Review Article

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TITANIUM-SETTLE FOR A BETTER METAL: A REVIEW

Jagadeesh H.G[1],Priyank Bhandari[2],Kuldeep[3],Ashish Choudhary[4],Jayvikram[5]

1.Prof. & Head, Department of Prosthodontics and Crown & Bridge,School of Dental Sciences, Sharda University, Greater Noida. U.P
2.Post Graduate Student, Department of Prosthodontics and Crown & Bridge,School of Dental Sciences, Sharda University, Greater Noida. U.P
3. Reader, Department of Prosthodontics and Crown & Bridge,Teerthankar Mahaveer Dental College & research Centre, TM University, Moradabad, U.P
4.Professor, Department of Prosthodontics and Crown & Bridge,School of Dental Sciences, Sharda University, Greater Noida. U.P
5.Professor, Department of Prosthodontics and Crown & Bridge,School of Dental Sciences, Sharda University, Greater Noida. U.P

ABSTRACT:

In oral rehabilitation of partially and fully edentulous patients dental implants have become a revolution. Success rates are very high in both healthy and medically compromised individuals, as reported by various studies. However, a failure pace of 1.5-6.7% is also apparent. Titanium alloys are considered to be the material of choice in dental implantology due to their biocompatibility, high strength and corrosion resistance in a physiological environment. In the world of dentistry, there is common perception that Ti (Titanium) is an inert or biologically compatible metal and cannot cause any allergic responses. Allergic reactions may also occur as result of ion releasing property of metal due to corrosion degradation process. The presence of corrosion reaction products lead to fractures of the abutment, implant-abutment interface or implant fixture. Conversely, this allergic response seems to be either ignored by clinicians or imperceptibly researched upon, and strongly associated to implants failure. So, this is an effort to review the literature on allergy to Ti and its relevance in dental implantology.

Keywords: Titanium, Allergy, Dental Implants, Corrosion, Biocompatibility.

INTRODUCTION:

In the human body, oral cavity is the portal entry and provides a unique environment for study of biological process involving metallic dental aids. Oral tissues are exposed to chemical & physical stimuli as well as the metabolism of about 30 species of bacteria. Yet, oral tissue remains healthy. [1,2]

The pH of saliva varies from 5.2-7.8. Many gram –ve & +ve species play a major role in the formation of dental plaque around the teeth and colonize the mucosal surface. Teeth restoration or any prosthesis including dental implant in the oral cavity has to function in one of the most inhospitable environment of the human body. They are subjected to larger temperature variations than any other parts.[3,4]

Factors such as quantity and quality of saliva pH, plaque, temperature, physical & chemical properties of food may influence

*Corresponding Author Address: Dr Priyank Bhandari,Post Graduate Student,School of Dental Sciences,Sharda University, Plot No. 32, 34, Knowledge Park-III,Greater Noida, U.P.-201306. Email: priyankbhandari48@gmail.com

the corrosion of the dental materials. Corrosion, the graded degradation of materials by electrochemical attack is of concern particularly when an implant, metallic filling or orthodontic appliance is placed in the human mouth. Henceforth, materials need to be selected very cautiously.

So, before selecting a material for dental application, it is necessary to remember that choice of material depends on a number of factors such as

Factors for selection of Implant Biomaterial [2,3,4]

Mechanical	Chemical	Electrical	Others
Modulus of elasticity	General corrosion	Physiochemical	Availability
Compressive Strength	Pitting corrosion	Morphologic	Biocompatibility
Tensile strength	Crevice corrosion	Biochemical	Cost
Elongation			Aesthetics
Metallurgy			

Dental implants have revolutionised oral rehabilitation in partially and fully edentulous patients. The success rate in healthy as well as medically compromised patient was great as reported in various studies. [5]

Titanium alloys are considered as the material of choice in Implantology due to their biocompatibility, high strength and corrosion resistance in a physiological environment. It is a general belief, that Titanium can't cause allergic reaction. However, this can be overlooked by clinicians as it is weakly researched upon. It may have a correlation with implant failure [5]. This is an attempt to review the literature on allergy to titanium, relevant to dental implants.

HISTORICAL BACKGROUND:

- For more than a hundred years, various metals have been investigated such as aluminium, copper, zinc, iron and carbon steels, silver, nickel, and magnesium for implantation in to the human body but all of these were discarded as being too reactive [5].
- Stainless steel was introduced as a new corrosion resistant material in the early 1900s and quickly utilized in surgical applications. Initially 18-8 stainless steel was used but, found to exhibit intergranular & gross pitting corrosion due to high carbon (0.08%) & low molybdenum content. Only the austenitic molybdenum-bearing 316 was used, although it was described as inherently corrodible [6].
- During the same period, cobalt-chromium and cobalt-chromium molybdenum alloys were introduced and utilized in dental and orthopaedic applications due to their corrosion resistance.
- The most corrosion resistant implant materials employed was titanium and its

alloys. They were first used in the 1960s and since the mid-1970s it has grown steadily and continues to increase. Titanium alloys (α & β phases), such as Ti-6Al-4V, Ti-5Al-2.5Fe, and Ti-6Al-7Nb provide ideal strength and corrosion resistance characteristics [6].

- Now days, to overcome the limitations and lessen the negative biological reactions, researches have been focused on designing alternative substitutes to titanium. These novel materials include Zirconia, Ceramics and Composites.

- Reed and Willman[7] in 1940 demonstrated the presence of galvanic currents in the oral cavity for the first time in detail.

- Burse et al[8] in 1972 illustrate an experimental protocol for in vivo tarnish evaluations and showed the importance of the proper elemental ratio in gold alloys compositions.

- Pourbaix[9] in 1984 reviewed the methods of electrochemical thermodynamics (electrode potential-pH equilibrium diagrams) and electrochemical kinetics (polarization curves) to understand and predict the corrosion behaviour of metals and alloys in the presence of body fluids.

- Sutow et al [10] in 1985 and Ravnholt G, Jensen J[11] in 1991 showed the crevice corrosion behaviour of implant materials. The galvanic corrosion of titanium in contact with amalgam and cast Prosthodontic alloys has been studied in vitro. They found no change in current/pH when titanium came in contact with carbon composite, stainless steel, cobalt, chromium except with amalgam.

- Geis-Gerstorfer et al[12] in 1994 stated that the galvanic corrosion of implant/superstructure systems is important in two aspects:

✓ The chances of biological effects that may result from the dissolution of alloy components and

✓ The flow of current from galvanic corrosion may lead to bone destruction.

- Torgersen et al[13] in 1995 studied that Various monoclonal antibodies have been analysed in cells of perivascular infiltration adjacent to steel and titanium: 11CD 1a (Langerhans cells), CD 11c (monocytes and macrophages), CD 45 RO (memory cells), CD 4 (T-helper cells), CD 45 RA (naive cells), CD 8 (T-suppressor cells), eosinophil cationic proteins (ECP), neutrophil elastase and HLA-DR. They concluded that there was no differences in sensitisation towards these two (steel and titanium) metals occurred. This phenomenon has been called the ‘pre-sensitisation’ phase.

- Stejskal et al[14] in 1999 reported allergic reactions to metals of delayed hypersensitivity type IV which can involve the oral tissues. They reviewed the possibility increased in lymphocyte sensitisation to various metals in 3162 subjects. One of the metals under consideration in their study was titanium. Their results indicated a

definite prevalence of a positive response to many metals, including titanium. They also anticipated that binding of metals with cell proteins changes the autogenicity and make them vulnerable to attack from immune-competent cells.

- Cortada, et al in 2000[15] had reported that metallic ions were released in the artificial saliva of titanium oral implants coupled with different metal superstructures.

- Aparicio, et al[16] in 2003 studied the corrosion behaviour of commercially pure titanium shot blasted with different materials and sizes of shot particles for dental implant applications. It was renowned that the osseointegration of pure titanium (CP-Ti) dental implant improved when it was shot blasted to increase its surface roughness after that this roughness was colonized by bone, which ultimately improves implant fixation.

- Antonio Scarano et al[17] in 2004 discussed the mechanisms of bacterial interaction with implant materials plus the connection between plaque accumulation and progressive bone loss around implants. Bacterial adhesion shows a direct positive correlation with surface roughness. Other surface characteristics also seem to be extremely important with regard to plaque formation. All the bacteria have different adhesion affinities for different materials. They justify the amount of percentage of bacteria covered the surface of titanium and zirconia implants.

By adapting the allergic plates on premolar & molar region and titanium (control) & zirconia (test) disk were glued on to the buccal aspect of each plate.

They concluded that 19.3% of bacteria present on control (titanium disk) and 12.5% on test (zirconium disk).So, zirconium implants may be suitable with low colonization of bacteria.

- Rigmor S. Flatebo et al [18] in 2006 revised that the metal sensitivity may or may not arise from exposure to titanium. Their aim was histological evaluation of non-perforated mucosa covering submerged maxillary titanium implants with regard to induced tissue reaction. They have done a study in which bone crest of 13 patients were exposed for threaded external hex implant placement but prior to wound closure a full mucosal tissue was biopsied from the muco-periosteal flap (baseline). After 6 months at the time of attachment connection again biopsies were taken by 6 mm punch. Tissues reaction were analysed by coded histometric analysis at four defined areas at increasing distance from oral epithelium, including ratio of inflammatory cells(IC)/epithelial cells, fibroblasts. They concluded that gingival tissues with intact oral epithelium & connective tissue with variable accumulation of IC. Higher fibroblast for level 3 in baseline compared to level 3 at 6 months.

Decreased fibroblast seen in between level 2 & 3 and 2 & 4 at 6 months.

- La Du Purez et al[19] in 2007 presented a case report with six implants of three types LIBB compression, Cylindrical & Brånemark implants placed in mandible. After 1 week follow up examination, patient had discomfort in the operative area. Clinical examination of site revealed minimal soft tissues swelling, no tissue of pus drainage. Patient sent with medication. However, patient symptoms become worse and five days later patient came with swelling in submental region and labial sulcus, frank pain, hyperaemia, but no signs of pus. An OPG revealed ill-defined ragged margin at the apices and lateral aspect of implant. But it does not resemble a typical peri-implant breakdown process but suggestive of widely spreading non-infective osteolytic process. The patient symptoms worsened & decided to remove the implants. Implants were mobile and surrounded tissue was hyperaemic. A thorough debridement & curettage was done and 8 surgical samples were taken for histological analysis. It revealed foci of sub acute inflammation moderate chronic inflammation consisting of lymphocytes, plasma cells & Histiocytes with comitant fibrosis, granulation tissues within foreign body giant cells. This might be the first indication that true titanium allergy or hypersensitivity to dental does exist.

- Allauddin Siddiqi et al[20] in 2011 depicted that titanium may result in hypersensitivity reaction and was described in terms of vague pain, skin rashes, fatigue and malaise and eventually implant loss. Titanium hypersensitivity was one of the factors responsible for implant failure but the databases of titanium related allergic reaction are still lacking. 127 publications were selected, with full text, from the database of MEDLINE & PUBMED with the key words being used “Ti hypersensitivity”, “Ti allergy”, “Ti release”. Most of them are related to orthopaedic discipline, reported wear debris from knee/ hip arthroplasties. The other consists of oral implants, cardiac pacemakers, pathology of cancer. They concluded that Ti can induce hypersensitivity in susceptible patients and play a critical role in implants failure.

- Abhishek Soni, Priyanka Kharbanda, Anil Kumar [21] in 2013 revealed that Titanium and its alloys were widely used for fabrication of dental implants also it became a gold standard for tooth replacement in dental implantology. These materials had attained mainstream use because of their excellent biocompatibility, favourable mechanical properties, and well documented beneficial results. Despite the various advantages of this material, few disadvantages have lead to search for new materials. The principal disadvantage of titanium was its dark greyish colour, which often visible through the peri-implant

mucosa, therefore impairing esthetic outcomes in the presence of a thin mucosal biotype. Unfavourable soft tissue conditions or recession of the gingiva may lead to compromised aesthetics, especially in the maxillary incisors. So, to overcome these limitations and lessen negative biological reactions, researches have been focused on designing alternative substitutes to titanium. The novel materials include Zirconia Ceramics and Composites. They were white and mimic natural teeth better than the gray titanium allows an 'improved' esthetic reconstruction for patients. Using white ceramic implants would preclude the dark shimmer of titanium implants when the soft peri-implant mucosa is of thin biotype or recedes over time.

- Sheela kumar Gujjari, Nada Musharraf Ali[5] in 2014 explained that dental implants had revolutionized oral rehabilitation in partially and fully edentulous patients. Ti alloys were considered the material of choice in Implantology due to their biocompatibility, high strength and corrosion resistance in a physiological environment. In the world of dentistry, that it can cause allergic reaction. It is now documented that environmental factors were contributed in the increasing occurrence of allergic reaction. It was presented with allergens such as skin rash, flush & eczema. Ti4Al6V4 consist of pure titanium and small amount of other elements, may act as "Impurities". Metal allergy assessment should be done in two stages: the first phase should be aimed at identifying potentially allergic patients based on the medical records, on the examination of signs & symptoms associated with Ti allergy and clinical events such as dekeratinize hyperplastic reaction of peri-implant mucosa. The second phase should be aimed at performing more specific TI allergy test.

DISCUSSION:

Since the 1960s, Titanium implants were extensively used to replace the missing natural teeth in Prosthodontics and they derive their biocompatibility from the alloying elements responsible for the formation of a continuous stable TiO2 passive film on its surface. Nevertheless, sporadic cases of intolerance have been reported, in which a group of patients suffer from repeated failure with titanium implants with no known cause coming forth [21].

Even after the excellent biocompatibility and corrosion resistance there was significantly small release of ions under the ideal conditions of passivity and with no damage to the implant surface. Corrosion of these implants may occur when the oral conditions were unfavourable as under mechanical trauma to the implant surface (during placement, subject induced, and trauma to assault) or the use of inappropriate metal combination as auxiliary prostheses (galvanism) [22].

The types of corrosion that is pertinent to the currently used alloys [6]:

1. Pitting,
2. Galvanic,
3. Stress-Corrosion cracking,
4. Fretting corrosion
5. Crevice,
6. Intergranular,
7. Corrosion fatigue

However, allergic reactions to titanium in dentistry have not received its due attention. Literature reports sensitivity to titanium ranging from 0.6 to 5% of the general population [23]. The patients who are sensitive to titanium show allergic reactions ranges from type I to IV with symptoms ranging from vague pain, skin rashes to implant failure.

Moreover, titanium allergy is barely recognized in mainstream medicine but the diagnosis is also an important step.

Three commonly used test [2] :

1. Epicutaneous tests (patch tests)
2. Prick test
3. LTT-Memory Lymphocyte Immuno Stimulation Assay (MELISA): This test is the only scientifically-proven test which can objectively diagnose titanium allergy and measure its severity[24].

Nevertheless small amounts of other elements associated with titanium alloys can act as “impurities” and can initiate allergic reactions in patients. But the Titanium alloys remain the preferred choice for dental implants.

Although, Harloff et al[2] used spectral analysis to investigate various titanium alloys, such as sponge titanium, $TiAl_6V_4$, and iodide titanium. The results of their study showed that titanium alloys contained very small amounts of additional elements such as beryllium, cobalt, chromium, copper, iron, nickel, and palladium. Forte et al[2] showed that these elements may be causative factors for different allergic reactions in patients with dental implants. On the other hand, Kulak and Arikan [2] reported no evidence that dental base metal alloys caused an increase in sensitization.

CONCLUSION:

In vivo no metal or alloy is completely inert. Metals experience a slow removal of ions through local and sequential variations in microstructure and surroundings. Despite of most recent inventive metallurgical & scientific progress plus remarkable advancement in the development and design of surgical and dental materials, failures do occur. Corrosion may be the most common reasons for dental implants failures. The risk as well as the detrimental consequences of it’s by products are major issues of clinical significance. Its biologic effect on dental implants is also an important health issues associated with any prosthesis in the body. A specific and responsive test should be developed to determine titanium hypersensitivity. Depending upon the galvanic corrosion behaviours, the choice can be made for implant and implant borne suprastructure.

Failure of implants can be minimized only if the mechanisms that ensure implant structural stabilization and bio acceptance are fully understood.

Individuals account a previous history of allergic reaction to a variety of known allergens was more vulnerable to presenting with an allergic reaction to titanium. A non-invasive patch test is advisable especially in patients with a previous history of allergy to other known metallic allergens.If a patient is conclusively proven to be susceptible for an allergic reaction to titanium, other means of treatment should be explored.

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