thus acting both on the superficial layer and in the immediate adjacent structures. It is assumed that the antimicrobial effect of silver is due to the formation of reactive oxygen forms and biologically active ions that damage the bacteria walls and prevent bacterial growth by binding to nucleic acids [8]. Recent study of Aurore et al. (2018) reported that Ag nanoparticles intensify bactericidal activity in osteoclasts [9]. A number of other papers emphasize that silver acts against surface adhered bacteria that do not have significant drug resistance [10, 11]. However, Tapalsky et al. demonstrated in their research that carbon coating alloyed by silver developed by the authors exhibits also the activity against extremely antibiotic resistant Pseudomonas aeruginosa isolate obtained from a patient with posttraumatic osteomyelitis.

Thus, further study of Ag-alloyed coating based on two-dimensionally ordered linear chain carbon seems rather promising due to evident anti-biofilm potential, wide spectrum of antimicrobial effect and no cytotoxicity for human cells. In particularly, early and delayed peri-focal response of surrounding tissues to samples implantation should be studied in order to evaluate the possibility of clinical trials.

References

1. Gbejuade H.O., Lovering A.M., Webb J.C. The role of microbial biofilms in prosthetic joint infections. *Acta Orthop*. 2015;86(2):147-158. DOI: 10.3109/17453674.2014.966290.
2. Koseki H., Yonekura A., Shida T., Yoda I., Horiuchi H., Morinaga Y. et al. Early staphylococcal biofi lm formation on solid orthopaedic implant materials: in vitro study. *PLoS ONE*. 2014;9(10):e107588. DOI: 10.1371/journal.pone.0107588.
3. Frade J.P., Arthington-Skaggs B.A. Effect of serum and surface characteristics on Candida albicans biofilm formation. *Mycoses*. 2011;54(4):e154-162. DOI: 10.1111/j.1439-0507.2010.01862.x.
4. Epstein A.K., Hochbaum A.I., Kim P., Aizenberg J. Control of bacterial biofi lm growth on surfaces by nanostructural mechanics and geometry. *Nanotechnology*. 2011;22(49): 494007. DOI: 10.1088/0957-4484/22/49/494007.
5. Perera-Costa D., Bruque J.M., González-Martín M.L., Gómez-García A.C., Vadillo-Rodríguez V. Studying the influence of surface topography on bacterial adhesion using spatially organized microtopographic surface patterns. *Langmuir*. 2014;30(16):4633-4641. DOI: 10.1021/la5001057.
6. Braem A., Van Mellaert L., Mattheys T., Hofmans D., De Waelheyns E., Geris L., et al. Staphylococcal biofilm growth on smooth and porous titanium coatings for biomedical applications. *J Biomed Mater Res A*. 2014;102(1):215-224. DOI: 10.1002/jbm.a.34688.
7. Romano C.L., Scarponi S., Gallazzi E., Romano D., Drago L. Antibacterial coating of implants in orthopaedics and trauma: a classification proposal in an evolving panorama. *J Orthop Surg Res*. 2015;10:157. DOI: 10.1186/s13018-015-0294-5.
8. Brennan S.A., Ní Fhoghlú C., Devitt B.M., O'Mahony F.J., Brabazon D., Walsh A. Silver nanoparticles and their orthopaedic applications. *Bone Joint J*. 2015;97-B(5): 582-589. DOI: 10.1302/0301-620X.97B5.33336.
9. Aurore V., Caldana F., Blanchard M., Kharoubi Hess S., Lannes N., Mantel PY. et al. Silver-nanoparticles increase bactericidal activity and radical oxygen responses against bacterial pathogens in human osteoclasts. *Nanomedicine*. 2018;14(2):601-607. DOI: 10.1016/j.nano.2017.11.006.
10. Qin H., Cao H., Zhao Y., Zhu C., Cheng T., Wang Q. et al. In vitro and in vivo antibiofilm effects of silver nanoparticles immobilized on titanium. *Biomaterials*. 2014;35:9114-9125. DOI: 10.1016/j.biomaterials. 2014.07.040.
11. Zhao Y., Cao H., Qin H., Cheng T., Qian S., Cheng M., et al. Balancing the osteogenic and antibacterial properties of titanium by codoping of Mg and Ag: an in vitro and in vivo study. *ACS Appl Mater Interfaces*. 2015;7(32):17826-17836. DOI: 10.1021/acsami.5b04168.

INFORMATION ABOUT AUTHOR:

Svetlana A. Bozhkova — Dr. Sci. (Med.), the Head of Research Department of Prevention and Treatment of Wound Infection and Department of Clinical Pharmacology, Vreden Russian Research Institute of Traumatology and Orthopedics, St. Petersburg, Russian Federation