

The problem of infections associated with implants – an overview

Marcin Wekwejt¹, Magda Dziaduszevska¹,
Anna Pałubicka^{2,3}

¹ Biomaterials Group, Department of Materials Engineering and Bonding, Gdańsk University of Technology, Gdańsk, Poland

² Department of Laboratory Diagnostics and Microbiology with Blood Bank, Specialist Hospital in Kościerzyna, Poland

³ Department of Surgical Oncologic, Medical University of Gdańsk, Poland

Abstract

Implant-associated infections are serious and relatively common complication that leads to implant loss. The purpose of this paper is to gather knowledge about this issue. A literature review of the epidemiology, risk factors and pathogenesis of infections related to implants was carried out. This position collects data on commonly used implants and infections associated with them from various fields of medicine and contains classifications of the main factors that predispose to this infection, frequency hierarchy and categorization of bacteria strain that cause them. The risk factors are grouped into four basic groups dependent on: the implant, the patient, the local environment and the surgical technique. It was found that this infections are the most common in the case of: ventricular assist devices, catheters, bone substitutes, dental and breast implants. The conclusion was made that implant-associated infections are usually caused by multiple strains of bacterial species, mainly by *Staphylococci*, especially *Staphylococcus aureus* and *Staphylococcus epidermidis*. The most important aspect of minimizing implant-associated infections is prevention. Summarize, besides of perioperative antibiotic prophylaxis, sterility of treatment and hygiene, the crucial aspect is also the design of implants.

**European Journal
of Medical Technologies**

2018; 4(21): 19-26

Copyright © 2018 by ISASDMT
All rights reserved

www.medical-technologies.eu
Published online 30.10.2018

Corresponding address:

Marcin Wekwejt
Biomaterials Group,
Department of Materials
Engineering and Bonding,
Gdańsk University of
Technology
Narutowicza 11/12
80-233 Gdańsk, Poland
marcin.wekwejt@
pg.edu.pl

Key words:

Implant-associated
infection, biomaterials
infection,
Staphylococci,
bioactive biomaterials,
Prophylaxis

Introduction

Implants and biomedical devices play an important role in treating diseases, restoring health and saving human life. In recent years, they have become an extremely common, valid and inseparable part of medicine [1]. Despite their benefits, their usage involves certain problems. The major ones are: inflammatory reaction, lack of integration with the surrounding tissue, total rejection and infection [2,3]. Generally, it is assumed that infections are one of the main reasons for removal of implants [3]. However, it is implants themselves that contribute to infection. Opening the body's layers and tissue damage by surgery, as well as implementation of foreign body into the interior allows bacteria to colonize in the body [1-3]. It is estimated that most of these infections occur in the form of biofilms, hence they are extremely resistant to host defences and therapy [2-4].

It is important in the aspect of prevention and therapy to have knowledge about a given issue. Hence, the aim of this paper is collecting data on implant-associated infections. The position contains the following classifications: frequency of infections related to implants, factors predisposing to their occurrence and the bacteria strains that cause them.

Methods

Studies were searched in electronic databases according to article titles, abstract contents, and relevance in

the field of implant-associated infection. The databases used in this research were: ScienceDirect, PubMed and Academic Google. The main terms applied were: implant infection, biomaterials infection, biofilm, risk factor implant infection and infections related to specific implants (e.g. orthopedic implant infection or dental implant infection). Articles were sought that provided knowledge about factors affecting the infection, the epidemiology of implant-associated infections and types of bacteria that cause these infections.

Results

Common factors influencing implant-associated infections

The pathogenesis of implant-associated infections is an extremely complex issue and a constant challenge for modern science. Generally, there are four groups of factors that can contribute to infection after implant placement (Fig. 1). These are factors related to: implant properties, patient's individual characteristics, environment properties and surgery technique.

Nowadays, designing implants is important for combating infections. Crucial aspects include: bio-material selection, production quality, surface treatment, geometry optimization and sterilization process. Furthermore, the current trend involves the application of bioactive coatings to implants that fight bacteria (e.g. releasing antibiotic or nanometals particles) [5-9].

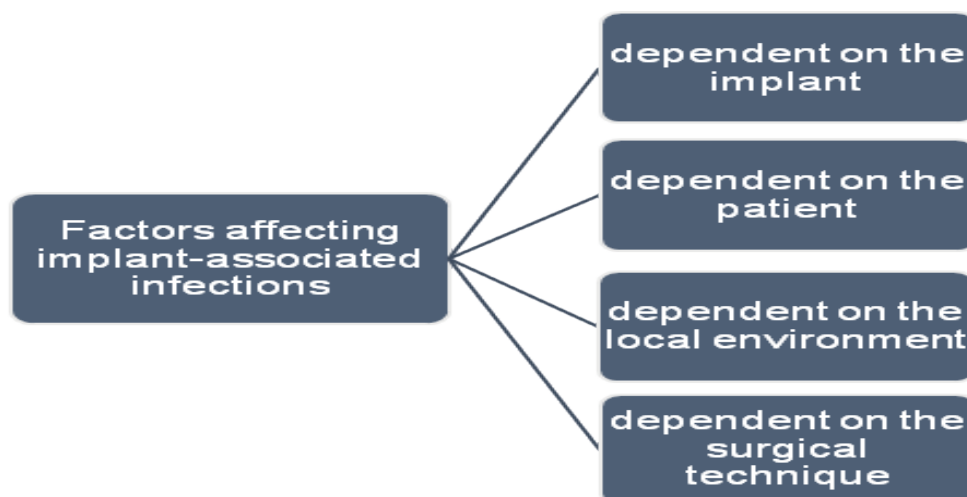


Fig. 1. Classification of factors affecting the risk of implant-associated infections

Other factors that can increase the risk of implant-associated infections are individual features of the patient, i.e. age, health status, BMI, coexisting diseases, using of stimulants, taking drugs, as well as hygiene [10-16].

Furthermore, the properties of the local environment where the implant will be placed can affect the infection. These include: nature of the body fluid (i.e. pH, ion composition, viscosity and circulation rate), quality of tissue, blood supply and vascular integrity, as well as adjacent inflammation or infection. However, if the implant is not biocompatible or the tissue is hypersensitive, it also will increase the risk of infection. Attention should be paid also to the aspect of bacterial contamination at various intensities depending on the place of implantation [3,15,17-20].

The surgery technique also affects the risk of implant-associated infections. The following factors can be distinguished: placement of the implant, its anatomic location, degree of opening the body surface, surgical trauma and degree of damage to surrounding tissues, advancement of perioperative bacterial contamination, reoperation, as well as experience and skills of surgeon [15,20-22].

All common factors related to implant-associated infections were collected in Tab. 1. It can be observed how complicated the character of these infections is. Four groups of factors are dependent on three different people: the implant designer, the surgeon and the patient.

Table 1.
Common factors affecting implant-associated infections

Factors affecting implant-associated infections:	
Properties of the implant [6-9]	<ul style="list-style-type: none"> • implant material • geometry and shape of implant • surface topography and roughness • hydrophilic surface with high surface free energy • surface purity and sterility
Individual features of the patient [10-16]	<ul style="list-style-type: none"> • age • obesity • co-morbidities: <ul style="list-style-type: none"> • diabetes • malnutrition • anemia • renal failure • HIV • drugs (e.g. anticoagulants or corticosteroids) • systemic illness • smoking • alcoholism • radiotherapy or/and chemotherapy • hygiene
Local environment properties [3,15,17-20]	<ul style="list-style-type: none"> • nature of the fluid • bone quality • adjacent inflammation or infection • soft tissue viability • vascular integrity • hypersensitivity of tissue to implant components
Surgical technique [15,20-22]	<ul style="list-style-type: none"> • surgical trauma • anatomic location of the implant • degree of opening the body surface • previous failure • perioperative bacterial contamination • experience and skills of surgeon

Frequency of implant-associated infections

The factors described above contribute to the fact that implant-associated infections have numerous risk of occurrence. Literature analysis of the frequency of these infections was collected in Fig. 2. However, these data are estimated because they come from various sources in which different criteria have been adopted. The aspect of defining the infection, adopting the time of its occurrence, as well as the number of data analyzed from the unit were particularly important. However, the collection allows to determine which implants are particularly predisposed to infection. It is also necessary to take into account the differences between the occurrence of bacterial contamination on the implant surface and the occurrence of implant-associated infections. Most implants will be covered during use with bacteria, this mainly applies to dental

implants, catheters or contact lenses. Hence, the key aspect is the proper use of implants. For example, frequent changes of catheters or proper hygiene of contact lenses during use or general oral hygiene in the case of dental implants [23-44].

The greatest risk of implant-associated infections occurs in the case of: ventricular assist devices, catheters, bone substitutes, dental and breast implants. However, the smallest frequency occurs in the case of orthopedic implants, such as: prosthetic joints or fracture stabilizing equipment (plates and screws).

Classification of common bacterial strains related to implant-associated infections

Implant-associated infections also have a various bacterial background. The analysis of bacterial strains causing these infections was collected in Tab. 2. In the vast majority infections associated with implants are

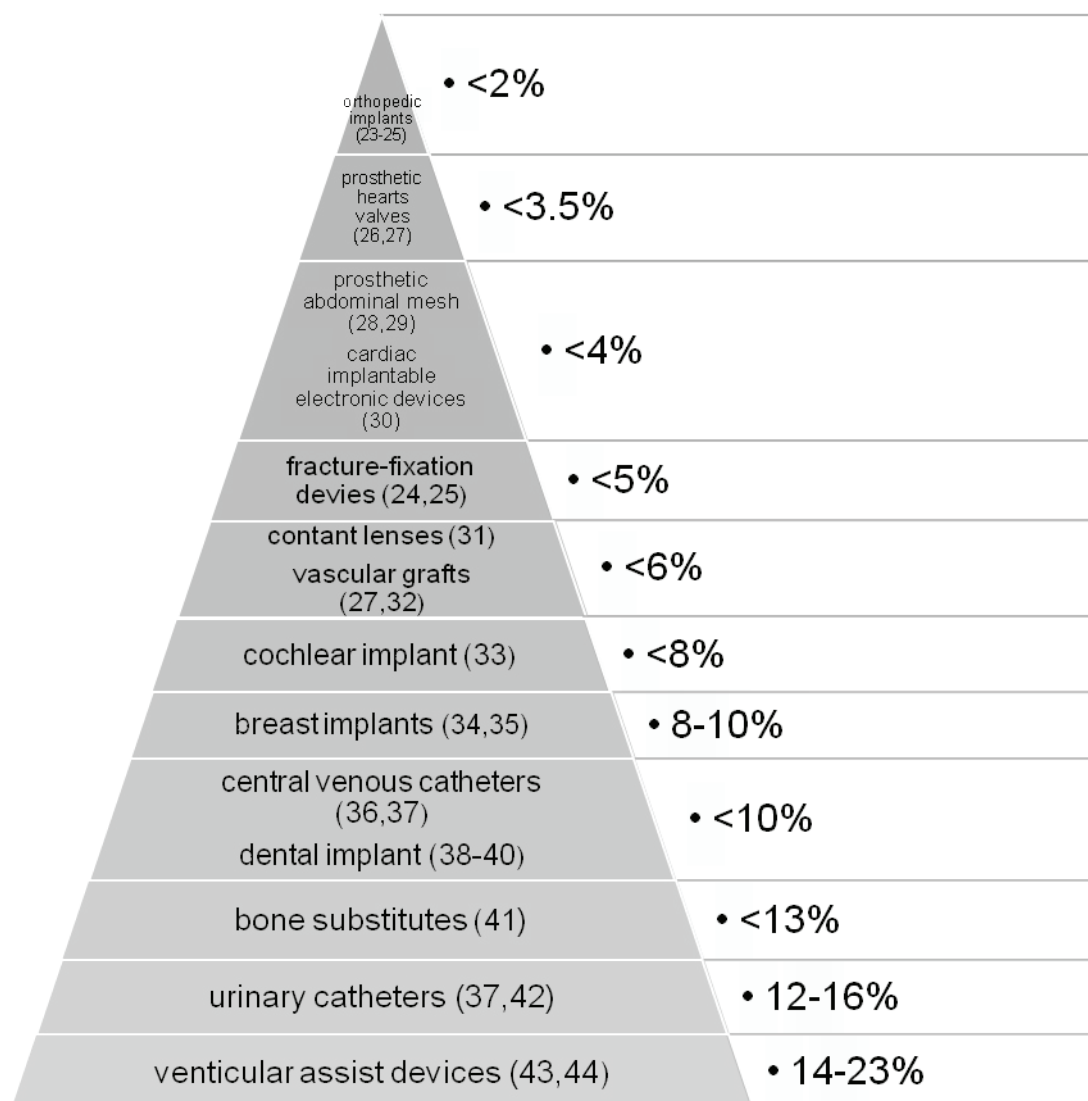


Fig. 2. Frequency of implant-associated infections

Table 2.

Common bacterial strains causing implant-associated infections

Orthopedic implant-associated infections [23-25,41]:
<ul style="list-style-type: none"> • Staphylococcus aureus • Staphylococcus epidermidis • Escherichia coli
Cardiovascular implant-associated infections [26,27,30]:
<ul style="list-style-type: none"> • Staphylococcus aureus • Escherichia coli • Staphylococcus epidermidis • Pseudomonas aeruginosa • Enterococcus faecalis
Visceral implant-associated infections [28,29]:
<ul style="list-style-type: none"> • Staphylococcus aureus • Staphylococcus epidermidis
Ophthalmic implant-associated infections [31]:
<ul style="list-style-type: none"> • Escherichia coli • Staphylococcus aureus • Staphylococcus epidermidis • Pseudomonas aeruginosa • Serratia spp • Staphylococcus spp
Breast implant-associated infections [34,35]:
<ul style="list-style-type: none"> • Staphylococcus aureus • Pseudomonas aeruginosa • Staphylococcus epidermidis
Dental implant-associated infections [38-40]:
<ul style="list-style-type: none"> • Prevotella intermedia • Prevotella nigrescens • Candida spp • Porphyromonas gingivali • Actinobacillus actinomycetemcomitans • Treponema denticola • Bacteroides spp • Streptococcus spp • Staphylococcus spp
Central venous catheter-associated infections [36,37]:
<ul style="list-style-type: none"> • Staphylococcus aureus • Staphylococcus spp
Urinary catheters-associated infections [37,42]:
<ul style="list-style-type: none"> • Escherichia coli • Klebsiella pneumoniae • Proteus mirabilis • Pseudomonas aeruginosa
Ventricular assist device-associated infections [43,44]:
<ul style="list-style-type: none"> • Staphylococcus aureus • Enterobacteriaceae • Pseudomonas aeruginosa • Corynebacterium spp
Genital prostheses-associated infections [45]:
<ul style="list-style-type: none"> • Staphylococcus epidermidis
Hearing implant-associated infections [46]:
<ul style="list-style-type: none"> • Staphylococcus aureus • Streptococcus pneumoniae • Haemophilus influenzae • Pseudomonas aeruginosa

caused by *Staphylococci*, especially *Staphylococcus aureus* and *Staphylococcus epidermidis*. The exceptions are dental implants, which infections in most cases are caused by anaerobic bacteria and urinary catheters, which are caused mainly by *Escherichia coli*. On the one hand, this knowledge gives a big advantage in the aspect of therapy selection, but on the other, the bacteria develop and mutate, as well as, implant-associated infections are caused by multiple strains of bacterial species. Furthermore, their resistance to drug therapy and creating biofilm structures is the growing problem. Bacteria are constantly mutating and become resistance to antibiotics, so fight against them become a crucial problem to medicine [25,35,38,42].

Prevention of implant-associated infections

Effective prevention and, as a consequence, minimizing the risk of developing implant-associated infections is possible while complying the adopted rules regarding the decontamination of the operating environment, the use of perioperative prophylaxis (the right choice of antibiotic, its dose and duration of therapy), proper hygiene, frequent changes of routine used implants, continuous training of medical personnel, as well as control and monitoring procedures are carried out.

Furthermore, bioactive implants presently become standard as well. They are designed to reduce the risk of surface contamination of bacteria or are equipped with antibacterial coating or modifiers [47-49].

Conclusions

- Implant-associated infection is a serious complication related to the use of implants in medicine.
- Four groups of factors favoring the occurrence of implant-associated infection are distinguished: dependent on the implant, dependent on the patient, dependent on the local environment and dependent on the surgical technique.
- The greatest risk of implant-associated infections occurs in the case of: ventricular

assist devices, catheters, bone substitutes, dental and breast implants.

- Implant-associated infections are usually caused by multiple strains of bacterial species.
- *Staphylococci* are responsible for the majority of infections associated with implants, especially *Staphylococcus aureus* and *Staphylococcus epidermidis*.
- A crucial problem is the resistance of bacteria to therapies. Hence, the prevention of infection seems to be the key aspect.
- Nowadays, in addition to perioperative antibiotic prophylaxis, sterility of treatment and hygiene, the crucial aspect of minimizing the risk of implant-associated infection is the design of implants.

Reference

1. Chapter in the book: Stoodley P, Hall-Stoodley L, Costerton B, et al. Biofilms, Biomaterials, and Device-Related Infections. In: Modjarrad K, Ebnesajjad S, ed. Handbook of Polymer Applications in Medicine and Medical Devices, William Andrew Publishing 2013: 77-101.
2. Schierholz JM, Beuth J. Implant infections: a haven for opportunistic bacteria. J Hosp Infect 2001;49:87-93.
3. Oliveira WF, Silva PMS, Silva RCS, et al. Staphylococcus aureus and Staphylococcus epidermidis infections on implants. J Hosp Infect 2018; 98: 111-117.
4. Doll K, Jongstaphongpun KL, Stumpp NS, et al. Quantifying implant-associated biofilms: Comparison of microscopic, microbiologic and biochemical methods. J Microbiol Methods 2016; 130: 61-68.
5. Wekwejt M, Moritz N, Świeczko-Żurek B, Pałubicka A. Biomechanical testing of bioactive bone cements – a comparison of the impact of modifiers: antibiotics and nanometals. Polym Test 2018; 70: 234-243.
6. Xing R, Lyngstadaas SP, Ellingsen JE, et al. The influence of surface nanoroughness, texture and chemistry of TiZr implant abutment on oral biofilm accumulation. Clin Oral Implants Res 2015; 26: 649-656.

7. Han A, Tsoi JKH, Rodrigues FP, et al. Bacterial adhesion mechanisms on dental implant surfaces and the influencing factors. *Int J Adhes Adhes* 2016; 69: 58-71.
8. Shah SR, Tataru AM, D'Souza RN, et al. Evolving strategies for preventing biofilm on implantable materials, *Mater Today* 2013; 16: 177-182.
9. Lin HY, Liu Y, Wismeijer D, et al. Effects of oral implant surface roughness on bacterial biofilm formation and treatment efficacy. *Int J Oral Maxillofac Implants* 2012; 28: 1226-1231.
10. Sánchez FR, Andrés CR, Arteagoitia I. Which antibiotic regimen prevents implant failure or infection after dental implant surgery? A systematic review and meta-analysis. *J Craniomaxillofac Surg* 2018; 46: 722-736.
11. Park KC, Lim SJ, Song YS, et al. Factors affecting peri-implant fracture following locking plate for osteoporotic distal femur fractures. *Orthop Traumatol Surg Res* 2017; 103: 1201-1204.
12. Morgenstern M, Erichsen C, von Räden C, et al. Staphylococcal orthopaedic device-related infections in older patients. *Injury* 2016; 47: 1427-1434.
13. Wu YTY, Willcox M, Zhu H, et al. Contact lens hygiene compliance and lens case contamination: A review. *Cont Lens Anterior Eye* 2015; 38: 307-316.
14. Mittal S, Shaw RE, Michel K, et al. Cardiac implantable electronic device infections: Incidence, risk factors, and the effect of the AigisRx antibacterial envelope. *Heart Rhythm* 2014; 11: 595-601.
15. Baek SH. Identification and preoperative optimization of risk factors to prevent periprosthetic joint infection. *World J Orthop* 2014; 5: 362-367.
16. Ponce NA, Oladeji LO, Raley JA, et al. Analysis of perioperative morbidity and mortality in shoulder arthroplasty patients with preexisting alcohol use disorders. *J Shoulder Elbow Surg* 2015; 24: 167-173.
17. Deny A, Loiez C, Deken V, et al. Epidemiology of patients with MSSA versus MRSA infections of orthopedic implants: Retrospective study of 115 patients. *Orthop Traumatol Surg Res* 2016; 102: 919-923.
18. Bauer TW, Zhang Y: Implants and implant reactions. *Diagn Histopathol* 2016; 22: 384-396.
19. Campoccia D, Montanaro L, Arciola CR. The significance of infection related to orthopedic devices and issues of antibiotic resistance. *Biomaterials* 2006; 27: 2331-2339.
20. Jamal M, Ahmad W, Andleeb S, et al. Bacterial biofilm and associated infections. *Chin Med J* 2018; 81: 7-11.
21. Aghaloo TL, Mardirosian M, Delgado B. Controversies in Implant Surgery. *Oral Maxillofac Surg Clin Noirth Am* 2017; 29: 525-535.
22. Meijer ST, Pereira NRP, Nota SPF, et al. Factors associated with infection after reconstructive shoulder surgery for proximal humerus tumors. *J Shoulder Elbow Surg* 2017; 26: 931-938.
23. Weale R, El-Bakri F, Saeed K. Pre-operative asymptomatic bacteriuria: a risk factor for prosthetic joint infection?. *J Hosp Infect* 2018 /in press/.
24. Metsemakers WJ, Kortram K, Morgenstern M, et al. Definition of infection after fracture fixation: A systematic review of randomized controlled trials to evaluate current practice. *Injury* 2018; 49: 497-504.
25. Montanaro L, Speziale P, Campoccia D, et al. Scenery of Staphylococcus implant infections in orthopedics. *Future Microbiol* 2011; 6: 1329-1349.
26. Hogg ME, Peterson BG, Pearce WH, et al. Bare metal stent infections: Case report and review of the literature. *J Vasc Surg* 2007; 46: 813-820.
27. Lodhia JV, Evans BJ. Heart valve surgery. *Surgery* 2018; 36: 75-82.
28. Mehrabi Bahar M, Jabbari Nooghabi A, Jabbari Nooghabi M., et al. The role of prophylactic cefazolin in the prevention of infection after various types of abdominal wall hernia repair with mesh. *Asian J Surg* 2015; 38: 139-144.
29. Guillaume O, Pérez-Tanoira R, Fortelny R, et al. Infections associated with mesh repairs of abdominal wall hernias: Are antimicrobial biomaterials the longed-for solution?. *Biomaterials* 2018; 167: 15-31.
30. Hussein AA, Baghdy Y, Wazni OM, et al. Microbiology of Cardiac Implantable Electronic Device Infections. *JACC: Clin Electrophysiol* 2016; 2: 498-505.
31. Stamler JF. The complications of contact lens wear. *Curr Opin Ophthalmol* 1998; 9: 66-71.
32. Mankin HJ, Hornicek FJ, Raskin KA. Infection in massive bone allografts. *Clin Orthop Relat Res* 2005; 432: 210-216.
33. Vila PM, Ghogomu NT, Odom-John AR, et al. Infectious complications of pediatric cochlear implants are highly influenced by otitis media. *Int J Pediatr Otorhinolaryngol* 2017; 97: 76-82.

34. Franchell S, Pesce M, Baldelli I, et al. Analysis of clinical management of infected breast implants and of factors associated to successful breast pocket salvage in infections occurring after breast reconstruction. *Int J Infect Dis* 2018; 71: 67-72.
35. Pałubicka A, Wekwejt M, Świeczko-Żurek B, Zieliński J. Powikłania po rekonstrukcji piersi: problem zakażeń i strategii prewencyjnej - przegląd literaturowy. *Chirurgia Plastyczna i Oparzenia*. 2017; 5: 89-97.
36. Santarpia L, Buonomo A, Pagano MC, et al. Central venous catheter related bloodstream infections in adult patients on home parenteral nutrition: prevalence, predictive factors, therapeutic outcome. *Clin Nutr* 2016; 35: 1394-1398.
37. Parra-Flores M, Souza-Gallardo LM, García-Correa GA, et al. Incidence of catheter-related infection incidence and risk factors in patients on total parenteral nutrition in a third level hospital. *Cir Cir* 2017; 85: 104-108.
38. Pye AD, Lockhart DEA, Dawson MP. A review of dental implants and infection. *J Hosp Infect* 2009; 72: 104-110.
39. Berglundh T, Persson L, Klinge B. A systematic review of the incidence of biological and technical complications in implant dentistry reported in prospective longitudinal studies of at least 5 years. *J Clin Periodontol* 2002; 29: 197-212.
40. Mombelli A, Müller N, Cionca N. The epidemiology of peri-implantitis. *Clin. Oral Implants Res* 2012; 23:67-76.
41. Mankin HJ, Hornicek FJ, Raskin KA. Infection in massive bone allografts. *Clin. Orthop. Relat. Res.*, 432 (2005), pp. 210-216
42. Flores-Mireles AL, Walker JN, Caparon M, et al. Urinary tract infections: Epidemiology, mechanisms of infection and treatment options. *Nat Rev Microbiol* 2015; 13: 269-284.
43. Schulte-Eistrup S, Reiss N, Schmidt T, et al. Greater Omentum Wrapping to Treat Systemic Ventricular Assist Device Infections. *Oper Tech Thorac Cardiovasc Surg* 2017; 22: 186-197.
44. Joost I, Bothe W, Pausch C, et al. Staphylococcus aureus bloodstream infection in patients with ventricular assist devices—Management and outcome in a prospective bicenter cohort. *J Infect* 2018; 77: 30-37.
45. Al Mohajer M, Darouiche RO. Infections Associated with Inflatable Penile Prostheses. *Sex Med Rev* 2014; 2: 134-140.
46. Peter M. Vila, Nsangou T. Ghogomu, Audrey R. Odom-John, Timothy E. Hullar, Keiko Hirose, Infectious complications of pediatric cochlear implants are highly influenced by otitis media, *International Journal of Pediatric Otorhinolaryngology*, Volume 97, 2017, Pages 76-82
47. Arciola CA, Campoccia D, Speziale P, et al. Biofilm formation in Staphylococcus implant infections. A review of molecular mechanisms and implications for biofilm-resistant materials. *Biomaterials* 2012; 33: 5967-5982.
48. Bartmanski M, Cieslik B, Glodowska J, et al. Electrodeposition (EPD) of nanohydroxyapatite – nanosilver coatings on Ti13Zr13Nb alloy. *Ceram Int.* 2017; 43: 11820-11829,
49. Michalska-Sionkowska M, Kaczmarek B, Sionkowska A, et al. Antimicrobial activity of new materials based on the blends of collagen/chitosan/hyaluronic acid with gentamicin sulfate addition. *Material Sci Eng* 2018; 86: 103-108.

