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IP Annals of Prosthodontics and Restorative Dentistry

Journal homepage: https://www.aprd.in/

Review Article

An insight into trabecular metal dental implants- An overview

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ARTICLE INFO

Article history:
Received 13-05-2024
Accepted 24-08-2024
Available online 02-12-2024

Keywords:
Trabecular
Tantalum
Titanium
Porous
Implant

ABSTRACT

Implants are one of several treatment options available for replacing lost teeth. Providing a viable option for patients who are partially or fully edentulous, dental implants have significantly changed oral rehabilitation. Dental implants are available in different materials with different types of treatments.Even though implant-supported prostheses have been shown to have high success rates, a small percentage still fail. Advancements in dental technology have revolutionized the way dental implants are designed and implemented. Porous Tantalum Trabecular Metal (PTTM) has been utilised in dental implants. Trabecular implant is a type of dental implant which has porous surface and similarity closer towards the bone microstructures, which allows for ingrowth and overgrowth of bone allowing for a better osseointegration.The excellent frictional characteristics of the porous tantalum material could improve implant stability against the surrounding bone. This article explores the features, benefits and applications of trabecular implants highlighting their potential to transform the future implant dentistry.

1. Introduction

For health and quality of life, an appropriate dentition is crucial. Despite improvements in preventive dentistry, edentulism continues to be a significant global public health issue. Edentulism can be either complete or partial. Age, awareness, accessibility to dental treatment, dentist/population ratios, and socioeconomic factors, all play a role in tooth loss.

Dental implants are the material of choice for tooth replacement and complete mouth rehabilitation. On the market, there are several types of material implants with various forms of surface treatment. Tantalum metal has seen an increasing number of uses in the production of implants in the orthopaedic and dental industries during the last two decades, due to its advantageous features for endosseous applications. Due to their relevant physicochemical characteristics, tantalum and its alloys can be used in numerous biomedical applications, including the manufacturing of prosthetic implants. Tantalum has a high stiffness (185 GPa) in its solid form. Whereas, in porous form it presents a reduced elastic modulus of 3GPa which is equivalent to that of human bone.[1] Tantalum's disadvantages include its high cost because of its limited availability and brittle nature, which makes machining it challenging.

Porous Tantalum Trabecular Metal (PTTM) implants, an alternative to traditional implants provides enhanced osseointegration and promotes long term stability. Trabecular implants are designed to mimic the natural

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https://doi.org/10.18231/j.aprd.2024.052

structure of trabecular bone found in the human body. Trabecular bone is characterised by its spongy, lattice like pattern that provides larger surface area for new bone growth and promotes faster osseointegration. Unlike traditional dental implants which have a smooth and uniform surface, trabecular dental implants replicate the structure and porosity of trabecular bone using advanced 3D printing technology. This unique design offers greater advantages, making the trabecular dental implants an innovative solution in dentistry for tooth replacement.

2. Design and Unique Features of Trabecular Dental Implants

Trabecular implants are made of tantalum material. Zimmer Biomet was the company that pioneered this type of orthopaedic technology (hip implants). Trabecular implants are constructed using a unique three- dimensional porous material known as Porous Tantalum Trabecular Metal (PTTM). PTTM has a more porous structure, closely resembling the bone microstructures, and has comparable elasticity.[2] These implants can be used in places with poor bone quality, where they can enable greater osseointegration. This advanced design ensures a secure foundation for the prosthetic crown providing a stable and functional dental restoration of the missing tooth.

The central portion of the titanium multi-threaded self-tapping endosseous dental implant (Tapered Screw-Vent® Implant. Zimmer Dental Inc.) has the PTTM material addition. It retains a screw-type design, but the apical and cervical sections have a rough surface developed through grit-blasting using hydroxyapatite or HA particles. The implant's titanium alloy (Ti-6Al-4V grade 5) and PTTM components are produced separately with the central core and cervical section of the titanium alloys milled as one unit and the apical section is milled independently in a similar manner. The PTTM sleeve, a 2 mm cylinder, is made up of tantalum coating and vitreous carbon core scaffold. The middle titanium alloy core is then inserted into the PTTM sleeve, and the core is subsequently laser fused to the apical part. The functionality and osseointegration of these trabecular metal dental implants are enchanced by use of combination of tantalum and titanium.[3,4]

The porous tantalum three-dimensional improvement of the titanium dental implant surface enables the combination of bone ongrowth and bone ingrowth, also known as Osseo incorporation. The design of the implant is such that it allows for Osseo incorporation through their osteoconduction middle section. The design of the implant is such that it allows for neovascularization and new bone formation. As the middle part of the implant is made of porous tantalum meshwork and the apical and coronal sections of implants are made of titanium alloy which is screw shaped, the advantages of using titanium alloy is that it enhances the osseointegration by microtexturing with Hydroxyapatite particles.[5] The biomechanical properties and the stability is increased due to the middle porous trabecular structure which is similar to the trabecular bone.[6,7] An open-cell dodecahedron repeat structure of the PTTM dental implants facilitates rapid endothelial budding and ingrowth. Like titanium, the tantalum layer of PTTM becomes highly unreactive when oxidized, making it biocompatible within the body. These implants use the conventional implant surgical kit and no other types of special instruments are required for placement of the same based on the design.The trabecular implants are available in a variety of different sizes similar to the conventional implants. The primary concern for this type of implant is the unique nature of the oral environment. The oral cavity is a complex, non-sterile area that can harbour over 500 different bacterial species. The interactions between saliva, host tissue, and microorganisms can make it challenging to predict how PTTM implants will respond to this complex environment. Additionally, there is a mechanical concern with PTTM-enhanced titanium dental implants. Due to the implant manufacturing process, the connection between the relatively small titanium core/PTTM in the midsection and the apical titanium portion may be prone to fracture, especially if placed in hard bone (type 1) with inappropriate higher torque.[3]

3. BioBoost Effect

Dental implants of the Trabecular Metal Implant type have a distinctive biological response known as the BioBoost Effect. Through the proliferation of naturally occurring growth factors associated to bone development, wound healing, and vascularization, this effect speeds up healing and bone formation. In comparison to conventional dental implants, the BioBoost Effect multiplies naturally occurring growth factors to promote quicker healing and early bone production. The BioBoost Effect is a distinctive mix of cancellous-like porosity and extremely biocompatible tantalum that is exclusively available on the Trabecular Metal Dental Implant. The bio boost effect helps in rapid recovery with accelerated healing with a 2-week loading protocol.

Even though each patient's oral health requirements are distinct, treating medically vulnerable dental patients such as those with diabetes, a history of infection at the implant site, heavy smokers, or people who have underlying conditions which delay healing, require extra care. In such circumstances, new treatment options are available that can encourage speedy recovery, such as the Trabecular Metal Dental Implant due to their bio boost effect.

Patients who have had a failed implant placement are more likely to have a subsequent failed implant. As a result, revising an implant placement next time is undesirable because the outcome is likely to be the same unless the conditions can be altered. When compared to standard

titanium implants, bio-boost technology with Trabecular metal implants promotes faster bone recovery. As a result, they are a good option for implant revision therapies.

4. Biomechanics of PTTM Dental Implants

PTTM material has similar elastic modulus to bone and is 80% porous with microstructures like bone. Dental implants made of titanium with PTTM enhancements have a surface area that is over 70% larger. These implants allow for the bone in growth and on growth and facilitates neovascularization thus enhancing the property of osseoincorporation. The implant's midsection consists of a porous tantalum meshwork, facilitating neovascularization and new bone growth directly into the implant. The coronal and apical sections are screw-shaped and crafted from a titanium alloy. These titanium alloy surfaces are micro-textured with hydroxyapatite to further enhance osseointegration. The Trabecular Metal dental implant mimics the structure of trabecular bone, resulting in better biomechanical properties and long-term stability.[8]

5. Limitations of Trabecular Dental Implants

The primary concern is based on its mechanical property. The connection between the titanium and tantalum is prone to fracture if used in type 1 (hard bone). Hence their placement is recommended for soft (type 3 and type 4) bone in order to avoid fracture.[3]

The next concern is the susceptibility to infections in the complex environment of the oral cavity. Due to the interactions between saliva, tissue and different microorganisms makes the predictability of porous tantalum trabecular metal implants difficult. Titanium and tantalum, both are very much similar in their biocompatibility and corrosion resistance features. As titanium dental implants are susceptible to infections like periimplantitis, we cannot neglect the chance of tantalum trabecular implant too in concern with susceptibility to infections.[3]

6. Discussion

Osseointegration is a crucial component of dental implants. It is dependent on a number of factors, including implant material, surface characteristics and implant design.[8–10] In order to achieve good osseointegration, primary implant stability is very essential. The primary stability reduces implant micromotion, enabling unobstructed osseointegration and healing. Until recently, the PTTM technology had not been applied to dental implants. Because of the advancement of porous tantalum metal, stronger, more biocompatible orthopaedic, craniofacial, and dental implants are now possible. High volumetric porosity, a low elastic modulus, and high frictional properties are some of the features of the porous tantalum metal. One approach to enhance osseointegration is by the use of porous tantalum material which has shown promising results.[8,11] The features of porous tantalum metal, like high frictional quality could perhaps improve implant stability against the surrounding bone.[3,12] Another added feature to note is the antibacterial efficacy of the tantalum coatings which are beneficial in averting peri-implant infections.[13]

In a study conducted by Al Deeb et al, they observed more peri-implant bone growth in close proximity to the tantalum region in comparison to titanium surfaces.[8] In addition, the study also demonstrated partial remodelling of bony trabeculae as well as the emergence of vascular canals. Another histological study in a case report, observed increased bone growth and osteocyte infiltration into the tantalum mesh region showing that the Trabecular Metal material encourages bone ingrowth for achieving secondary implant stability.[14]

The benefit of trabecular form of PTTM is that it aids in the elastic modulus being similar to the bone, mechanically superior to other alloys used in dental implants. PTTM technology was developed to build a three-dimensional scaffold for bone ingrowth around dental implants. Numerous in vitro researches and clinical studies have shown that rough surfaces are preferable to smooth surfaces in terms of early bone-to-implant contact.[15–17] There is a positive link between the implant's surface roughness and its integration with bone tissue.[18]

The trabecular metal implant's open-cell dodecahedron structure promotes fast endothelial neovascularization, followed by osteoblastic differentiation and matrix production. This aids in bone ingrowth and also helps to sustain immediate loading in the case of orthopaedic implants, which might be seen as an added benefit when trabecular dental implants are considered. The trabecular structure of tantalum metal in case of PTTM enhanced titanium dental implants, enhances osseointegration by improved bone implant interface. The porous structure of the trabecular implant which is similar to the natural spongy bone, is one of the reasons for the osseous ingrowth. Table 1 discusses about the studies on the efficacy of PTTM -Dental Implants.[11,19–24]

7. Conclusion

Case selection and precise treatment planning play an important role in the success of dental implant. Tantalum trabecular dental implants are shown to have outstanding mechanical and physical qualities that are suitable for enhancing biological osseous incorporation. Long term studies will help the use of the porous tantalum trabecular metal enhanced titanium dental implants in more complex cases with ease and success.

8. Source of Funding

None.

Table 1: Studies showing the efficacy of PTTM -Dental Implants

Author/ year	Study design	Sample size	Population	Follow-up	Authors conclusion
Piero Papi, 2014 [19]	Clinical trial	6 subjects, 25 implants	Oral and maxillofacial post oncologic patients	Examined at 7, 14,28 days and 1/30 [once a month] for next 18 months.	This study represents the first clinical trial of PTTM dental implants in post-oncological patients and our preliminary results indicate that PTTM dental implants could have a clinical efficacy in prosthetic rehabilitation of these patients.
Markus Schlee 2015 [20]	Nonrandomized controlled trial	total 268 subjects 377 implants.	Healthy subjects	Total study period 5 years. 1 year interim results evaluated	TM dental implants were clinically effective under various clinical conditions in an uncontrolled cross section of patients
Cristian Peron 2016 [21]	Non-randomized, uncontrolled study	26 implants	Healthy subjects	Assessed at 2 weeks followed by 1,3,6, 12 months	Predictable clinical outocmes.
Celia Clemente 2018 [22]	Clinical trial	23 subjects, 24 implants	Healthy subjects	2, 3,6 and 12 wks of healing	PTTM implant osseoincorporation resulted from osteogenic tissue network over 12 weeks and was comparable to trabacular volumes in posterior edentulous jaws
E. K. Hefni 2018 [23]	Clinical trial- split mouth design	8 subjects 32 implant cylinders	osteopenic patients	2,4 weeks	Within the limitations of the present study, PTTM exhibited a more robust response towards early bone formation and mineralization, which may potentially enhance early osseointegration.
Alexander R. Edelmann 2018 [24]	Retrospective study	82 subjects 205 implants	Healthy subjects	5 years	1. PTTM-enhanced dental implants (TM implants) had a relatively lower risk of bone loss and higher probability for bone gain, especially in immediate implant placement. 2. Despite the fact that the use of DBM (Demineralized Bone Matrix) shows relatively less bone loss in both types of implant, bone graft did not have significant effect on marginal bone loss in the presence of different types of implants (TM versus Ti). 3. DBM may be a good alternative to autografts and other bone regenerative materials.
Sompop Bencharit 2019 [11]	Prospective split-mouth design	12 subjects	Healthy subjects	2 weeks for anterior 4 weeks for posterior	Based on the limitations of this study, PTTM material enhances initial healing compared to Ti alloy in the mandible of healthy subjects. Further studies in other areas of the oral cavity, such as maxilla, and with different patient population such as diabetics or patients with osteopenia, are needed to examine if PTTM will have similar effects in patients with compromised implant healing due to systemic conditions or bone quality/quantity problems.

9. Conflict of Interest

None.

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Cite this article: Kanathila H, Patil S, Poojary B, Shabari U B, Upadhya M, Patwardhan K. An insight into trabecular metal dental implants- An overview. *IP Ann Prosthodont Restor Dent* 2024;10(4):270-274.