Bactiguard® Technology

Lucia Pontiroli PhD, Saurabh Lal PhD, Imran Khan PhD
Zimmer Biomet, Global Anti-Infective Technologies Research Team

Background and Clinical Need

Healthcare-associated infections (HAI) are one of the major challenges in medicine: 3.2 million people are estimated to receive an infection diagnosis every year in Europe, of whom approximately 37,000 become fatal [1]. This leads to 16 million extra-days of hospital stay, and an annual cost of approximately € 7 billion across Europe [2]. The frequency of periprosthetic infections after arthroplasty can vary broadly depending on site and type of reconstruction, ranging from 1-2 % for a primary arthroplasty [3] to as high as 36 % in the case of megaprosthesis [4]. It has been calculated that affected patients have a lower chance of survival at 5 years than people affected by three of the most common types of cancer [5], as illustrated in Figure 1.

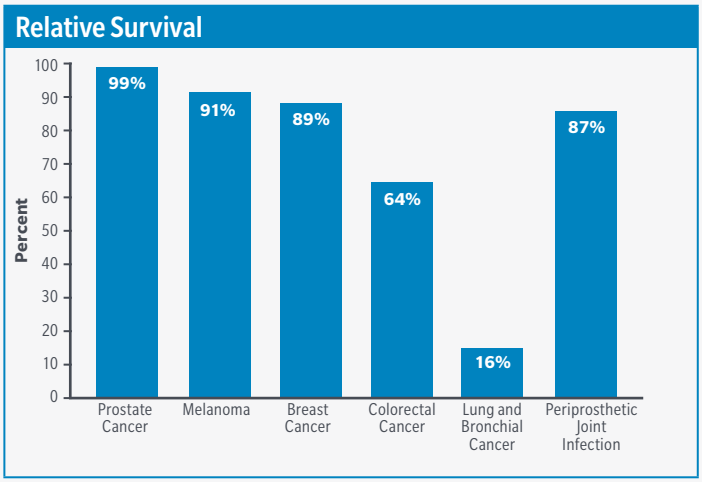

Figure 1. Five-year survival rate of patients affected by the most common forms of cancer, compared to patients affected by periprosthetic joint infection [5].

In orthopaedic trauma, it has been estimated that up to 30 % of cases may result in infection [6]. Almost 80 % of all open fractures present some bacterial contamination [7], many of which may develop into early, delayed and/or late established infections. The risk of infection can also differ widely depending on the classification of open fracture, varying between 0-2 % for Type I fractures, between 2-10 % for Type II fractures, and between 10-50 % for Type III fractures [8,9]. A recent linear regression analysis of the available literature published since 2000 in peer-reviewed journals and conducted by Zimmer Biomet estimated that infections following intramedullary nailing (IMN) are diagnosed, on average, in the 1.6 % of cases for closed fractures and 11.9 % of cases for open fractures, with 0.1 % and 7.5 % of deep infections in closed and open fractures, respectively [10]. A breakdown of overall and deep infection rates per surgical site is presented in Table 1.

Site	Overall Infection Rate (%)	Deep Infection Rate (%)
Tibia	6.46	1.27
Distal Femur	3.92	0.94
Proximal Femur	1.53	0.09
Humerus	1.26	0.79
Ankle	7.9	5.01

Table 1. Rate of infection following IMN [10].

Socioeconomic Impact

Implant associated infections not only have a devastating impact on the quality of life of patients, but also have significant socioeconomic consequences.

These infections place a significant personal burden on healthcare professionals [11] and an economic burden on healthcare systems. It has been estimated that, in Belgium, treatment costs for deep infections following tibial fractures are approximately 6.5 times higher than uninfected cases [12]. In the UK, infections following proximal femoral fractures present a median cost of £ 24,410 with length of stay of 132.5 days, compared to uninfected cases that present a median cost of £ 7,210 and require a length of stay of 30 days [13]. In Italy, an average additional cost of € 9,560 was estimated in case of orthopaedic surgical site infections [14].

Families and wider society are also hugely impacted [15], as patients affected by implant associated infections require additional care and assistance, and their mental health is negatively affected [16]; younger patients are significantly less likely to return to work within a year from fracture [17, 18], and elderly patients have a significantly increased risk of mortality and of not returning to their own home when they require further surgery following complications after fixation of proximal femoral fractures [19].

The Role of the Biofilm

The primary challenge with treating or eradicating implant-associated infections is the ability of certain bacteria to create a protected community called a biofilm. As represented in Figure 2, shortly after planktonic or 'free floating' bacteria have come into contact with a surface, they start to proliferate and embed themselves in an organic matrix known as the extracellular polymeric substance (EPS). Inside the biofilm, aggregates of bacterial microcolonies are shielded from the surrounding environment, making them less susceptible to the attacks of the immune system or to regular dosage of antibiotics [20].

As the biofilm matures, it can release new planktonic bacteria into the environment, resulting in a new cycle of biofilm formation and spread of the infection. The entire process from the colonisation of a surface by planktonic bacteria to the creation of a mature biofilm can take place in a few days [21].

It has been estimated that biofilms account for over 80% of microbial infections in the body as publicly announced by the US National Institutes of Health [22,23].

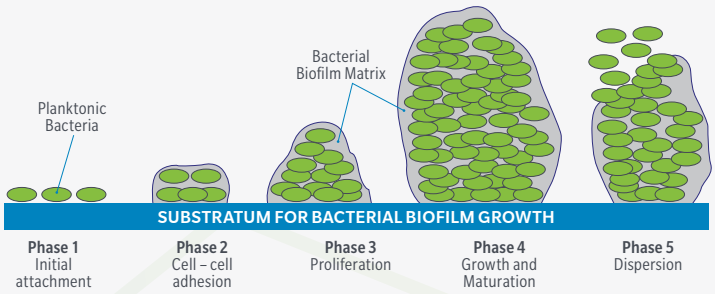

Figure 2. Biofilm formation on an implant surface.

Antibiotic Resistance

Current strategies for the control of implant associated infections rely primarily on the administration of local and systemic antibiotics. However, it is well known that bacteria develop resistance to antibiotics, even more so in healthcare facilities rather than in the community [24]. There were an estimated 4·95 million (3·62–6·57) deaths associated with bacterial antimicrobial resistance in 2019 [25]. Without alternative treatments to antibiotics, it has been predicted that, by the year 2050, 10 million people worldwide will die every year due to multi-resistant microbial infections, overtaking the number of deaths caused by cancer [26].

The decreased susceptibility of bacteria grown in biofilms to antibiotics highly reduces the chances of eradicating these infections, thus further increasing the risk of triggering antibiotic resistance. Every year, more than 670,000 infections occur in the EU/EEA due to antibiotic-resistant bacteria, with the death of 33,000 people and with a cost for healthcare systems of € 1.1 billion as a direct consequence [27]. To address the growing concerns over antibiotic resistance and to ensure responsible antibiotic stewardship, Bactiguard Technology provides an alternative non antibiotic-releasing approach to tackle biofilms.

History of Bactiguard Technology [28]

The Bactiguard Technology has its origins in the work of Nobel Prize laureate Gustaf Dahlén. Billy Södervall, started to apply the noble metal coating to medical devices in the 70's.

The coating was first applied to urinary catheters through a partnership with BD (Becton, Dickinson & Company, previously C.R. Bard), with the first FDA clearance in 1994. Since then, various medical devices with the Bactiguard Technology have been approved. These include Foley catheters, central venous catheters, endotracheal tubes and orthopaedic trauma implants. To date over 200 million Bactiguard coated products have been sold worldwide (including Europe, U.S., Japan, China, Brazil, India and Mexico) [29].

In 2019, Bactiguard and Zimmer Biomet entered into a global, exclusive licensing agreement for orthopaedic trauma implants, which led to the CE marking of the ZNN™ Bactiguard and ANN™ Bactiguard at the beginning of 2021.

Below is a timeline showing history of Bactiguard Technology.

1912 –	**Gustav Dahlén,** Swedish Nobel Prize laureate in Physics. The man behind the AGA lighthouse system, from which Bactiguard Technology originates
1978 –	**Billy Södervall** starts developing the Bactiguard Technology
1980 –	Partnership with **C.R. Bard**
1994 –	FDA 510k
1995 –	Patent in the US
2005 –	Bactiguard AB founded
2008 –	Launch of **BIP Foley**
2013 –	Launch of **BIP CVC** and **BIP ETT**
2015 –	License agreement with **Vigilenz**
2016 –	Launch of **BIP ETT Evac**
2018 –	Launch of **BIP Foley Tiemann & Female** Launch of **BIP CVC** with **Raulerson Syringe** CE mark of orthopaedic trauma implants with Bactiguard
2019 –	Partnership with **Zimmer Biomet**
2020 –	Acquisition of Malaysian **Vigilenz**
2021 –	CE mark of **ZNN Bactiguard** and **ANN Bactiguard**

BIP: Bactiguard Infection Prevention
ETT: Endotrancheal Tube
CVC: Central Venous Catheter

The Bactiguard Technology

Coating Characterization

The Bactiguard Technology is a stable and durable metallic coating that is firmly bound to the implant surface through strong covalent bonds [30,31].

More specifically, the Bactiguard coating is a noble metal alloy coating containing silver, gold and palladium that is applied to substrates via a wet chemistry process. The coating consists of a thin, non-continuous layer of discrete clusters, as shown by the Scanning Electron Microscope (SEM) and Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) images in Figure 3 and Figure 4, respectively [32].

The amount of noble metals released by the coating has been shown to be well below the applicable tolerable intake or permitted daily exposure, thus demonstrating the toxicological safety of the Bactiguard coating [33,34]. In addition, since the coating is covalently bonded to the substrate, it does not meet the definition of a 'nanomaterial' according to the definition stated in the 2017/745/EU Medical Device Regulation [35].

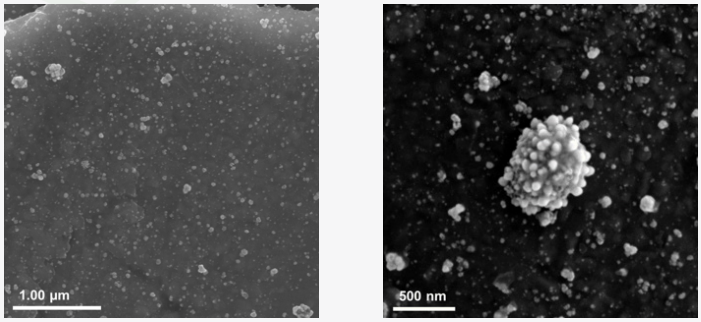

Figure 3. SEM micrographs of a titanium substrate with the Bactiguard Technology at lower (left) and higher (right) magnification. (SEM images taken internally at Zimmer Biomet).

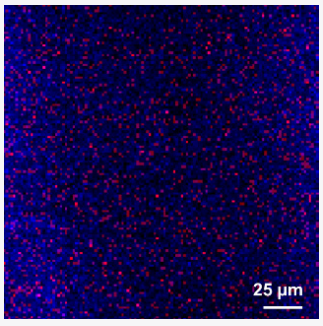

Figure 4. ToF-SIMS image showing the distribution of palladium (red) and silver (blue) on a silicone substrate [32].

Mechanism of Action

The noble metals in the Bactiguard coating have different electro-potentials and so, in combination, this results in a 'galvanic effect' that generates pico-currents (trillionth of an Ampere, 10^{-12} A) on the implant surface. These pico-currents lead to reduced adhesion of microorganisms to coated surfaces and, consequently, decreased possibility of biofilm formation, as discussed later [36-40].

Comprehensive laboratory testing has established the mechanism of action of Bactiguard technology by confirmation of the physical mechanism of reduction of microbial adhesion by galvanic effect [41-43] and absence of mechanisms based on antimicrobial elution [44-49].

The electric potentials and currents that produce this galvanic effect in the coating have been measured via Electrostatic Force Microscopy (EFM) [41] and PeakForce TUNA Atomic Force Microscopy (AFM) [42], respectively (Figure 5). The current was found to vary between 0 to almost 250 pA, with an average of 71 pA compared to 0.17 pA in the uncoated control [42]. The magnitude of these currents is very small, and only detectable *in vitro* with these highly sensitive instruments.

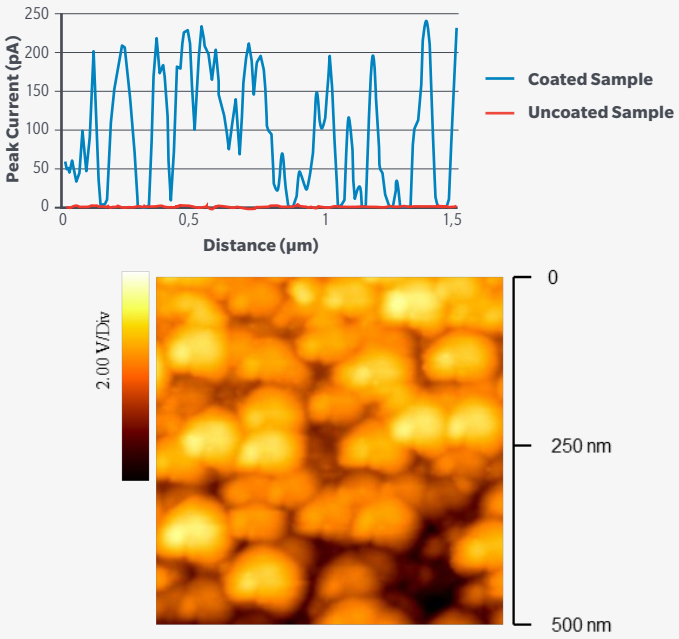

Figure 5. Top: Current distribution over a line on coated and uncoated stainless steel, measured using PeakForce TUNA AFM [42]. Bottom: EFM image showing the electric potential distribution on Bactiguard-coated glass slide [41].

The measured currents affect microbial adhesion by interfering with the respiratory chain, which in bacteria is located in the inter-membrane space, thus close to the surrounding environment. On the contrary, in eukaryotic (human) cells, which are about ten times larger than bacteria, the mitochondria (the respiratory organelles) are situated inside the cell membrane and are therefore more protected and less affected by electrical currents of such a small magnitude [50].

The anti-adhesive nature of the Bactiguard coating has been demonstrated through *in vitro* microbial tests based on methods adapted from the work of Ahearn and co-workers at Georgia State University [52,53]. Numerous substrates, representing different Bactiguard-coated devices, have been tested against different microbial species; relevant results are summarised in Table 2.

Substrate	*Microbial Strain*	*% Reduction in adhesion*
Ti6Al4V rods	*S.aureus*	*84%*
Ti6Al4V rods	*P.aeruginosa*	*99.997%*
Silicone BIP Foley catheter	*S.aureus (including MRSA)*	*97%*
Silicone BIP Foley catheter	*P.aeruginosa*	*81%*
Silicone BIP Foley catheter	*E.coli*	*96%*
Latex Foley Catheter	*C.albicans*	*70%*
Latex Foley Catheter	*P.aeruginosa*	*85%*
Latex Foley Catheter	*E.coli*	*93%*
Polyvinyl chloride BIP ETT	*S.aureus (including MRSA)*	*91%*
Polyvinyl chloride BIP ETT	*E.coli*	*99.7%*
Polyvinyl chloride BIP ETT	*P.aeruginosa*	*97%*
Polyurethane BIP CVC	*S.aureus*	*72%*
Polyurethane BIP CVC	*P.aeruginosa*	*77%*

Table 2. Reduction in adhesion of microbes when the Bactiguard coating was applied to different substrates, compared to uncoated controls [43]. The Ti6Al4V rods were representative surrogates of ZNN/ANN Bactiguard implants. MRSA: methicillin- resistant Staphylococcus aureus.

Anti-infective implant surfaces need to balance cytotoxicity and antimicrobial efficacy and hence support the adhesion of bone-related cells (e.g., osteoblasts) while inhibiting bacterial adhesion [54]. Non-eluting anti-infective technologies may provide some benefits over eluting devices such as a reduced risk of local tissue toxicity and in vivo effectiveness over longer periods.

The absence of elution-based antimicrobial mechanisms has been confirmed by widely-used microbiological/analytical tests such as: zone of inhibition testing (ASTM E2149-10) to confirm the absence of elution-based microbial inhibition and killing [44]; cellular reactive oxygen species (ROS) testing to confirm the absence of mechanisms associated with ROS release [45]; high-resolution electron microscopy of microbes and membrane permeability assay to confirm no cellular membrane damage by the coating [46,47]; immersion test (ISO10993-5) to confirm the absence of antimicrobial concentration of ions; and bulk/localized pH testing to confirm no pH mediated mechanism [48,49].

In Vivo Evidence

In Vivo Animal Studies

The reduction in bacterial adhesion observed in vitro has also been observed in vivo as significant reduction in S.aureus CFUs on the implant in a mouse model of periprosthetic joint infection [55]. Reduction in biofilm formation was also observed in this study using SEM imaging.

The effects on bone of Bactiguard-coated, commercially pure titanium screws has been evaluated in a rabbit in vivo model where bone integration was found comparable to that of uncoated screws [56].

Clinical Evidence

The reduction in bacterial adhesion observed *in vitro* has been shown to translate into reduction in infection rates in the clinical setting as well, for all Bactiguard-coated devices. Since urinary catheters were the first coated devices to enter the market, numerous studies have been published over the years reporting positive outcomes [57-62], the most recent being a randomised, prospective, multicentre study on 1,000 patients that showed a reduction in infections of 69 % compared to uncoated catheters over a mean duration of catheterization of 11 days [63]. A 52 % reduction in infection rate (median catheterization time 13 days) [64] and significantly fewer adverse events (mean catheterization time 9.2 days, range 4 to 16 days) [65] were also observed for Bactiguard coated CVC devices, whilst ETT devices showed reduced high-grade biofilm formation (median intubation time 3.6 days) [66] and a 67 % reduction in infection rates at 5 days [67].

Recent publications provided safety and efficacy evidence of the Bactiguard technology [55,69] in orthopedic trauma. Two articles using intramedullary nailing systems with the Bactiguard coating were published in 2022 and 2023. The first study was a retrospective, single-center case series study in Malaysia using the OrthoSynTM Nails [30]. Fracture-related infections and bone healing were analysed in patients with Gustilo type IIIa or IIIb open femoral and tibial fractures. The study showed positive results, with an infection rate of 8.6% (3/35) and a fracture union rate of 93.8% (30/32). Another single centre retrospective study using the ZNN Bactiguard Tibia Nails was conducted in a Level 1 Major Trauma centre in the UK [69]. In this study, open and closed tibial fractures at risk for developing complications were included and followed up over 12 months. The authors reported infection and union rates of 3.2% (1/31) and 96.7% (30/31), respectively. Despite the low number of cases in these studies, the results show that Bactiguard technology has great potential for infection control in fracture patients.

Four international multi centre prospective post-market clinical follow-up (PMCF) studies have been set up to build stronger clinical evidence. These PMCF studies are covering all indications of the ZNN coated with the Bactiguard technology (Tibia, Proximal Femur, Distal Femur, and Hip), and include eight EMEA countries so far. Overall, they intend to enrol up to 600 Bactiguard cases.

Durability

The durability of the coating after implantation has been observed in a retrieval study including qualitative and quantitative analysis of a nail retrieved from a patient after 8 months: all the metal elements of the coating were still detected, and were still within the coating specification [31], which suggests that the coating was still effective.

This is also supported by clinical studies related to Bactiguard-coated devices, which have shown that the use of these products reduces the number of antibiotic days [58], as well as the prevalence of antibiotic resistance in the treated population [59].

Notably, no adverse event related to the Bactiguard coating has ever been recorded over more than 25 years that products have been on the market [70]. This includes CVCs, where the Bactiguard coating is in direct contact with the blood stream, and Foley urinary catheters periodically changed throughout the lifetime of some patients, thus subjecting them to the repeated exposure to the coating every time the catheter is exchanged.

Conclusion

The Bactiguard Technology consists of a thin, non-continuous layer of clusters of a silver, gold and palladium alloy, which generates galvanic currents that reduce microbial adhesion to implant surfaces, and thus decrease the possibility of biofilm formation.

The coating is non-eluting, durable, and does not contain antibiotics. This avoids challenges associated with handling of products or their shipping and storage, as it does not require controlled temperatures and conditions as seen with alternative solutions using antibiotics.

The Bactiguard Technology is well-established, with proven clinical safety and efficacy [71] in reducing infection rates from urinary catheters, endotracheal tubes and central venous catheters.

The use of the Bactiguard Technology on titanium alloys for trauma applications has also shown effectiveness [43], and is expected to aid in reducing the burden of orthopaedic implant associated infections, while also supporting fracture repair.

Although the use of Bactiguard-coated intramedullary nails does not substitute for standard preventive antibiotic protocols, the availability of a non-antibiotic prophylactic solution provides an alternative approach to infection management. This is particularly timely given that the current infection control scenario is ever more challenged by antibiotic resistance.

Disclaimers

ZNN and ANN Bactiguard are intended to reduce the risk of implant related infections, but are not indicated for the treatment of established infections.

Use of this product does not replace existing standard practice for infection control such as the use of prophylactic antibiotics.

References

1. European Centre for Disease Prevention and Control, Economic evaluations of interventions to prevent healthcare-associated infections – Literature review. Stockholm: ECDC, 2017.
2. World Health Organization, Report on the Burden of Endemic Health Care-Associated Infection Worldwide - Clean Care is Safer Care. WHO 2011.
3. Izakovicova et al., Periprosthetic joint infection: current concepts and outlook. EFORT Open Reviews 4: 482-494, 2019.
4. Savvidou et al., Efficacy of antimicrobial coated orthopaedic implants on the prevention of periprosthetic infections: a systematic review and meta-analysis. The Journal of Bone and Joint Infection 5(4): 212-222, 2020.
5. Zmistowski, A quarter of patients treated for PJI dead within 5 years. Orthopedics Today, 2012. https://www.healio.com/news/orthopedics/20130104/a-quarter-of-patients-treated-for-pji-dead-within-5-years (Accessed on 12th March 2021).
6. Schwarz et al., 2018 International Consensus Meeting on Musculoskeletal Infection: Research Priorities from the General Assembly Questions. Journal of Orthopaedic Research 37(5): 997- 1006, 2019.
7. Seekamp et al., Bacterial Cultures and Bacterial Infections in Open Fractures. European Journal of Trauma and Emergency Surgery 26(3): 131-138, 2000.
8. Neubauer et al., Open fractures and infection. Acta Chirurgiae Orthopaedicae et Traumatologiae Čechoslovaca 73(5): 301-312, 2006.
9. Kim et al., Gustilo-Anderson classification. Clinical Orthopaedics and Related Research 470(11): 3270-3274, 2012.
10. Data on file at Zimmer Biomet (Kaufmann, Infections after IMN of Long Bones Synthesis. 2020. (DK Consulting review)).
11. Mallon et al., Surgeons are deeply affected when patients are diagnosed with prosthetic joint infection. PLoS ONE 13(11): e0207260, 2018.
12. Metsemakers et al., Infection after fracture fixation of the tibia: Analysis of healthcare utilization and related costs. Injury 48(6): 1204-1210, 2017.
13. Pollard et al., Deep wound infection after proximal femoral fracture: consequences and costs. Journal of Hospital Infection 63(2): 133-139, 2006.
14. Nobile et al., Developing a model for analysis the extra costs associated with surgical site infections (SSIs): an orthopaedic and traumatological study run by the Gaetano Pini Orthopaedic Institute. Antimicrobial Resistance and Infection Control 4(Suppl 1): 68, 2015.
15. Golics et al., The impact of disease on family members: a critical aspect of medical care. Journal of the Royal Society of Medicine 106(10) 399-407, 2013.
16. Brinker et al., The Devastating Effects of Tibial Nonunion on Health-Related Quality of Life. The Journal of Bone & Joint Surgery – American Volume 95(24): 2170-2176, 2013.
17. Napierala et al., Infection reduces return-to-duty rates for soldiers with Type III open tibia fractures. Journal of Trauma Acute Care and Surgery 77(3), Suppl. 2: S194-S197, 2014.
18. Olesen et al., The cost of infection in severe open tibial fractures treated with a free flap. International Orthopaedics (SICOT) 41: 1049-1065, 2017.
19. Thakar et al., The cost and consequences of proximal femoral fractures which require further surgery following initial fixation. The Journal of Bone and Joint Infection [Br] 92-B(12): 1669-1677, 2010.
20. Katsikogianni and Missirlis, Concise review of mechanisms of bacterial adhesion to biomaterials and of techniques used in estimating bacteria-material interactions. European Cells and Materials 8:37-57, 2004.
21. Lebeaux et al., From in vitro to in vivo Models of Bacterial Biofilm-Related Infections. Pathogens 2: 288-356, 2013.
22. Davies D., Understanding biofilm resistance to antibacterial agents. Nat Rev Drug Discov. 2(2):114-22, 2003.
23. https://grants.nih.gov/grants/guide/pa-files/PA-03-047.html.
24. https://www.cdc.gov/hai/patientsafety/ar-hospitals.html (Accessed on 12th April 2021).
25. Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet. 399(10325):629-655, 2022.
26. O'Neill, Review on Antimicrobial Resistance Antimicrobial Resistance: Tackling a crisis for the health and wealth of nations. London: Review on Antimicrobial Resistance. 2014. Available from:https://amr-review.org/sites/default/files/AMR%20Review%20Paper%20-%20Tackling%20a%20crisis%20for%20the%20health%20and%20wealth%20of%20nations_1.pdf (Accessed on 6th April 2021).
27. Organisation for Economic Co-operation and Development, Antimicrobial Resistance – Tackling the Burden in the European Union. Briefing note for EU/EEA countries. OECD Publishing, Paris; 2019.
28. https://www.bactiguard.com/ (Accessed on 11th July 2024).
29. Data on file at Bactiguard AB (VMD-CE-019).
30. Data on file at Bactiguard AB (REP-17293).
31. Data on file at Bactiguard AB (REP-16514).
32. Data on file at Bactiguard AB (0172-5006-REV).
33. Data on file at Bactiguard AB (REP-15617).
34. Data on file at Bactiguard AB (REP-14495).
35. EC (European Commission) (2017). Regulation (EU) 2017/745 of the European Parliament and of the Council of 5 April 2017 on medical devices.

36. Bernaus M, Guillem-Marti J, Bermúdez-Castel A, Calero JA, Torres D, Veloso M, Font-Vizcarra L. Reducing bacterial adhesion to titanium surfaces using low intensity alternating electrical pulses. World J Orthop 2022; 13(6): 578-586.
37. Freebairn, Linton, Harkin-Jones, Jones, Gilmore & Gorman, Electrical methods of controlling bacterial adhesion and biofilm on device surfaces, Expert Rev. Med. Devices 10(1), 00–00 (2013).
38. Hong et al., Effect of Electric Currents on Bacterial Detachment and Inactivation, Biotechnology and Bioengineering, Vol. 100, No. 2, June 1, 2008.
39. Jiwei Li et al., Electroactive materials: Innovative antibacterial platforms for biomedical applications, Progress in Materials Science, Volume 132, 101045, 2023.
40. Hakamada, M et al., Antibacterial activity of ultrathin platinum islands on flat gold against Escherichia coli. Scientific Reports, 10, 9594, 2020.
41. Data on file at Bactiguard AB (1384-1004-ER).
42. Data on file at Bactiguard AB (2497-5006-ER).
43. Data on file at Bactiguard AB (REP-15819; REP- 17096; REP-18299).
44. Data on file at Bactiguard AB (REP-18445; REP-15696).
45. Data on file at Bactiguard AB (REP-17253).
46. Data on file at Bactiguard AB (REP-16705).
47. Data on file at Zimmer Biomet (CBE-REPORT-OCT2023-Bactiguard membrane permeability test report).
48. Data on file at Bactiguard AB (REP-17101).
49. Data on file at Zimmer Biomet (TR_SW_00922).
50. Alberts et al., Molecular Biology of the Cell. 6th edition, New York: Garland Science; 2015. Current Microbiology 41: 120-125, 2000.
51. Chung et al., A prospective interventional study to examine the effect of a silver alloy and hydrogel-coated catheter on the incidence of catheter-associated urinary tract infection. Hong Kong Medical Journal 23(3): 239-245, 2017.
52. Gabriel et al., Effects of silver on adherence of Bacteria to Urinary Catheters: In vitro studies. Current Microbiology 30: 17-22, 1995.
53. Ahearn DG et al., Effects of hydrogel/silver coatings on in vitro adhesion to catheters of bacteria associated with urinary tract infections. Curr Microbiol. Aug;41(2):120-5, 2000.
54. Kaspiris, A et al., Current Progress and Future Perspectives in Contact and Releasing-Type Antimicrobial Coatings of Orthopaedic Implants: A Systematic Review Analysis Emanated from In Vitro and In Vivo Models. Infect. Dis. Rep., 16, 298-316, 2024.
55. Kendal J et al., Decreasing bacterial colonization: Non-eluting Zimmer Bactiguard® implant coating decreases burden of implant infection seven days after surgery, Annual Musculoskeletal Tumor Society Meeting, Poster 18, 2022.
56. Svensson et al., Osseointegration of titanium with an antimicrobial nanostructured noble metal coating. Nanomedicine: Nanotechnology, Biology, and Medicine 9: 1048-1056, 2013.
57. Karchmer et al., A Randomized Crossover Study of Silver-Coated Urinary Catheters in Hospitalized Patients. Archives of Internal Medicine 160: 3294-3298, 2000.
58. Lederer et al., Multicenter Cohort Study to Assess the Impact of a Silver-Alloy and Hydrogel-Coated Urinary Catheter on Symptomatic Catheter-Associated Urinary Tract Infections. Journal of Wound Ostomy & Continence Nursing 41(5): 1-8, 2014.
59. Banaszek et al., Effectiveness of silver alloy-coated silicone urinary catheters in patients with acute traumatic cervical spinal cord injury: Results of a quality improvement initiative. Journal of Clinical Neuroscience 78: 135-138, 2020.
60. Rupp et al., Effect of silver-coated urinary catheters: Efficacy, cost-effectiveness, and antimicrobial resistance. American Journal of Infection Control 32(8): 445-450, 2004.
61. Stenzelius et al., Noble Metal Alloy-Coated Latex Versus Silicone Foley Catheter in Short-Term Catheterization: A Randomized Controlled Study. Scandinavian Journal of Urology and Nephrology 45(4): 258-264, 2011.
62. Chung et al., A prospective interventional study to examine the effect of a silver alloy and hydrogel-coated catheter on the incidence of catheter-associated urinary tract infection. Hong Kong Medical Journal 23(3): 239-245, 2017.
63. Kai-Larsen et al., Foley catheter with noble metal alloy coating for preventing catheter-associated urinary tract infections: a large, multi-center clinical trial. Antimicrobial Resistance & Infection Control 10(40), 2021.
64. Goldschmidt et al., Prevention of Catheter-Related infections by Silver Coated Central Venous Catheters in Oncological Patients. Zentralblatt für Bakteriologie 283(2): 215-223, 1995.
65. Björling et al., Evaluation of central venous catheters coated with a noble metal alloy – A randomized clinical pilot study of coating durability, performance and tolerability. Journal of Biomedical Material Research Part B: Applied Biomaterials, 106B: 2337–2344, 2018.
66. Thorarinsdottir et al., Biofilm formation on three different endotracheal tubes: a prospective clinical trial. Critical Care 24: 382, 2020.
67. Tincu et al., Ventilator associated pneumonia: do silver-coated endotracheal tubes really work? [poster]. Euroanesthesia, Berlin 30th May – 2nd June 2015.
68. Karupiah et al., Use of a Novel Anti-Infective Noble Metal Alloy Coated Titanium Orthopedic Nail in Patients with Open Fractures: A Case Series from Malaysia. Antibiotics (Basel),11(12): 1763, 2022.
69. Kotsarinis et al., Stabilization of Tibial Fractures at Risk of Complications With the Bactiguard Intramedullary Nail: Early to Medium Results With a Novel Metal-Coated Device. J Orthop Trauma, 37(11S): S12-S17, 2023.
70. Data on file at Bactiguard AB (REP-03324).
71. 3581.1-EMEA-en Summary of Clinical Data on Safety, Performance and Efficacy of the Bactiguard Noble Metal Alloy Coating, Aug 2021.

Legal Manufaturer of Instruments
Zimmer, Inc.
1800 W. Center St.
Warsaw, Indiana 46580
USA

Legal Manufaturer of Instruments
Zimmer GmbH
Sulzerallee 8
8404 Winterthur
Switzerland

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308 b, Jalan Perindustrian Bukit Minyak 18
Penang Science Park, 14100 Penang
Malaysia

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