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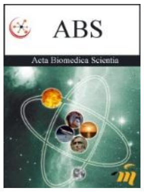

TITANIUM IN PROSTHODONTICS AND ITS MATERIAL ASPECT- AN UPDATED REVIEW

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ABSTRACT

The evolution of titanium (Ti) applications to medical and dental implants has dramatically increased in the past few years because of titanium's excellent biocompatibility, corrosion resistance and desirable physical and mechanical properties. A growing trend involves the use of titanium as an economical and biocompatible replacement for existing alloys for fixed and removable prostheses. This paper highlights current knowledge on material properties, passive oxidation, film formation, surface activation, cell interactions, casting and machining of cpTi and its potential clinical applications in dentistry.

INTRODUCTION

Metals have been used as biomaterials for many centuries. Around 1565 gold plate was reported to be used to repair cleft palate defects. Gold alloys and their substitutes are formed by a casting process developed by Taggart in 1907. Since then, cast gold restorations have been routinely used in clinical dentistry. With advances in dental porcelain in the 1960s and the significant increase in the price of gold in the 1970s, alternative alloys such as palladium alloys and base metal alloys were developed. The allergenic and carcinogenic properties of base metal alloys used in dentistry especially nickel and beryllium-based alloys have fueled controversy [1]. The evolution of titanium (Ti) applications to medical and dental implants has dramatically increased in the past few years because of titanium's excellent biocompatibility, corrosion resistance and desirable physical and mechanical properties. A growing trend involves the use of titanium as an economical and biocompatible replacement for existing alloys for fixed and removable prostheses.

However, long term evaluation of titanium casting, joining, and porcelain bonding have to be done before this wonder metal can be used routinely in clinical dentistry.

Classification of Titanium and its Alloys [2]

Based on the addition of small traces of other elements such as oxygen, iron, and nitrogen, ASTM committee on materials for surgical implants recognizes four grades of commercially pure titanium and two titanium alloys (Ti-6Al-4V and Ti-6A1-4V extra low interstitial (ELI).) All six of these materials are commercially available as dental implants.

There are three general forms of titanium base alloys: alpha alloys, alpha-beta alloys, and beta alloys. At temperatures upto 882°C, pure titanium exists as alpha alloys (hcp). Above that temperature, pure titanium undergoes a transition from hcp structure (alpha) to a bcc structure (beta). Alloying elements are added to stabilize one or the other of these phases by either raising or lowering the transformation temperatures. The elements oxygen, aluminium, carbon, and nitrogen stabilize the alpha phase of titanium. Elements that stabilize the beta

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phase include manganese, chromium, iron and vanadium.

Vanadium stabilizes the beta phase of Ti-6A1-4V alloy, so that it exists as a combination of alpha and beta phases. The combination of phases gives the alloy strength. In general, alpha titanium is weldable, but difficult to work with at room temperature. Beta titanium, however, is malleable at room temperature and is thus used in orthodontics. The (α+β) alloys are strong and formable but difficult to weld [3].

CHEMISTRY OF TITANIUM

An extremely reactive metal, titanium forms a tenacious oxide layer that contributes to its biocompatibility and electro chemical passivity. This stable oxide with a thickness of 2O-50 A° forms in the order of nanoseconds, and it repassivates in a time on the order of nanoseconds. However, these alloys are prone to gap corrosion and discoloration in the oral cavity. Therefore titanium is electrochemically inactivated by the addition of small percentage (0.15%) of a metal of platinum group to improve the anticorrosion properties of the alloys by inducing a firm passive coating.

PHYSICAL AND MECHANICAL PROPERTIES OF TITANIUM [4,5]

Density of titanium alloys is 4.5g/cm³ (considerably less than gold or Ni-Cr or Co-C r alloys). The mechanical properties of titanium and its alloys surpass the requirements for an implant material. Dental implants require strength levels greater than that of bone and an elastic modulus close to that of bone. The ultimate tensile strength of spongeous bone is about 83 MPa and cortical bone is about 117 MPa. The yield strength of cp grade 1 titanium to cp grade 1V titanium increases from 170 to 483 MPa. Strength is beneficial because materials better resist occlusal forces without fracture or failure. Lower modulus is desirable because the implant biomaterial better transmits forces to the bone.

BIOLOGICAL PROPERTIES [7]

Titanium and its alloys are inert, have excellent biocompatibility and predictability when compared to the non-alloyed titanium. During the first week the implant is surrounded by a fluid space that contains proteins, erythrocytes, inflammatory cells and cell debris. The inflammatory cells present in this space seldom adhere to the surface of the non-alloyed titanium and do not appear activated. Plaque accumulation of titanium or hydroxylapatite (HA) coated titanium is less than on natural teeth because of its high surface energy.

CASTING

Casting is done by conventional lost wax technique using calcia bonded investment material. This is a the recently developed investment for casting titanium inlay, crown and bridge with binder - calcia refractory – zirconia

Pure titanium melts at 3,035°F (1,668°C) and reacts readily with conventional investments and gases like oxygen, nitrogen and carbon. Therefore, it must be cast and soldered with special equipment in oxygen free environment.

New alloys of titanium with nickel that can be cast by more conventional methods are being developed. They release verity little ionic nickel and bond well to porcelain. New methods of forming titanium crowns and copings by CAD/CAM technology avoids the problem of casting altogether.

TITANIUM MACHINING

The initial application of titanium to dentistry was machined Ti dental implants. As an alternative to lost wax casting, the Procera system (Nobelpharma) with titanium machining has been developed by Andersson et al [2] for the fabrication of unalloyed titanium crowns and fixed partial dentures.

The external contour of a titanium crown or coping can be shaped out of a solid piece of titanium by a milling machine, while the internal contour of the titanium crown is spark eroded with a carbon electrode.

Single titanium crowns can be fabricated with this method, and multiple unit fixed prostheses can be made by laser welding individual units together [5].

ACCURACY OF FIT

Blackman et al [6] examined the fit of 20 cast titanium copings divided into two equal groups with 45 and 90 degree shoulders. The surface of marginal discrepancy was greatest with the 90 degree configuration. Casting shrinkage occurred particularly along the horizontal axis in the plane of the shoulder. It was concluded that Ti crown copings can be cast with acceptable fitting accuracy.

TITANIUM AND COMPLETE DENTURE FRAMEWORKS [3]

Titanium’s high-fusing temperature and chemical activity are primarily responsible for the casting of this metal. So new techniques like spark erosion (electro erosion) and machine duplication termed “copymilling” have been introduced. These recent techniques have given promising solution to the problems encounterd during casting in the past.

Ti-6A1-4V is one of the superplastic alloys that exhibits excellent elongation (more than 1,000%) at a temperature of 800°C to 900°C.This super plasticity deformation is obtained by grain-boundary sliding or dislocation with a fine-grain structure (diameter 4 to 10 micro meters) and thus applied to denture framework fabrication.

The retention of acrylic resin to the titanium base is an important consideration. Noriyuki Wakabayashi et al confirmed that bond strength between a denture-base resin containing an adhesion-promoting monomer and Ti-6Al-4V alloy that had been airborne particle abraded using aluminum oxide particles was statistically equivalent to that between the same resin and a cobalt-chromium alloy casting. However when he usefulness of Ti as a metal for removable partial denture (RPD) was evaluated, it was seen that removable partial denture frameworks that were 0.70 mm thick had better castability than did 0.35 mm thick RPD frameworks, suggesting that if Ti is used for RPD frameworks, a thicker wax pattern is needed than is used in casting of a conventional denture framework with Co-Cr alloys. Also, Ti commonly failed to cast perfect mesh specimens, but Co-Cr alloys did not have this problem.

TITANIUM AND FIXED PARTIAL DENTURE

The low coefficient of thermal expansion (CTE) of titanium (about 9 x 10^{-6}/°C) compared to those of the conventional low-fusing porcelains (about 13 x 10^{-6}/°C) raised the concern of thermal compatibility. However, porcelains manufactured to bond to titanium are currently commercially available. The Procera porcelain (Procera, Nobelpharma: Goteborg, Sweden) was formulated for machine-milled crowns, while the Duceratin porcelain (Degussa, South Plainfield NJ) was formulated for cast titanium crowns. The strength of porcelain-fused-to-metal structures is related to mechanical properties of the metal framework, the veneering porcelain, the porcelain-metal interface, and their interactions.

TITANIUM AND IMPLANTS [9]

Titanium and its alloys are important in dental and surgical implants because of their high degree of biocompatibility, their strength and their corrosion resistance. Pure titanium, theoretically, may form several oxides (TiO, $Ti0_2$ and Ti_20_3). Of these, TiO_2 is the most stable and therefore the most commonly used under physiologic conditions. These oxides form spontaneously on exposure of Ti to air. However, when an implant is introduced into the body, complex reactions begin to take place at the oxide/bio environment interface. The oxide that forms in the body may therefore, be somewhat different than that which forms in air. Also, the normal level of Ti in human tissue is 50 ppm. Values of 100 to 300 ppm are frequently observed in soft tissues surrounding Ti implants. At these levels, tissue discoloration with Ti pigments can be seen. This rate of dissolution is one of the lowest of all passivated implant metals and seems to be well tolerated by the body. The clinical significance of this data is substantiated by more than 20 years of clinical experience with pure Ti and Ti 6A1 4V alloys.

TITANIUM PLASMA SPRAYED

The first rough titanium surface introduced was coating with titanium powder particles in the form of titanium hydride. Porous or rough titanium surfaces have been fabricated by plasma spraying a powder form of molten droplets at high temperatures in the order of 15,000°C, argon plasma is associated with nozzle to provide very high velocity 600 m/sec partially molten particle c titanium powder (0.05 to 0.1mm diameter) projected onto a metal or alloy substrate. The plasma sprayed layer after solidification (fusion) is often provided with a 0.04 to 0.05mm thickness. This porous surface can result in an increase in tensile strength through in growth of bony tissues into three dimensional features. High shear forces determined by the torque testing methods and improved force transfer into the periimplant area have also been reported.

HYDROXYAPATITE COATING [7]

Hydroxyapatite coating by plasma spraying was brought to the dental profession by deGroot. HA coating has been credited with enabling HA-coated Ti or Ti alloy implants to obtain organized bone adjacent to implant surface with a higher degree of mineralization, which may enhance the biomechanics and initial load-bearing capacity of the system. Implants of solid sintered hydroxyapatite have been shown to be susceptible to fatigue failure. This situation can be altered by the use of a CPC (calcium phosphate coating) along metallic substrates. Although several methods may be used to apply CPC coatings, the majority of commercially available implant systems are coated by a plasma spray technique. Advantage of CPC coatings is that they can act as a protective shield to reduce potential slow ion release from the Ti-6A1-4V substrate. Also, the interdiffusion between titanium and calcium, and phosphorus and other elements may enhance the coating substrate bond by adding a chemical component to the mechanical bond.

TITANIUM AND MAXILLOFACIAL PROSTHESIS-THE CRANIAL PROSTHESIS [8]:

Titanium has been recently used in fashioning cranial prostheses. This metal is a strong but light material that is soft enough to be swaged in a die-counterdie system. Moreover it can be strain hardened and thus become stronger with manipulation. Sheets that are 0.6 1mm thick are adequate and its radiodensity permits most radiographic studies. After the metal prosthesis is shaped, trimmed, and polished, tissue acceptance of the implant is enhanced by anodizing it in a solution of 80% phosphoric acid, 10% sulphuric acid, and 10% water[8].

The osseointegration technique allows the placement of titanium implants in to the bone which project through the skin, providing points of attachment for prosthetic devices. Titanium implants are used for retention of bone anchored Hearing Aid (BAHA).

CONCLUSION

Based on their physical properties and

biocompatibility, titanium and its alloys have emerged as the metals of choice in dental implant industry. The application of titanium to fixed and removable prostheses is still in the developmental stages. Concerns regarding castability, porcelain bonding, and joining have been reported. At present time, use of titanium restorations or prostheses is low because of lack of knowledge of the material among dentists and long-term c1inic follow-up. Increased use of titanium in prosthodontics depends on research and clinical trials to compare its effectiveness, as an equivalent or superior metal, to existing metals. The future of titanium in dentistry looks promising.

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CONFLICT OF INTEREST:
The authors declare that they have no conflict of interest.

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