Titanium applications in dentistry

ADA COUNCIL ON SCIENTIFIC AFFAIRS

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.

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. 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.

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. 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).

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, 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). 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. Contamination with even low concentrations of atmospheric oxygen can lead to signifi-
Equipment is available to cast titanium into single- and multiple-unit-crown-and-bridge frameworks, implant-supported structures and partial or full denture bases. Using laser welding or electric spot welding.

**DENTAL USES**

Titanium has been used in cast dental prostheses since the 1970s. 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. High fusing temperatures also can lead to excessive oxide formation, and a recent study 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.

**IMPLANTS**

For more than 25 years, titanium has been used for both endosseous and subperiosteal implants. 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. 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
Affairs updated its position regarding the use of endosseous implants as a treatment modality for full or partially edentulous patients. 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. 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.
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)