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Nanotechnology Usage to Increase Success of Implant A Review Article

Ahmed Ali Al-Hilaly [(1)] *
Akram Faisal Alhuwaizi [(2)]

[(1,2)] Department of Orthodontic, College of Dentistry, University of Baghdad, Baghdad, Iraq.

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***Corresponding Author:**
Email:
Ahmed.Ali22031@codental.uobaghdad.edu.iq
(B.D.S) Department of Orthodontic, College of Dentistry, University of Baghdad, Baghdad, Iraq.

Abstract

Background: The introduction of orthodontic miniscrews for anchorage control made the force application for different orthodontic treatment approaches easier and increased their effectiveness. Some problems may occur during miniscrews use, such as inflammation of soft tissue around the implant, mobility, and failure.

Aim: This review paper focuses on the peri-implant disease and the use of nanotechnology to solve this problem and increase the orthodontic miniscrew success rate.

Methodology: Electronic searching was performed until 2024 articles in PubMed, ResearchGate, and Google Scholar by using the keywords (miniscrew, mini-implant, peri-implant health, peri-implantitis, peri implant mucositis, and antimicrobial nanoparticles); and fifty-nine articles are selected, exclusion criteria are articles that are unpublished and web pages.

Conclusions: Microorganisms colonization around the implant cause peri-implantitis. Peri-implantitis is the most common cause responsible for miniscrew failure. Nanoparticles work as potent antimicrobial agents to enhance peri-implant health. Nanoparticles increase miniscrew stability by facilitating rapid bone formation around the implant.

Introduction:

The introduction of temporary anchorage devices (TADs) allowed orthodontists to achieve significant clinical outcomes that were previously considered impossible using standard anchorage methods.

The use of TADs in orthodontics has made tremendous progress since 1983; when the first clinical case showed the potential for precise control of anchoring in humans (1). The teeth that need to be moved are

subjected to small, continuous pressure during the orthodontic process to act as the anchoring unit for the other teeth. The teeth that serve as anchors must be stable. The orthodontic community has been able to overcome the constraints of conventional anchorage due to the development of temporary anchorage devices. Orthodontic miniscrews (OMSs) have expanded the orthodontic field's boundaries. When anchorage is considered critical, inadequate, or likely to cause unfavorable side effects like vertical displacements caused by intermaxillary force systems, skeletal anchorage has largely replaced conventional anchorage (2). Different kinds of complicated malocclusions can now be successfully treated using OMSs (3, 4). OMSs give good to excellent results in complex orthodontic scenarios without affecting facial esthetics or depending on patient compliance (2, 5, 6).

OMSs are used in practical settings because of their small dimensions, ease of installation and removal, and lower cost compared to other systems (7, 8). OMSs used to intrude and retract the anterior and distalize or protract the molars (9-11), and in micro-osteoperforations to speed up tooth movement (12, 13).

Dental implant represents an advance management in contemporary dentistry, with excellent success rate (14). OMSs, different from osseointegrated dental implants, do not need osseointegration and can be loaded immediately after they are inserted (7, 15). Hence, attaining primary stability is essential for effectively utilizing OMSs as temporary anchorage devices (7). Primary stability mostly relies on mechanical interlocking between the OMS threads and the bone that surrounds it (16). However, OMSs can occasionally become unstable and fail after placement. The rate of success OMSs (60 % - 93%) (16, 17), while osseointegrated dental implants success rate is between 96% and 99% (6). Many factors affect the success rate of OMSs, which include cortical bone thickness and density in the implantation area, cigarette use, and peri-implant hygiene care (6, 9, 10, 18). The main problematic factor in using OMSs is the failure of these devices. Loss of implant may result from peri-implantitis, which results from colonization of peri-implant pocket by bacteria. Most of the factors that lead to the failure of an implant can be controlled by clinicians through good treatment planning before surgery (19). This goal may be achieved by inhibition of microorganisms that cause peri-implantitis, by coating the OMSs by antimicrobial agents such as antimicrobial nanoparticles (20).

Peri-implant health:

The osseointegrated implants are surrounded by tissues called peri-implant tissues (21).

The peri-implant tissue has two compartments:

a-The hard tissue compartment provided high implant stability by the contact relationship between bone and implant surface.

b-The soft tissue compartment means “peri-implant mucosa” During the process of healing of the wound this tissue is formed following implant/abutment placement (21-23).

The general treatment result of implant-supported restorative therapy is significantly impacted by implant loss. Destroying peri implant tissues can negatively affect the success and survival of the implant, and recognizing disease requires knowing the features of healthy peri implant tissue (24).

Epithelium and connective tissue components of the mucosal barrier develop to the titanium surface after implant installations. It is believed that properly installed implants may create the ideal environment for both soft and hard tissue healing and that the titanium implant's shape may not be as significant as previously thought (25).

The oral environment, including constant contact with bacteria in the biofilm existing on the teeth and implants surfaces, continuously poses a threat to the gum, the peri-implant soft tissue, and their seal. When compared to the peri implant mucosa, the gingiva typically showed a more noticeable host response, although not statistically significant (26).

The mucosa around the implant is considered healthy when it contains a connective tissue core covered by epithelium that is either keratinized or non-keratinized. The health of the periodontium is negatively impacted by cementing material remnants left behind after the cemented retained prosthetics is cemented (27). The majority of the orthodontic miniscrew is in contact with calcified bone, while the remaining part comes into contact with fibrous tissue, bone marrow, or vascular structures. The literature correctly identifies the properties of peri-implant tissues in health (23).

According to Sanz and Chapple (28), the loss of clinical signs of inflammation is essential to conclude that an area has healthy peri-implant tissue, so there is no peri-implant mucositis and peri-implantitis.

Peri-implant diseases include:

Peri-Implant mucositis:

Peri-implant mucositis means inflammation of the mucosa surrounding a dental implant that does not result in any bone resorption around the implant. The key factors for defining peri-implant mucositis are the presence of inflammation in the peri-implant mucosa and the lack of bone resorption around the implant (29).

According to Heitz-Mayfield and Salvi (30), peri-implant mucositis is caused by an imbalance in the relationship between the host and bacteria at the interface between the implant and the mucosa. This disease can be reversed by restoring the host's biomarkers to normal levels.

In addition to erythema, edema, and/or suppuration, bleeding from peri-implant tissue during probing is the main practical characteristic of peri implant mucositis. Peri-implant mucositis diagnosis requires clinical indications of inflammation. Because of the swelling of tissue around the implant, peri-implant mucositis frequently increases probing depth. Experimental research on humans and animals has provided compelling evidence that plaque is the causative agent of peri-implant mucositis. There is limited evidence for non-plaque-induced inflammation of mucosa around dental implants (31, 32).

Studies showed that resolving the inflammation signs may require more than three weeks after reintroducing bacterial control and maintaining good oral hygiene (33, 34).

Peri-implantitis:

Peri-implantitis is a progressive and irreversible disease of the tissue around the implant (bone and mucosa) and is accompanied by loss of the bone, reduced osseo-integration, increased pocket depth, and suppuration (32).

In addition to x-rays that show bone resorption relative to prior examinations, peri-implantitis locations show clinical signs of inflammation, bleeding on probing and/or suppuration, increased probing depths, and/or recession of the mucosal edge. Probing depth at peri-implantitis-presenting locations is associated with bone loss and, therefore, serves as a indicator of the disease's severity. It's critical to understand that each patient's pace of bone loss progression may differ (35).

Peri-implant mucositis occurs before peri-implantitis. Patients who are diagnosed with peri-implant soft tissue inflammation have a greater possibility of developing peri-implantitis, particularly if they do not receive routine maintenance therapy. Prevention of peri-implantitis development can be obtained by treating peri-implant mucositis effectively (36).

There is clear evidence that individuals with a history of severe periodontitis, poor bacterial management, and no routine maintenance care following implant therapy are more likely to develop peri-implantitis. There is conflicting evidence on tobacco use and diabetes as possible risk factors for peri implantitis (37, 38).

There are limited evidences that link peri-implantitis to the position of implants that does not enhance dental care and maintenance. It is yet unknown how keratinized mucosa around the peri-implant, titanium micro-particles, and bone necrosis that results from compression, over-heating, micro-motion, and bio-corrosion increase peri-implantitis possibility. The changes in the amount of

bone surrounding the implant are linked to visible inflammation signs in the clinical setting. Nevertheless, there are circumstances in which bone resorption around a dental implant may happen due to iatrogenic events, such as the improper placement of the implant or surgical injury (31).

Peri-implantitis therapy shows anti-infective therapy methods effectively reduce soft tissue inflammation and inhibit the advancement of the disease; systemic and local antibiotic applications (e.g. tetracycline, doxycycline, amoxicillin, metronidazole, and minocycline) led to significant reductions of pocket depths (39).

Application of nanoparticles:

Antimicrobial nanoparticles:

Nanoparticles can bind to and penetrate Gram-negative and positive bacteria cell walls, disrupting cell function by liberating associated ions (40). As a result, NPs are useful for disease prevention and treatment caused by bacterial resistance to drugs and biofilm inhibition.

Although the precise method of action of NPs is unknown, the antibacterial mechanism can be categorized into three categories.

The following are the antibacterial mechanisms:

1- Affecting protein synthesis by interacting with bacterial proteins (40).

2- Inducing cell lysis by engaging with peptidoglycan cell walls and membranes "Peptidoglycan (PG) is an essential and conserved exoskeletal component in all bacteria that protects cells from lysis" (41);

3- Blocking DNA replication by connecting with bacterial (cytoplasmic) DNA (40, 42).

These medicines interrupt dental biofilm production in four different ways**:**

(1) Prevent the Biofilm adhesion and formation.

(2) Destroying a biofilm that already exists.

(3) Reducing the biofilm's growth processes.

(4) Destroying the individual microorganisms in the biofilm (43).

Antimicrobial activity of Silver nanoparticles (AgNP):

Silver has been used as an antibacterial and anti-inflammatory for a very long time in medicine. By combining nanoparticles with OMS, silver nanoparticles (AgNP) provide the opportunity to regulate the development of oral biofilms. Titanium OMSs that have been treated using AgNP-coated biopolymer (Ti-BP-AgNP) demonstrate very good anti-bacterial characteristics, which renders them highly promising biomaterials that can be implanted in humans. The surface of Ti-BP-AgNP exhibited significant antibacterial efficacy against the oral bacteria Streptococcus mutans, Streptococcus sanguinis, and Aggregatibacter actinomycetemcomitans (44). The resin with AgNP supplement did not show anti-bacterial activity against streptococcus mutans. Furthermore, they displayed a noticeable color alteration and more sorption than the AgNP-free materials (45).

Saafan et al. (46) conclude combination of Methylene Blue, 650 nm diode laser and AgNPs may be among the highly effective modern antimicrobial therapeutics in dentistry.

Focusing on improving the longevity of dental mini-implants by covering them with nanoparticles for better osseointegration and antibacterial characteristics. Once coated with nanoparticles of the type silver doped hydroxyapatite, they become durable and safe due to their good tissue integration and ability to fight bacterial infections. Bacterial colonization is well known to be an issue with medical devices such as OMSs. As a result, using nanoparticle-coated OMSs for the prevention of infection caused by pathogenic microbes in the mouth cavity is a viable option. This will increase OMSs and implant success rate (47).

Antimicrobial activity of chlorhexidine hexametaphosphate nanoparticles (CHX-HMP NPs):

Chlorhexidine is the most effective anti-plaque agent available today. It is regarded as the gold standard anti-plaque agent, by which other anti-plaque and anti-gingivitis agents are evaluated for effectiveness. Its effectiveness can be attributed to its bacteriostatic and bactericidal properties and its substantiveness within the oral cavity (48, 49).

Chlorhexidine (CHX) due to its antimicrobial effects is commonly used antiseptic mouthwash, used by dental practitioners and the public (50).

CHX induces cytoplasm congealing at high doses and broad membrane damage including phospholipid bilayers at low concentrations. CHX digluconate, a broad-spectrum antibacterial and antifungal drug, is widely utilized in the dental field as a mouth rinse. It does not induce bacterial resistance (51). CHX is an antimicrobial agent that belongs to the biguanide class of drugs that is efficacious against gram-negative, and gram-positive bacteria and yeasts (52).

Sodium HMP is a cyclic inorganic phosphate widely utilized in the food industry and dental field because sodium HMP able to inhibit the production of tartar and prevent staining of the teeth (53-55), while Brady et al.(56) show that HMP is ineffective in monkeys with previously existing dental tartar.

Adding a dose of HMP to the 1% sodium fluoride gel increased its protective impact to levels comparable to the 2% sodium fluoride gel (54).

Researches were performed by Wood et al. (57) and Barbour et al. (53) to make substances that release chlorhexidine by using HMP NPs. These nanoparticles are utilized to produce a porous aggregating coating on a titanium surface. This coating released soluble CHX continually throughout the study. Growth of bacteria was decreased on the NP-coated surface compared to non-coated titanium and titanium exposed to an aqueous solution of CHX (57).

Chlorhexidine and Na-HMP have been extensively utilized in dentistry as antibacterial mouthwash and anticalculus agents. They have demonstrated efficacy against oral microorganisms that contribute to the formation of white spot lesions (WSLs). According to the study, CXH-HMP NPs can be applied to an elastic power chain to allow continuous release of the antibacterial over long periods. Force degradation of the power chain was unaffected by the coatings. Utilizing such a coating on a power chain can offer antibacterial action to help prevent white spot lesions and reduce biofilm development (58). The animal study proves that the antimicrobial nanoparticle reduces the infection associated with the insertion of OMSs by decreasing the number of inflammatory cells and increasing bone cell number enhancing the bone healing process. CHX-HMP NPs have been shown to decrease or eliminate inflammation around OMSs in rabbits (59). This may lead to decrease in the peri-implant soft tissue inflammation and increase in OMSs and dental implant success rate.

Nanoparticles used to enhance implant stability:

Partial osseointegration of OMSs leads to some clinical problems with OMSs removal was seen even on OMSs with smoother surfaces (15). The balance is therefore believed to lie in designing an ideal surface that can promote early osseointegration and make it simple to remove OMS once it is no longer needed. Biocompatible coatings such as titanium nanotubes were investigated to see if the nanotubular layer can improve primary osseointegration and act as an interface layer between freshly generated bone, it showed that coatings influence osteoblast proliferation, differentiation, and matrix mineralization and should be further studied for applications in OMS (60).

Adding collagen and chitosan to nano-hydroxyapatite was more efficient in speeding bone formation than nano hydroxyapatite only, this will increase stability and hence increase the success rate of OMSs (61).

Conclusions:

Microorganisms' colonization around the implant causes peri-implantitis. Peri-implantitis is the major cause responsible for miniscrew failure. Nanoparticles work as potent antimicrobial agents to enhance peri-implant health. Nanoparticles increase stability by facilitating rapid bone formation around the implant.

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