Titanium applications in dentistry

ADA COUNCIL ON SCIENTIFIC AFFAIRS

ABSTRACT

Background. The ADA Council on Scientific Affairs outlines the status of titanium and titanium alloys used in dentistry and provides its recommendations concerning their use in clinical practice.

Conclusions. Titanium and titanium alloys, based on their physical and chemical properties, appear to be especially suitable for dental implants and prostheses. For the construction of endosseous implant devices, titanium and its alloys have become well-accepted and can be considered the materials of choice.

Clinical Implications. For crown and bridge prostheses, dentists can consider titanium and its alloys as viable options to more traditional noble and base metal alloys, but careful selection of processing methods and laboratory skill are necessary to ensure success.

The use of titanium and titanium alloys for medical and dental applications has increased dramatically in recent years. Historically, titanium has been used extensively in aerospace, aeronautical and marine applications because of its high strength and rigidity, its low density and corresponding low weight, its ability to withstand high temperatures and its resistance to corrosion.[1]

Over the past three decades, the development of new processing methods—such as lost-wax casting, computer-aided machining and electric discharge machining—has expanded titanium's useful range of applications in biomedical devices.[2] 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. This report outlines the current status of titanium and titanium alloys used in dentistry and presents the Council's recommendations concerning their use in clinical practice.

Both titanium and titanium alloys appear to be especially suitable for dental implants and prostheses.

PHYSICAL AND CHEMICAL PROPERTIES

Titanium, in the form of the oxide rutile, is abundant in the earth's crust. Titanium ore can be refined to metallic titanium using a method called the Kroll process.[3] In its metallic form at ambient temperature, titanium has a hexagonal, close-packed crystal lattice (α phase), which transforms into a body-centered cubic form (β phase) at 883 C (with a melting point of 1,680 C).[4]

Many of titanium's physical and mechanical properties make it desirable as a material for implants and prostheses. The strength and rigidity of titanium are comparable to those of other noble or high noble alloys commonly used in dentistry,[1,4] and titanium's ductility, when chemically pure, is similar to that of many dental alloys. Titanium also can be alloyed with other metals, such as aluminum, vanadium or iron, to modify its mechanical 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-Al-Nb).[5] 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. Additionally, dental porcelain can be fused and bonded to titanium to produce an esthetic, lifelike restoration.

Titanium's highly reactive nature provides both advantages and disadvantages for its use. 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.[6] Contamination with even low concentrations of atmospheric oxygen can lead to signifi-

Downloaded from jada.ada.org on August 23, 2009

cant loss of ductility. The molten alloy also can react readily with refractory investment materials, requiring careful selection of compatible materials, removal of the surface-reacted layer of metal or both.

This same reactivity is responsible for many of titanium's favorable properties. The metal oxidizes almost instantaneously in air to form a tenacious and stable oxide layer approximately 10 nanometers thick.[1,6] This oxide layer provides a highly biocompatible surface and a corrosion resistance similar to that of noble metals. In addition, the oxide layer allows for bonding of fused porcelains, adhesive polymers or, in the case of endosseous implants, plasma-sprayed or surface-nucleated apatite coatings.

CASTING

Dental castings are made via pressure-vacuum or centrifugal casting methods.[7] The metal is melted using an electric plasma arc or inductive heating in a melting chamber filled with inert gas or held in a vacuum. The molten metal then is transferred to the refractory mold via centrifugal or pressure-vacuum filling.

Castings of titanium commonly are used to fabricate crowns, bridge frameworks and full or partial denture frameworks. Several commercial machines for casting titanium are available, but their cost is considerably higher than that for standard dental casting equipment.[1] Materials with low reactivity are used to prevent surface reaction with the molten metal, and materials with high setting expansion are used to compensate for the high casting shrinkage of titanium.

MACHINING

Dental implants generally are machined from billet stock of pure metal or alloy. Dental crowns and bridge frameworks also can be machined from solid metal stock via computer-aided machining. Abrasive machining of titanium, however, is slow and inefficient, which greatly limits this approach. Another method for fabricating dental appliances is electric discharge machining, which uses a fabricated graphite die (often reproduced from the dental working die) to erode the metal to final shape via spark erosion.[8] Multiple dental prostheses also can be connected using laser welding or electric spot welding.

DENTAL USES

Titanium has been used in cast dental prostheses since the 1970s.[4] Equipment is available to cast titanium into single-and multiple-unit-crown-and-bridge frameworks, implant-supported structures and partial or full denture bases. Methods have been developed for fusing dental porcelain to titanium for crowns and bridges, but the choice of dental porcelain is limited by two critical factors: the porcelain fusion temperature must be below 800 C to avoid the α to β phase transition, and the coefficient of thermal expansion of the porcelain must match that of the metal.[2,4] High fusing temperatures also can lead to excessive oxide formation, and a recent study[9] showed that porcelain fired under inert atmosphere resulted in improved bonding. Furthermore, it is difficult to maintain consistency in titanium dental castings because of their inherently poor castability, and few laboratories are able to provide this service. Though titanium is economical, biocompatible and readily available, the technologies necessary for casting, machining, welding and veneering this metal are relatively new and more expensive than those used for conventional dental metals. For these reasons, the use of titanium for dental castings has not become a prevalent laboratory and clinical practice.

Equipment is available to cast titanium into single- and multiple, unit-crown-and-bridge frameworks, implant-supported structures and partial or full denture bases.

IMPLANTS

For more than 25 years, titanium has been used for both endosseous and subperiosteal implants.[10] Endosseous implants have taken the form of rods, posts and blades made of either pure titanium or titanium alloys. The passivating oxide on the implant surface permits close apposition of physiological fluids, proteins, and hard and soft tissues to the metal surface. This process, whereby living tissue and an implant become structurally and functionally connected, is called osseointegration.[11] Titanium also has been used successfully as a biocompatible implant material, and continual improvements in both device design and clinical implantation techniques have led to well-accepted and predictable procedures.

In 1996, the ADA's Council on Scientific

Downloaded from jada.ada.org on August 23, 2009

Affairs updated its position regarding the use of endosseous implants as a treatment modality for full or partially edentulous patients.[12] In this 1996 update, the Council stated that ADA-Accepted endosseous implants, including those made of pure titanium or titanium alloys, can be used only to treat carefully selected patients with whom the relative merits of benefit and risk have been fully discussed. Before the 1996 update, the Council had not recommended endosseous implants for routine clinical practice.[13] Nevertheless, the Council's report indicated that many factors must be considered when deciding whether to use endosseous implants as a treatment option, and that some of these factors required further study. Some of the factors identified by the Council included the use of single-tooth implants, new methods of retaining prostheses, effects of various surface treatments and coatings on titanium and titanium alloys, and oral hygiene issues. If endosseous implants are to be placed, however, titanium and titanium alloys are recommended due to their biocompatibility and clinical success.

CONCLUSIONS

Both titanium and titanium alloys, based on their physical and chemical properties, appear to be especially suitable for dental implants and prostheses. Processing difficulties, however, have limited titanium's usefulness in fixed and removable prostheses. For the construction of endosseous implant devices, titanium and its alloys have become well-accepted and can be considered the materials of choice.

The Council recommends that practitioners continue to use implants in selected patients for whom the risks and benefits have been carefully weighed and thoroughly discussed. For crown and bridge prostheses, dentists can consider titanium and its alloys as viable options to more traditional noble and base metal alloys, but careful selection of processing methods and laboratory skill are necessary to ensure success. To date, however, there are few clinical data available that compare the long-term success of titanium restorations with those made from more traditional metals. ■

The ADA Council on Scientific Affairs thanks Dr. Frederick C. Eichmiller, Paffenbarger Research Center, Gaithersburg, Md., for his contribution to this report.

Address reprint requests to American Dental Association, Council on Scientific Affairs, 211 E. Chicago Ave., Chicago, Ill. 60611.

1. Wang RR, Fenton A. Titanium for prosthodontic applications: a review of the literature. Quintessence Int 1996;27:401-8.
2. Walter M, Reppel PD, Boning K, Freesmeyer WB. Six-year follow-up of titanium and high-gold porcelain-fused-to-metal fixed partial dentures. J Oral Rehabil 1999;26:91-6.
3. Renner AM. The versatile use of titanium in implant prosthodontics. Quintessence Dent Technol 2001;188-97.
4. Lautenschlager EP, Monaghan P. Titanium and titanium alloys as dental materials. Int Dent J 1993;43:245-53.
5. McCracken M. Dental implant materials: commercially pure titanium and titanium alloys. J Prosthodont 1999;8:40-3.
6. Brown D. All you wanted to know about titanium, but were afraid to ask. Br Dent J 1997;182:398-9.
7. Zinelis S. Effect of pressure of helium, argon, krypton and xenon on the porosity, microstructure, and mechanical properties of commercially pure titanium castings. J Prosthet Dent 2000;84:575-82.
8. Lovgren R, Andersson B, Carlsson GE, Odman P. Prospective clinical 5-year study of ceramic-veneered titanium restorations with the Procera system. J Prosthet Dent 2000;84:514-21.
9. Atsu S, Berksun S. Bond strength of three porcelains to two forms of titanium using two firing atmospheres. J Prosthet Dent 2000;84:567-74.
10. Rizzo AA, ed. Proceedings of the consensus development conference on dental implants. J Dent Educ 1988;52(special issue):677-827.
11. Albrektsson T, Zarb GA, eds. The Brånemark osseointegrated implant. Chicago: Quintessence; 1989:21-78.
12. Council on Scientific Affairs. Dental endosseous implants: an update. JADA 1996;129:1238-9.
13. Council on Dental Materials, Instruments and Equipment. Dental endosseous implants. JADA 1986;113:949-50.

Downloaded from jada.ada.org on August 23, 2009

ADA has placed titanium and titanium alloys, because of their excellent biocompatibility, between high noble and noble alloys in the revised classification system. (Code: D 2794, D 6794)

ADA American Dental Association

ADA POSITIONS & STATEMENTS

REVISED CLASSIFICATION SYSTEM FOR ALLOYS FOR FIXED PROSTHODONTICS

The ADA Council on Scientific Affairs has finalized a revised classification system for alloys for fixed prosthodontics. The Council revised this classification system based on a review of the scientific literature, particularly with regard to the use of titanium and titanium alloys in dentistry. This Council review appears in a report entitled "Titanium applications in dentistry," which was published in the March 2003 Journal of the American Dental Association.

As indicated in the following table, the Council has placed titanium and titanium alloys, because of their excellent biocompatibility, between high noble and noble alloys in the revised classification system.

Revised Classification System for Alloys for Fixed Prosthodontics

Classification	Requirement
High Noble Alloys	Noble Metal Content ≥ 60% (gold+ platinum group*) and gold ≥ 40%
Titanium and Titanium Alloys	Titanium ≥ 85%
Noble Alloys	Noble Metal Content ≥ 25% (gold + platinum group*)
Predominantly Base Alloys	Noble Metal Content < 25% (gold + platinum group*)

*metals of the platinum group are platinum, palladium, rhodium, iridium, osmium and ruthenium

Return to Top

Quick Links
For more topics related to the needs of patients, see: Oral Health Topics A-Z