Nanotechnology In Temporary Anchorage Devices

Dr. Chelza X[1], Dr. Anand Sivadasa[2]

[1]Consultant Orthodontist in Private Practice,
Malabar Smile Care, Malabar Hospitals, Kozhikode, Kerala, India

[2]Consultant Surgeon, Plastic and Reconstructive Surgery,
Baby Memorial Hospital, Calicut, Kerala

Corresponding author: Dr. Chelza X; Email: chelzax13@gmail.com

ABSTRACT

Introduction: Nanotechnology is the technique of manipulating matter at nano level. It has assured promising results in many fields of medicine including dentistry. There has been a wide range of application for nano particles in orthodontics, periodontics and also in prosthetic dentistry. Nano particle incorporated biomaterials has given promising results in many disciples of orthodontics. Nanoparticle coated brackets, arch wires and ligatures have assured promising results in revolutionising the orthodontic treatment mechanics. Temporary anchorage devices are one of the recent inventions which has revolutionised the orthodontic field. They are known to provide efficient means of anchorage and also support different types of tooth movements making them less complicated, although they may be associated with infections in the site of insertion and loss of stability. This article discusses the application of nano-particles in temporary anchorage devices, application of the same to reduce the incidence of peri-implantitis and loss of stability and the clinical evaluation of the same.

KEYWORDS: Nanotechnology, mini-implants, nano-particles, orthodontics

INTRODUCTION

Nanotechnology, a multidisciplinary science, aims at the creation of materials, devices, and systems at the nanoscale level. It is the manipulation, precise placement, measurement, modelling, or manufacture of sub-100-nanometer scale matter. In other words, it has been described as the ability to work at atomic, molecular, and supramolecular levels to understand, create, and use material structures, devices, and systems with fundamentally new properties and functions resulting from their small structure.[1]

The theory of nanotechnology may be extended to dentistry and orthodontics in distant future, where nanorobots with specific motility mechanisms navigate through periodontium to remodel it directly, accelerating orthodontic tooth movement. Another application of this technique is to scale back root resorption during orthodontic treatment.

Also, orthodontic brackets have been coated with nitrogen doped titanium dioxide having antibacterial effects.[12] Nanomechanical sensors can be fabricated and be incorporated into the base of orthodontic brackets so as to provide feedback about the applied orthodontic forces.[2] Friction during tooth movement may be reduced by using composite nano-coatings made of nickel-phosphorous or Cobalt. Friction may also be reduced, while maintaining strength, by modifying brackets with polysulfone-embedded hard alumina nanoparticles.[3]

In recent times, temporary anchorage devices (TADs) including mini screws, miniplates and implants have been integrated for orthodontic purposes. They have insertion sites within the bone and enhance orthodontic anchorage directly if they work as independent anchorage or indirectly if they support and reinforce the anchoring teeth.[4] Healthy peri-implant tissue plays a vital role as a biologic barrier to bacteria. Tissue inflammation, minor infection, and peri-implantitis may occur after mini screw placement.[5]

Peri-implantitis is inflammation of the surrounding implant mucosa with clinically and radiographically evident loss of bony support, bleeding on probing, suppuration, epithelia infiltrations, and progressive mobility. Inflammation of the peri implant soft tissue has been related to a 30% increase in failure rate.[6]

Nanotechnology may be incorporated to develop a temporary anchorage device which can reduce the incidence of pain and discomfort, with minimal changes in their functional characteristics. Surface modifications may include pharmacologically active pre-incorporated antibacterial agents or compounds, like antibiotics, antiseptics, metal ions, or organic molecules which may change the implant from a passive, pharmacologically inert medical device, to something more similar to a drug agent, with unpredictable long-term effects and challenging regulatory issues.[7]

Nanoparticles in temporary anchorage devices

Currently, TADs are manufactured with smooth titanium surfaces. Complications associated with stability and patient safety can arise during mini screw placement and after orthodontic loading. Soft tissue complications like aphthous ulceration, soft tissue coverage of mini screw head and auxiliary, pain, inflammation, infection and peri-implantitis are common. So, it is vital is to attenuate the pain and peri-implant infection related to the insertion of temporary anchorage devices which may be achieved with the assistance of surface modifications using pharmacologically active substances.

Historically, two main strategies have been proposed for effective antibacterial surface treatment either “contact killing” or “drug eluting”. Antibacterial surface technologies can employ metals (silver, zinc, copper, etc.), non-metal elements (e.g., iodine, selenium), organic substances (antibiotics, anti-infective peptides, chitosan, other substances), and their combinations.[10] Antibacterial activity of the majority of metal coatings is closely linked to the ionic or nano form rather than to the bulk material.[7]

Silver is the most prevalent metal employed in biomedical applications. Dissolved silver cations are biochemically active agents that interfere with bacterial cell membrane permeability and cellular metabolism.[9] Silver also contributes to formation of reactive oxygen species and other mechanisms that potentially influence prokaryotic cells. Copper and zinc also have potent antibacterial effects on a broad spectrum of bacterial species.[8] Another interesting technology is expounded to modification of commonly used alloys, like titanium. The anti-infective potential of titanium dioxide layers has been widely investigated and proven effective in vitro both alone or together with other substances. Non-metal elements like hydrogen, chlorine, iodine, or oxygen are commonly employed in biomedicine for their anti-infective properties. Selenium bound covalently onto the surface of titanium or titanium alloy implant discs has been shown to forestall Staphylococcus aureus and Staphylococcus epidermidis attachment without affecting osteoblast viability.[9]

Clinical evaluation

Coating implants with antimicrobial peptides, cytokines, or other molecules critical for host response to bacteria invasion has proven experimentally effective against a broad spectrum of pathogens. Antimicrobial peptides, like antibiotics, function via damage of the cell wall and inhibition of key bacterial protein synthesis.[9] Additionally, they exert influence upon inflammation, tissue healing, and apoptotic events; resistance to antimicrobial peptides has been reported less frequently than to antibiotics. Initial experiments demonstrated that a thin layer of antimicrobial peptides affixed onto the surfaces of metal alloys exhibit excellent antibacterial effects against typical pathogens.[7]

Long-term impact of permanently coated implants with antibiotics and other organic compounds, never used before either for local or general administration, does raise concerns regarding possible induction of bacterial resistance, local, and general toxicity and possible detrimental effects on implant osteointegration, ultimately preventing clinical applications so far. It is therefore important to own a close intimacy between the bone and the surface of the mini screw, as this permits better stability and greater resistance to orthodontic forces. Furthermore, inflammatory processes can affect the primary stability and determine a premature loss of the screw.

The stability and osseointegration of mini screws surface modified by nanotechnology has been evaluated by two studies: the studied surface was characterized by TiO2 (titanium dioxide) nanotube arrays. The TiO2 nanotube arrays were loaded with RhBMP-2 (recombinant human bone morphogenetic protein-2) and ibuprofen and were compared with a control group of standard mini screws.

The effects of the drugs were evaluated in vivo and they found that drug-modified mini screws had a positive effect on tissue health.[10]

These modified mini screws can convey other drugs, like antibiotic agents, aspirin and Vitamin C, to decrease inflammation at the insertion site and patient discomfort. This modification to the materials has also proved important in ensuring greater surface roughness of the aids and improving wettability compared to conventional products.

CONCLUSION

Although application of nanotechnology in orthodontics is taken into account to be in its infancy, there is enormous potential in research in this area including nano-designed orthodontic bonding material, possible nano-vector for gene delivery for mandibular growth stimulation, and nano-LIPUS devices. In an exceedingly fast-growing world of nanotechnology, the hope would be to induce these technologies into clinical application sooner or later. To conclude, the future in orthodontic treatment will benefit greatly through nanotechnology should all the current attempts succeed to its clinical application at an affordable cost to the orthodontist and patients.

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