Antimicrobial Coating of Medical Implants

Prof Dr Nusret Köse

Orthopaedic implants are used routinely worldwide for surgical treatment of the musculoskeletal conditions. The primary aim of these devices is to provide mechanical stabilization so that alignment and function of bone can be maintained during physiologic loading. By providing stability to the injured limb or body part, foster earlier return to function.

Although bulk properties of an implant can initially determine the material suitability, the physical properties and chemistry of the material surface are crucial to the function of many biomedical devices. While physical modification results in a change in the topography or morphology of the surface, chemical treatment can result in surface functionalization. Modifying the surfaces of the implants can prevent corrosion, enhance biocompatibility, and improve osseointegration without compromising the bulk properties.

Implant-related infection is one of the leading reasons for failure in orthopaedics and trauma, and results in high social and economic costs. Surgical site infection (SSI) after implant use for closed fracture has a reported incidence ranging from 0.5% to 10%, and up to 50% after open fractures. Various antibacterial coating technologies have proven to be safe and effective both in preclinical and clinical studies, with post-surgical implant-related infections reduced by 90% in some cases, depending on the type of coating and experimental setup used.

The most preferred method to increase the compatibility of metallic implants with bone tissue is to coat their surfaces with calcium phosphate based ceramics. The next logical step is to prevent implant-related infections by adding antimicrobials to it. Given the high risk of antibiotic resistance associated with antibiotic-loaded coatings and other problems, non-antibiotic substances are a much more attractive alternative. Among the various substances, silver stands out with its inhibition of bacterial attachment, its broad antibacterial spectrum, its long-term antibacterial effect and its less prone to resistance development. By using silver in combination with ceramic bioactive surface material such as hydroxyapatite, we obtain a product with both high bone integration and antimicrobial activity.

Surface modification falls under two categories: physical and chemical.

With little to no change in the chemistry, such as etching, grit-blasting, and machining. Well-established chemical techniques include plasma and chemical vapor deposition, atomic layer deposition, and electro-chemical deposition [3], [4], [5], [6]. Chemical treatment can result in oxideing/nitriding/carbiding a surface, surface functionalization, ion infusion, single layer coatings, or coatings comprising many layers of different compositions.
The goal of modifying the surface of a biomaterial is to create a specific chemical and physical environment that offers a favorable cellular response in hard or soft tissue. In cases where tissue integration is desired the physical environment includes macro, micro, and even nanoscale features that allow for cells to adhere, proliferate, and migrate.

The most important problems of these implants which are applied to the patients are their inability to attach to the bone and their susceptibility to infection. The incidence of implant-related infections in orthopedics may be more than 50% depending on the site and application. Infection is the most feared and problematic complication in implant associated surgical procedures. Implant-related infections are a major problem for both patients and healthcare providers. Prevention of implant-related infections is vitally important because of the economic, social and psychological problems associated with this complication.

In the field of orthopedics and traumatology, the most preferred method to increase the compatibility of metallic implants with bone tissue is to coat their surfaces with calcium phosphate based ceramics. The next logical step is to prevent implant-related infections by adding antimicrobials to it. Given the high risk of antibiotic resistance associated with antibiotic-loaded coatings and other problems, non-antibiotic substances are a much more attractive alternative. Among the various substances, silver is a substance that stands out with its inhibition of bacterial attachment, its broad antibacterial spectrum, its long-term antibacterial effect and its less prone to resistance development. If silver is used in combination with ceramic bioactive surface material such as hydroxyapatite, we obtain a product with both high bone integration and antimicrobial activity.
While the other talks in this Symposium will focus on emerging novel Osteoarthritis modulating factors and potential future molecular remedies, in my lecture I would like to give an overview about our current understanding of microenvironmental factors which impact chondrocytes and thus potentially alter disease progression. In line with the topic, “hypoxia” has been shown to influence the metabolism of healthy and pathologically altered chondrocytes as well as extracellular matrix turnover and cell survival. Moreover, specific changes in the local microenvironment and how they influence chondrocyte differentiation in vitro and in vivo will be discussed. To this end, I will address our current understanding of the molecular regulation of chondrocyte terminal differentiation and how this alters the course of osteoarthritic symptom development through the initiation of a disease-amplifying feedback loop. Finally, among others, altering mammalian target of rapamycin (mTOR) signaling, using FK506- or “hyperosmotic” treatment strategies, or pharmaceutically targeting epigenetics, will be illustrated as promising future options to improve current treatment strategies of focal chondral lesions and inhibit the progression of Osteoarthritis.

In the 21st century, orthopedic surgeons put more effort in individuals with musculoskeletal problems to participate in society and maintain their physical and mental activities. Nowadays, in all medical fields regenerative medicine is the new hope for tissue damage regeneration or total organ replacements. Moreover, one of the most important applications of regenerative medicine in the field of orthopedics is the biological treatment of cartilage injury. High prevalence of cartilage injury in the population is not only a clinical and economic burden, but also an important problem for health system and life quality. Epidemiologically, it has been shown that 61 percent of the 1000 arthroscopies have similar cartilage lesions. Cartilage has a poor intrinsic capacity for repair because of its avascular nature. The treatment of focal articular cartilage lesions remains a challenging clinical problem. Untreated lesions can predispose affected joints to pain and dysfunction. An early stage treatment of joint cartilage lesion is critical for relief of the symptoms, regaining of the joint function and avoids the progress of the osteoarthritis.
The treatment options for these lesions continue to evolve and expand. The lesion size, lesion location, patient demand and treatment history should be considered when selecting a surgical approach. The best results among all the surgical and medical treatments are belong to engineered regenerative tissue scaffolds, because all the other current treatments can cause many complications such as donor site morbidity, fibrocartilage formation, joint stiffness, arthrofibrosis, and infection. Cell-based therapies have shown some superiority over conventional treatment options such as microfracture and mosaicplasty, especially for large defects.

This presentation serves to review the current regenerative medicine approach for joint cartilage lesions, and a comparison of its pros and cons with the other conventional cartilage treatment procedures.