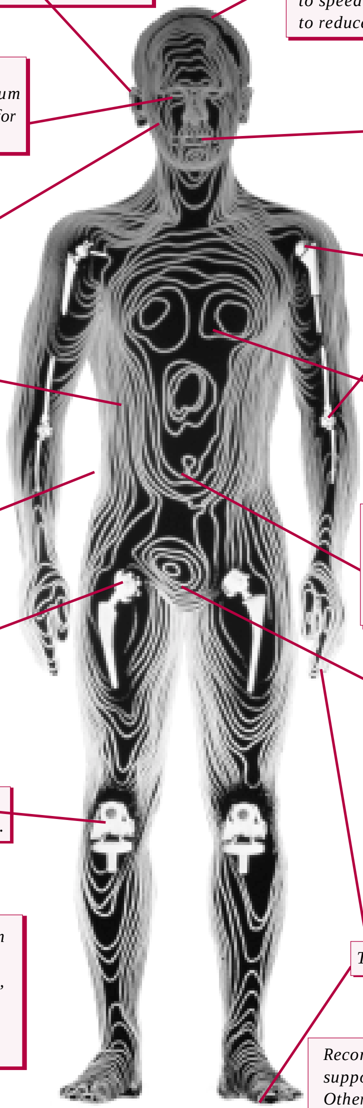
Why is titanium the metal of choice for medical applications from head to toe?



Biocompatibility that's head and shoulders above other materials

Because it is absolutely inert in the human body, immune to attack from bodily fluids, compatible with bone growth, and strong and flexible, titanium is the most biocompatible of all metals.

Titanium was first used in surgery in the 1950's and in dentistry a decade earlier, and is now extensively and routinely accepted by medical professionals as the material of choice for prosthetics, internal fixation, inner body devices and instrumentation.

With the significant benefits titanium offers patients, surgeons and engineers, use of the metal should increase in the future, driven by the aging baby boomer generation, the trend toward more active lifestyles, and the pressure to control health care costs.

Unique properties make titanium the ultimate biomedical choice

Inert to human body fluids: Substantial, regular use has proven that titanium is completely resistant to body environments, under stress, fatigue and in crevice conditions. This is due to its protective oxide film, which forms naturally in the presence of even trace amounts of any form of oxygen. The film is highly adherent, insoluble and chemically non-transportable, preventing reaction to tissue.

This film also gives titanium its unique soft grey appearance. While titanium may not be as shiny as other metals, it is resistant to abnormally corrosive septic conditions.

Osseointegrates: Due to its high dielectric constant, titanium has the property that it can bind to bone and living tissue. Since the implants tissues physically bond with bone, they last longer than when made of materials that need adhesives. The forces required to break the bond are quite high.

Strong, yet light weight: Titanium is lighter weight than stainless steel (approximately 56% as dense) yet has a yield strength twice that of stainless steel and ultimate tensile strength almost 25% higher. This gives it the highest strength-to-weight ratio of any metal suited to medical use. In addition, its density is similar to bone, enabling superior x-ray, MRI and computed tomography images.

Flexible: Titanium's modulus of elasticity and coefficient of thermal expansion match those of human bone, reducing the potential for implant failure. When beta alloyed (as with niobium and zirconium), titanium is used for low modulus applications; when alpha-beta alloyed (as with, titanium is useful for applications requiring greater modulus, such as bone plate.

Non-magnetic: Titanium is not susceptible to outside interference and won't trigger metal detectors.

Easily worked: Conventional metal processing tools and techniques can be used to form, machine and join titanium. Workability is comparable to stainless steels and Tungsten Inert Gas welding is readily performed without a vacuum (for example, to weld a titanium prosthetic vertebra to a titanium STORZ fixation plate).

CONTINUING ADVANCES PROMOTE WIDER USE AND LOWER COST

Research and development on titanium's medical applications is concentrated on new alloys, production technologies, surface treatments that improve biocompatibility and prevention of fretting fatigue.

Isothermal forging: This technique is being used to form parts that meet strength and rupture elongation specifications, with significant cost savings over conventionally manufacturing.

Powder metallurgy: This technology is promising for fabricating titanium alloyed with niobium and tantulum, to reduce costs.

Coatings: To enhance biocompatibility, titanium can be coated, by plasma spray or chemical reaction, with hydroxy apatate (a calcium phosphate ceramic). Coatings are also used to improve wear resistance.

EXAMPLE TITANIUM ALLOYS FOR MEDICAL USE

Titanium is available in commercially pure and alloyed product forms, as prefabricated components as well as mill products including bar, plate and sheet. Alloying and heat treating yield a wide range of mechanical properties, and it is almost always possible to balance the requirements of surgeons, who demand full tissue compatibility (where commercially pure titanium is the benchmark) with the preferences of medical product developers who prefer stronger alloys (for more economical fabrication). Alloying materials favor non-toxic elements including niobium, zirconium, tantalum, molybdenum and tin; nickel, chromium and cobalt, which can be toxic, are avoided. In general, the stronger beta alloys are used in low modulus applications; alpha-beta alloys are used when a greater modulus of elasticity is needed (for example bone plate).

Commercially Pure Grades 1 - 4: Unalloyed titanium is the most corrosion resistant. Its mechanical properties, including strength, ductility, formability and weldability vary with small additions of oxygen and iron. Grade 1 contains lowest levels of oxygen and iron, prod the most formable metal, higher grades have progressively greater oxygen contents for higher strength.

Ti 6Al-4Veli (extra low interstitial): Ti6-4, an alpha-beta alloy, has long been used in orthopedic surgery with proven clinical success. The eli grade was developed for improved fracture toughness and improved cryogenic ductility. Implants (spinal fixation, staples, needles) are a principal use.

Ti-5Al-2.5Fe: This alpha-beta alloy is used for heart pacemaker electrodes; it is biocompatible and the porosity of its surface permits good signal quality.

Ti-6Al-7Nb: This is an alpha-beta alloy with mechanical properties similar to 6-4, but better corrosion resistance. When hot forged, it is possible to attain good economic performance. It is also being investigated for casting of dental crowns.

Ti-13Nb-13Zr: This near-beta alloy, used for orthopedic implants, has low modulus and high strength, is formable and highly corrosion resistant. It can also be surface hardened to optimize biocompatibility.

Ti-15Mo-3Nb: This is a beta alloy with higher strength and lower modulus than 6-4 and no aluminum or vanadium. It offers improved long term performance in orthopedic implants.

Ti-12Mo-6Zr-2Fe (TMZF): This relatively new alloy has a low modulus, excellent mechanical properties, corrosion resistance and formability, good wear and notch fatigue resistance.

INTERNATIONAL TITANIUM ASSOCIATION
1871 Folsom Street, Suite 200
Boulder, Colorado 80302-5714 USA
(303) 443-7515 Phone
(303) 443-4406 Fax
www.titanium.org

I0201 10/99