Journal Homepage: - www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI: 10.21474/IJAR01/19951
DOI URL: http://dx.doi.org/10.21474/IJAR01/19951

ISSN NO. 2320-5407

RESEARCH ARTICLE

ROLE OF TITANIUM IN PROSTHODONTICS

Shajahan P.A[1], Rohit Raghavan[2] and Faseela P.P[3]

1. Professor, Department of Prosthodontics, Royal Dental College, Palakkad, Kerala.
2. Professor and Head, Department of Prosthodontics, Royal Dental College, Palakkad, Kerala.
3. Post Graduate Student, Department of Prosthodontics, Royal Dental College, Palakkad, Kerala.

Manuscript Info

Manuscript History
Received: 17 September 2024
Final Accepted: 27 October 2024
Published: November 2024

Key words:-
Titanium alloy, RPD, FPD, Implant, Osseointegration

Abstract

Titanium has revolutionized the field of prosthodontics due to its exceptional properties. This light weight, yet incredibly strong metal has become a cornerstone in dental restorations. The basic properties of titanium like biocompatibility,corrosion, strength,shape memory etc. are discussed in detail. These properties of titanium make it the miracle metal in dentistry.

Introduction:-

Titanium is a chemical element with the symbol Ti and atomic number 22. Titanium was first discovered by William Gregor in 1791 who called it menachite. . It was rediscovered by a German chemist M.G. Klaproth in 1795 who named it titanium, after the powerful mythological first sons of the earth the titans. The use of titanium and titanium alloys for medical and dental applications has increased dramatically in recent years.Today, titanium and titanium alloys are used for the fabrication of prosthetic joints, surgical splints, stents and fasteners, dental implants, dental crowns and partial denture frameworks.[1]

Properties

ASTM International (the American Society for Testing and Materials) recognizes four grades of commercially pure titanium, or Ti, and three titanium alloys (Ti-6Al-4V, Ti-6Al-4V Extra Low Interstitial [low components] and Ti-AlNb).[2]Titanium is a highly reactive metal that readily passivates to form a protective oxide layer, which accounts for its high corrosion resistance. The low density of titanium provides for high-strength, lightweight prostheses.Dental porcelain can be fused and bonded to titanium to produce an aesthetic, life like restoration. Titanium must be melted in a vacuum or under inert gas to prevent oxidation and the incorporation of oxygen that can lead to embrittlement of the cast metal.

Biocompatibility

Excellent biocompatibility is the most practical aspect for the application in dentistry. This useful biological property of titanium is based on the existence of titanium oxide (TiO_2) layers, which are naturally formed in oxygencontaining environments. It is also possible to be produced with various artificial techniques, e.g., anodizing.[3]Titanium is relatively inert, corrosion resistance metal because of its thin (approximately 4nm) surface oxide layer. Studies have shown that Titanium readily adsorbs protein like albumin, laminin, glycosaminoglycans, collagenase, fibronectins, complement proteins, fibrinogens etc. from the biological fluids.[4]

Corresponding Author:- Faseela P.P
Address:- Post Graduate Student, Department of Prosthodontics, Royal Dental College, Palakkad.

Osseointegration

Bränemark observed the fusion of bone with titanium chambers when he had placed them into the femurs of rabbits. Titanium is one of the best metals that allows for this integration.[5]Because it is absolutely inert in the human body, immune to attack from body fluids, compatible with the bone growth, strong and flexible.[6]Theosseointegration rate of titanium dental implants is related to their composition and surface roughness or application of osteoconductive coatings.[7]

Toxicity

Pure titanium and Ti–6Al–4V alloy have been mainly used as implant materials. V-free titanium alloys like Ti–6Al–7Nb and Ti–5Al–2.5Fe have been then developed because toxicity of V has been pointed out. Al- and V-free titanium alloys as implant materials have been developed. Most of them areá+â type alloys. â type titanium alloys composed of non-toxic elements like Nb, Ta, Zr, Mo or Sn with lower moduli of elasticity and greater strength have been developed recently.[8]

Strength

The strength and rigidity of titanium are comparable to those of other noble or high noble alloys commonly used in dentistry. Titanium has a relatively high tensile strength. Titanium has a tensile strength of between 30,000 and 200,000 lbs. per square inch. Titanium alloy contains roughly six weight percent of aluminum and four weight percent of vanadium, which doubles its tensile strength relative to commercially-pure titanium, but reduces its ductility. The yield strength (170 – 480 MPa).[9]

Shape memory

Nitinol [also known as a shape memory alloy (SMA), smart alloy, memory metal, or muscle wire] is an alloy that "remembers" its shape. Nitinol possess a unique combination of properties, including superelasticityand shape memory, which are very attractive for biomedical applications. NiTi has been used in orthopedic and orthodontic implants. Their ability to recover large strains and dissipate mechanical work without macroscopic permanent deformation has generated significant interest in various field. Among all SMA, titanium nickel (TiNi) is the most important alloy.[10]

Titanium in complete denture

Due to the material's advantageous qualities, titanium (Ti) and its alloys, especially Ti6Al-4V, have been successfully used in the fabrication of whole and partial dentures. One important procedure for shaping these materials for dental purposes is superplastic forming (SPF). By heating the material to around 60% of its melting temperature (0.6Tm in Kelvin), this approach helps to prevent problems that are common with other processes, such as thermal mismatch, casting shrinkage, and porosity.A slow strain rate (usually between $5 \times 10^{-4}\ s^{-1}$ and $1 \times 10^{-4}\ s^{-1}$) is applied during SPF in order to reduce the possibility of internal stresses that could cause dimensional changes after the material cools. The material can elongate significantly during this process—up to ten times more than at ambient temperature—because it is usually carried out at high temperatures and with a regulated strain rate.The SPF technique involves heating the material inside a sealed die and applying controlled amounts of inert gas pressure to push it into the die's pattern. Superplastic alloys are perfect for producing complicated shapes that are challenging to create with conventional methods because they can be stretched to several times their initial length without breaking, and the material's flow stress grows fast with an increasing strain rate. Applications of this technology include the successful production of denture bases and key connectors for partial dentures.[11]

Titanium in removable partial denture prosthesis-

Because of its excellent corrosion resistance, strength, and low density, researchers have been able to use it in removable partial denture prostheses. Despite being effective, hypersensitivity reactions had been documented with standard base metal partial denture alloys, Ti was thought of as a substitute for these alloys. The evaluation of titanium and its alloys for rpd revealed a number of benefits over traditional alloys, including greater resilience, which makes it more similar to gold alloys. This feature would enable the RPD's retentive clasp arm to be positioned in deeper abutment undercuts. Ti has a lower density than gold alloys, about 25% less than that of Cr-Co alloys, which is advantageous when making a detachable partial denture with all metal components, as it significantly reduces the prosthesis' total bulk. [12]

Titanium in fixed partial denture prosthesis

High noble and noble alloys were first to be used in this field. They have the longest record of successful clinical use demonstrating excellent castability and fit as well. However the allergic and carcinogenic potentials of nickel and beryllium were reported in patients. Titanium with its excellent corrosion resistance, bioinertness, and favorable mechanical properties such as low density, high elastic modulus, and adequate strength fulfill most of the criteria. The casting of titanium crowns was noted in early 1970's with works of Waterstratt of US National institute of standards and technology. Alternatives to casting were investigated in the form of machine duplication and spark erosion was introduced by Andersson et al and it is being used clinically with success.[13]

Titanium in implantology:

In addition to its low modulus of elasticity, strength in hollow tube machinability, and ability to be heat-sintered in powder form or plasma-sprayed to generate a porous implant surface, titanium is a material of choice due to these properties. Its importance inimplantology:-

1) The characteristics of titanium's surface oxide are clearly linked to the material's shown high biocompatibility, highest corrosion resistance.

2). Concept of Osseointegration: In the absence of an intervening soft tissue layer, it can be roughly characterised as the dynamic interaction between living bone and that of a biocompatible implant.

3). The structural nature of the contact between titanium implants and tissue: The process by which epithelial cells adhere to titanium surfaces is similar to that of natural tooth .Collagen fibres would eventually form a thin cuff around the implant abutment deep within the gingival fissure. Fibroblasts produced glycosaminoglycans during healing coat the implant surface. Fibronectin binds to collagen and glycosaminoglycans, acts as the "glue" between the implant and type IV collagen of the lamina densa, is produced by fibroblasts and endothelial cells that are present in the extracellular matrix of the healing wound. Implants lack a gingival sulcus and periodontal ligament, in contrast to natural teeth. In the absence of dental plaque, the epithelium has been seen to tightly and relatively inflammatorily adapt to the implant collar. Implant's relationship with surrounding tissue is largely determined by how biological components like collagen, osteoblasts, fibroblasts, and blood components interact with passive titanium oxide (TiO_2) that forms on the surface of an implant.

4). Surface treatments for titanium implants: One of the most popular methods is surface modification because it allows for the selective alteration of surface characteristics without sacrificing the materials' desired bulk properties. Numerous factors, including anatomical location, implant size and design, surgical technique, loading effects, biological fluids, age and sex, and, in particular, surface features, influence the osseointegration process. Surface qualities are thought to regulate the initial interactions between implanted materials and the biological environment; they regulate the quantity and quality of cell adhesion on the surface and, as a result, the growth of cells and tissues. The following techniques can be used to modify a surface: mechanically: by sandblasting with Al_2O_3 or ZrO_2; chemically: by acid etching; mechanical and chemical combination; electrochemical; ion implantation.[14]

Conclusion:-

Titanium was primarily used in dentistry because of its exceptional biocompatibility, which completely changed the field of craniofacial and dental implants. The successful osseointegrationof titanium, in which the material merges with bone directly, represented a major breakthrough in dental implants. Success rates for these surgeries have grown over time because to advancements in implant design, surface features, and clinical implantation techniques.

Global interest in the viability of employing titanium for both permanent and detachable prostheses started to grow. The bio-inertness of titanium, which reduces harmful reactions with bodily tissues, and its advantageous mechanical qualities, which include low density, sufficient strength, and flexibility, are among its appealing qualities.

References:-

1. McCracken M. Dental implant materials: commercially pure titanium and titanium alloys. J Prosthodont 1999;8:40-3
2. Jorge JRP, Barão VA, Delben JA, Faverani LP, Queiroz TP, Assunção WG. Titanium in dentistry: historical development, state of the art and future perspectives. J Indian Prosthodont Soc. 2013;13(2):71–7. 2
3. Wang RR, Fenton A. Titanium for prosthodontic applications: a review of the literature. Quintessence Int 1996;27:401-8
4. Hobkirk J.A, Watson R.M, Lloyd J.J. Searson, "Introducing Dental Implants: Implants: An Introduction", Elsevier Science, China, 3 – 18, 2003.

5. Michael R Norton. “The History of Dental Implants: A report”, US Dentistry, 24 – 26, 2006
6. Le Guehennec L,.Soueidan A,.Layrolle P, Amouriq Y., Surface treatments of titanium dental implants for rapid osseointegration.; Dent Mater; 2007; Jul;23(7); 844-54
7. Kurod D, Niinomi M, Morinaga M, Kato Y, Yashiro T; Design and mechanical properties of new â type titanium alloys for implant materials. Material science and engineering, 1998, Vol 243, (1-2), 244-249
8. Lautenschlager EP, Monaghan P. Titanium and titanium alloys as dental materials. Int Dent J, 1993, 43:245-53.
9. Nanocontact characterization of shape-memory titanium-nickel films by Ma, Xiaoguang, PhD, UNIVERSITY OF CALIFORNIA, BERKELEY, 2005, 0 pages; 3211436
10. MaunoKononenetalTi framework removable partial denture used for patient allergic to other metals.JProsthet Dent. 1992:73;4-7
11.) Preston DJ: Cobalt - Chromium - Titanium alloy for Removable Partial Dentures. Int J. Prosthet 1997; 10:309 – 317
12. Hummel SK, Marker VA, Pace L, McCarthy S, Ford P Retentive foree of Ti vs, Co-Cr RPD elasps ¡abstract 14S3|, J Dent Res 1994:73:287,
13. Koizumi H, Takeuchi Y, Imai H, Kawai T, Yoneyama T. Application of titanium and titanium alloys to fixed dental prostheses. Journal of prosthodontic research. 2019;63(3):266-70.
14. Branemark, P., Zarb, G. &Albrektsson. TissueIntegrated Prostheses Osseointegration in Clinical Dentistry. (1985) Chicago: Quintessence Publishing Co. Inc. The International Journal of Oral and Maxillofacial Implants 13, 17-29.