How Good Are Those Implants?

Although titanium is used widely as an implant material in medicine, its use in dentistry has become exceptional. It is considered an inert metal but the reality is that it does corrode and release ions which are transported throughout the body. This is even supported by literature published in the Australian Dental Journal [1] and many others. [2,3,4,5,6,7]

A summary of the research which follows shows that many effects are possible from exposure to titanium;

- Damage to human bronchial cells[8]
- Stimulate bone resorption[9]
- Antibody Mediated immune responses[10]
- Excessive corrosion of Titanium is caused by exposure to fluoride[11,12,13]
- Generalized allergic reactions[14,15]
- Amalgam and Titanium in the same mouth increases corrosion of the amalgam and thus the increased release of mercury[16]
- Titanium and amalgam produce dramatic ph changes and a change in taste sensation[17]
- Some are carcinogenic[18] (it is possible that NiTiSMA particles are directly carcinogenic)
- High electrical currents are generated between titanium implants and other metals in the mouth[19,20]

Immune reactivity to Titanium is barely recognized in mainstream medicine (see our references at the bottom of this page) - yet laboratories using the MELISA® technology have reported that as many as one in ten people can be affected by it. For those affected with titanium allergy, the symptoms can be multiple and bewildering. These can range from simple skin rashes to muscle pain and fatigue.

From foodstuff to medicine, titanium is now an everyday metal. Several brands of candy, such as Skittles and M&M, have titanium dioxide in the coating - often described by its E-number: E171. Some brands of toothpaste contain titanium particles. Hospitals use titanium implants to rebuild bones after accidents.

More than just a rash: the effects of titanium allergy

Like all metals, titanium releases particles through normal corrosion. These metals become ions in the body and then bind to body proteins. For those who react, the body will try to attack this structure. This starts a chain reaction which can lead to many symptoms including chronic fatigue syndrome (CFS) or, in the most severe cases, Multiple Sclerosis (MS). The MELISA® test is the only scientifically-proven test which can diagnose titanium allergy and measure its severity.

Those who test positive should avoid exposure or remove the titanium from their body to stop the internal reaction. This can be simple, like changing brand of toothpaste. Or it can be more complex, such as replacing titanium implants.

Titanium: where to find it;

Titanium dioxide (TiO_2) is widely used in consumer products, as it is non-toxic - even though it triggers allergies in certain people. It is known as a "pearling agent" as it makes paper and paint glossy and white. Always check the content of food stuff, pills and cosmetics for titanium dioxide. It is found in the following:

- Body implants, such as Brånemark (for teeth) or to rebuild bones.
- Dentistry: as a colour pigment in composites
- Sunscreen agents: Finely ground titanium dioxide will block the harmful ultraviolet rays from the sun.
- Confectionery: Used to make candy look brighter and adding a crunchy coat to for example chewing gum.
- Cosmetics: Used to brighten and intensify the colour of make-up. It is regularly found in shadow, blush, nail polish, lotions, lipstick and powder.
- Toothpaste: Used as a pigment agent to make the toothpaste whiter.
- Paint: TiO_2 will improve the durability of coatings and gives white colour.
- Plastic carrier bags: Improves durability and gives white colour.
- Medical pills and vitamin supplements may also get their white coating from titanium dioxide.
- Piercing & Jewelry: For example watches and all types of body piercing. Less people are allergic to titanium than for example to nickel.

Further studies on Titanium

SEE WWW.MELISA.ORG

Ultrafine titanium dioxide particles in the absence of photoactivation can induce oxidative damage to human bronchial epithelial cells.
Gurr JR, et al. Toxicology. 2005 Sep 15;213(1-2):66-73.
Department of Tourism, Hsing Wu College, No. 11-2 Fen-Liao Road, Linkou, Taipei, Taiwan 24452, ROC. 090012@mail.hwc.edu.tw

Ultrafine titanium dioxide (TiO(2)) particles have been shown to exhibit strong cytotoxicity when exposed to UVA radiation, but are regarded as a biocompatible material in the absence of photoactivation. In contrast to this concept, the present results indicate that anatase-sized (10 and 20 nm) TiO(2) particles in the absence of photoactivation induced oxidative DNA damage, lipid peroxidation, and micronuclei formation, and increased hydrogen peroxide and nitric oxide production in BEAS-2B cells, a human bronchial epithelial cell line. However, the treatment with anatase-sized (200 and >200 nm) particles did not induce oxidative stress in the absence of light irradiation; it seems that the smaller the particle, the easier it is for the particle to induce oxidative damage. The photocatalytic activity of the anatase form of TiO(2) was reported to be higher than that of the rutile form. In contrast to this notion, the present results indicate that rutile-sized 200 nm particles induced hydrogen peroxide and oxidative DNA damage in the absence of light but the anatase-sized 200nm particles did not. In total darkness, a slightly higher level of oxidative DNA damage was also detected with treatment using an anatase-rutile mixture than with treatment using either the anatase or rutile forms alone. These results suggest that intratracheal instillation of ultrafine TiO(2) particles may cause an inflammatory response.

Titanium particles stimulate bone resorption by inducing differentiation of murine osteoclasts. **Bi Y**, et al. J Bone Joint Surg Am. 2001 Apr;83-A(4):501-8.
Department of Orthopaedics, Case Western Reserve University, Cleveland, Ohio 44106-5000, USA.

BACKGROUND: Loosening of orthopaedic implants is mediated by cytokines that elicit bone resorption and are produced in response to phagocytosis of implant-derived wear particles. This accelerated bone resorption could be due to increased osteoclastic activity, survival, or differentiation. Although a number of in vitro studies have shown that wear particles increase osteoclastic activity, the increase was less than twofold in all cases. The objective of the current study was to test the hypothesis that wear particles stimulate bone resorption by inducing osteoclast differentiation. METHODS: Conditioned media were prepared from murine marrow

cells or human peripheral blood monocytes incubated in the presence or absence of titanium particles. The effects of conditioned media on osteoclast differentiation were examined with use of a recently developed assay in which osteoclast precursors are co-cultured with mesenchymal support cells. RESULTS: The present study showed that titanium particles induced both murine marrow cells and human peripheral blood monocytes to produce factors that stimulated osteoclast differentiation. The mean increase in osteoclast differentiation was 29.3+/-9.4-fold. The stimulation of osteoclast differentiation led to a parallel increase in bone resorption. The amount of stimulation was regulated in a dose-dependent manner by the concentration of both titanium particles and conditioned media. The stimulation of osteoclast differentiation required interactions between the cells and the particles themselves and, therefore, was not due to metal ions, soluble contaminants released from the particles, or submicrometer particles. In contrast, conditioned media from control cells incubated in the absence of titanium particles had no detectable effect on any of the examined parameters. CONCLUSIONS: The present study showed that titanium particles stimulate in vitro bone resorption primarily by inducing osteoclast differentiation. In contrast, the titanium particles had only small effects on osteoclast activity or survival.

Immunohistochemical study of the soft tissue around long-term skin-penetrating titanium implants. Holgers KM, et al Biomaterials. 1995 May;16(8):611-6. Department of Anatomy and Cell Biology, University of Goteborg, Sweden.

Bone-anchored percutaneous titanium implants have become a well-established clinical procedure with a low incidence of adverse reactions. However, passage through the skin leads to a breach in the barrier to exogenous pathogens. In the present study, monoclonal antibodies were used to investigate the distribution of lymphocyte subpopulations in the soft tissue around such implants. Eight biopsies from patients with clinically irritated skin, five from non-irritated and eight from skin without skin-penetrating implants were analysed. The number of immune cells was increased in the group of patients with skin penetration compared with patients without skin penetration. In the group with clinical irritation there was an increased level of B-lymphocytes compared with those without irritation. The data suggest that there is an immunological compensation for the mechanical loss in barrier function at these implants and that an antibody-mediated response is present at clinical signs of irritation.

In vitro corrosion of titanium. **Strietzel R**, et al. Biomaterials. 1998 Aug;19(16):1495-9. BEGO, Bremer Goldschlagerei, Bremen, Germany.

Titanium is used in dentistry for implants and frame work because of its sufficient chemical, physical and biological properties. The corrosion behaviour is from high interest to value biocompatibility. A static immersion test was undertaken with a

titanium test specimen (30 mm x 10 mm x 1 mm, immersion time = 4 x 1 w, n = 3 for each series). The following parameters were investigated: specimen preparation, grinding, pH-value, different casting systems, comparison with CAD/CAM, influence of: chloride, thiocyanate, fluoride, lactate, citrate, oxalate, acetate. Atomic absorption spectroscopy was used to analyse the solutions weekly. The course of corrosion was investigated photometrically. Titanium reveals ion releases [(0.01-0.1) microg/(cm2 x d)] in the magnitude of gold alloys. There is little influence of grinding and casting systems in comparison with organic acids or pH value. The ion release increases extreme (up to 500 microg/(cm2 x d)) in the presence of fluoride. Low pH values accelerate this effect even more. Clinically, no corrosion effects were observed. Nevertheless it is recommended that it is best to avoid the presence of fluoride or to reduce contact time. In prophylactic fluoridation of teeth, a varnish should be used.

- (This is another good reason to avoid fluoride toothpastes)

Sensitivity to titanium. A cause of implant failure? Lalor PA, Revell PA, Gray AB, Wright S, Railton GT, Freeman MA. London Hospital Medical College, England J Bone Joint Surg Br. 1991 Jan;73(1):25-8

Abstract:
Tissues from five patients who underwent revision operations for failed total hip replacements were found to contain large quantities of particulate titanium. In four cases this metal must have come from titanium alloy screws used to fix the acetabular component; in the fifth case it may also have originated from a titanium alloy femoral head. Monoclonal antibody labelling showed abundant macrophages and T-lymphocytes, in the absence of B-lymphocytes, suggesting sensitisation to titanium. Skin patch testing with dilute solutions of titanium salts gave negative results in all five patients. However, two of them had a positive skin test to a titanium-containing ointment.

A case of allergic reaction to surgical metal clips inserted for postoperative boost irradiation in a patient undergoing breast-conserving therapy Tamai K, Mitsumori M, Fujishiro S, Kokubo M, Ooya N, Nagata Y, Sasai K, Hiraoka M, Inamoto T. Department of Therapeutic Radiology and Oncology, Graduate School of Medicine, Kyoto University, 54 Shogoin-Kawahara-cho, Sakyo-ku, Kyoto 606-8507, Japan Breast Cancer. 2001;8(1):90-2

Abstract:
We report a case of a 28-year-old woman with right-sided breast cancer. The patient had been treated for atopic dermatitis since her infancy. She underwent breast-conserving surgery (BCS) in July 1998, and three titanium clips were placed at the margin of the excision cavity at the time of surgery. Two months after surgery, the patient exhibited a rapid

exacerbation of atopic dermatitis. Various drugs were suspected to be the cause of the allergic reaction, but the results of a bi-digital O-ring test (BDORT) suggested an allergic reaction to titanium clips. In August 1999, the patient underwent a second operation to remove the titanium clips under local anesthesia. Allergy to surgical titanium clips is a rare complication, but in patients with a history of severe allergic diseases, a preoperative immunologic examination should be performed and the patient's history of metal allergy should be investigated.

Biocompatibility of dental casting alloys Geurtsen W Department of Conservative Dentistry and Periodontology, Medical University Hannover, D-30623 Hannover, Germany. Crit Rev Oral Biol Med. 2002;13(1):71-84.

Introduction:
Most cast dental restorations are made from alloys or commercially pure titanium (cpTi). Many orthodontic appliances are also fabricated from metallic materials. It has been documented in vitro and in vivo that metallic dental devices release metal ions, mainly due to corrosion. Those metallic components may be locally and systemically distributed and could play a role in the etiology of oral and systemic pathological conditions. The quality and quantity of the released cations depend upon the type of alloy and various corrosion parameters. No general correlation has been observed between alloy nobility and corrosion. However, it has been documented that some Ni-based alloys, such as beryllium-containing Ni alloys, exhibit increased corrosion, specifically at low pH. Further, microparticles are abraded from metallic restorations due to wear. In sufficient quantities, released metal ions-particularly Cu, Ni, Be, and abraded microparticles-can also induce inflammation of the adjacent periodontal tissues and the oral mucosa. While there is also some in vitro evidence that the immune response can be altered by various metal ions, the role of these ions in oral inflammatory diseases such as gingivitis and periodontitis is unknown. Allergic reactions due to metallic dental restorations have been documented. Ni has especially been identified as being highly allergenic. Interestingly, from 34% to 65.5% of the patients who are allergic to Ni are also allergic to Pd. Further, Pd allergy always occurrs with Ni sensitivity. In contrast, no study has been published which supports the hypothesis that dental metallic materials are mutagenic/genotoxic or might be a carcinogenic hazard to man. Taken together, very contradictory data have been documented regarding the local and systemic effects of dental casting alloys and metallic ions released from them. Therefore, it is of critical importance to elucidate the release of cations from metallic dental restorations in the oral environment and to determine the biological interactions of released metal components with oral and systemic tissues.

Corrosion of titanium and amalgam couples: effect of fluoride, area size, surface preparation and fabrication procedures. Johansson BI Bergman B Dent Mater (1995 Jan) 11(1):41-6

OBJECTIVES. The aim of this investigation was to study the effect of surface treatments and electrode area size on the corrosion of cast and machined titanium in contact with conventional and high-copper amalgams in saline solutions with and without added fluoride ions. METHODS. The potentials and the charges transferred between amalgam and titanium couples were registered using standard electrochemical methods. RESULTS. Conventional amalgam corroded more than high-copper amalgams in contact with titanium in saline solutions. Adding fluoride to the solution made the titanium potential more active and enhanced the corrosion of titanium in combination with high-copper amalgams. The amalgam corrosion increased with a five-fold enlargement of the titanium area. The increase was significant for one titanium-amalgam combination. Surface preparations affected the electrochemical behavior, and surface alterations were occasionally observed on wet-ground titanium specimens. No significant differences were found in comparisons of cast and lathe- cut titanium. SIGNIFICANCE. Surface preparations and fluoride affect the electrochemical activity of titanium.

Galvanic corrosion and cytotoxic effects of amalgam and gallium alloys coupled to titanium. Bumgardner JD Johansson BI Eur J Oral Sci (1996 Jun) 104(3):300-8

The aim of this study was to examine and compare the galvanic corrosion of a conventional, a dispersed high-copper, and a palladium- enriched spherical high-copper amalgam and a gallium alloy coupled to titanium in saline and cell culture solutions, and to evaluate the effects of the couples on cultured cells. The potentials and charge transfers between amalgams and titanium were measured by electrochemical corrosion methods. Cytotoxicity of the couples, as indicated by the uptake of neutral red vital stain, was determined in 24-h direct contact human gingival fibroblast cell cultures. Results of this study indicated that before connecting the high-copper amalgams to titanium, the amalgams exhibited more positive potentials which resulted in initial negative charge transfers, i.e. corrosion of titanium. However, this initial corrosion appeared to cause titanium to passivate, and a shift in galvanic currents to positive charge transfers, i.e. corrosion of the amalgam samples. Lower galvanic currents were measured for the amalgam-titanium couples as compared to the gallium alloy-titanium couple. Coupling the conventional or the palladium-enriched high-copper amalgams to titanium did not significantly affect the uptake of neutral red as compared to cells not exposed to any test alloy. However, significant cytotoxic effects were observed when the dispersed-type high-copper amalgam and the gallium alloy were coupled to titanium. Even though the corrosion currents measured for these couples were less

than gold alloys coupled to amalgam, these results suggest there is the potential for released galvanic corrosion products to become cytotoxic. These data warrant further investigations into the effects of coupling amalgam and gallium alloys to titanium in the oral environment.

Effects of titanium-dental restorative alloy galvanic couples on cultured cells.
Bumgardner JD Johansson BI J Biomed Mater Res (1998 Summer) 43(2):184-91

The potential exists for titanium and amalgams to become galvanically coupled in the oral cavity. While low galvanic corrosion rates have been measured in vivo for titanium-amalgam or mercury-free alloy couples, concerns exist over released corrosion products and adverse tissue responses. It was hypothesized in this study that coupling titanium to amalgams or gallium alloys increased the release of metallic corrosion products and decreased cellular activity and function. The effects of titanium coupled and uncoupled to a conventional amalgam, palladium- enriched spherical high copper amalgam, a dispersed type high copper amalgam, and a mercury-free gallium alloy were evaluated in 24-h cell culture tests. Viability, proliferation, and collagen synthesis were evaluated by the uptake of neutral red, 3H-thymidine, and immunoassay of procollagen, respectively, and compared to cells not exposed to any test material. The gallium alloy-titanium couple resulted in significant decreases in cellular viability, proliferation, and collagen synthesis as compared to the other coupled and uncoupled samples. Few differences in the cellular responses of the other coupled and uncoupled samples were observed. Atomic absorption analyses indicated increased release of metal ions from the amalgam and gallium alloy samples coupled to titanium as compared to their uncoupled condition, although the differences were not always significant. Galvanic corrosion of amalgam- titanium couples in the long term may become significant, and further research is needed. Coupling the gallium alloy to titanium may result in increased galvanic corrosion and cytotoxic responses.

Corrosion current and pH rise around titanium coupled to dental alloys.

Ravnholt G Scand J Dent Res (1988 Oct) 96(5):466-72

Corrosion reactions around titanium, usually considered biologically inert, might be provoked by coupling it galvanically with more corrodible dental alloys. Experiments in vitro simulating the conditions of a titanium dental implant or root canal post coupled to an amalgam filling, demonstrated corrosion current densities up to 31 microA/cm2, anodic pH values around the amalgam down to 2, and cathodic pH values around the titanium up to 10. The amounts of tin released by the enhanced corrosion of amalgam might contribute measurably to the daily intake of this element; the corrosion current generated reached values known to cause taste sensations. If the buffer systems of adjacent tissues in vivo are not able to cope with the high pH generated around the titanium, local tissue damage may ensue; this relationship is liable to be overlooked, as it leaves no evidence in the form of corrosion products.

Morphological transformation of BHK-21 cells by nickel titanium shape memory alloy particles encapsulated by titanium oxide Qin R Peng S Jiang X Chung Hua I Hsueh Tsa Chih (1995 Nov) 75(11):663-5, 708-9

The special treatment process formed a compact titanium oxide thin film on the surface of medical nickel titanium shape memory alloy

(NiTiSMA) particles (< or = 5 microns). The BHK-21 cells were cultivated in 10% infant calf serum containing NiTiSMA particles and NiTiSMA particles encapsulated by titanium oxide respectively, and morphological transformation clones were observed. The results showed that NiTiSMA particles induced obviously morphological transformation clones, and that NiTiSMA particles induced obviously morphorogical transformation of BHK-21 cells (the rate of morphological transformation clones was 13.46%), especially in TPA medium. The rate of morphological transformation in the group containing NiTiSMA particles was not more significantly different than that in the positive control group. The rate of morphological transformation in the group containing NiTiSMA particles encapsulated by titanium oxide was not more significantly different than that in the negative control group, but significantly different than that in the NiTiSMA particles group. Therefore, it is possible that NiTiSMA particles are directly carcinogenic and that NiTiSMA particles encapsulated by titanium oxide are not potentially carcinogenic.

Corrosion behavior of 2205 duplex stainless steel. Platt JA Guzman A Zuccari A Thornburg DW Rhodes BF Oshida Y Moore BK Am J Orthod Dentofacial Orthop (1997 Jul) 112(1):69-79

The corrosion of 2205 duplex stainless steel was compared with that of AISI type 316L stainless steel. The 2205 stainless steel is a potential orthodontic bracket material with low nickel content (4 to 6 wt%), whereas the 316L stainless steel (nickel content: 10 to 14 wt%) is a currently used bracket material. Both stainless steels were subjected to electrochemical and immersion (crevice) corrosion tests in 37 degrees C, 0.9 wt% sodium chloride solution. Electrochemical testing indicates that 2205 has a longer passivation range than 316L. The corrosion rate of 2205 was 0.416 MPY (milli-inch per year), whereas 316L exhibited 0.647 MPY. When 2205 was coupled to 316L with equal surface area ratio, the corrosion rate of 2205 reduced to 0.260 MPY, indicating that 316L stainless steel behaved like a sacrificial anode. When 316L is coupled with NiTi, TMA, or stainless steel arch wire and was subjected to the immersion corrosion test, it was found that 316L suffered from crevice corrosion. On the other hand, 2205 stainless steel did not show any localized crevice corrosion, although the surface of 2205 was covered with corrosion products, formed when coupled to NiTi and stainless steel wires. This study indicates that considering corrosion resistance, 2205 duplex stainless steel is an improved alternative to 316L for orthodontic bracket fabrication when used in conjunction with titanium, its alloys, or stainless steel arch wires.

Evaluation of restorative and implant alloys galvanically coupled to titanium.

Venugopalan R Lucas LC Dent Mater (1998 Jun) 14(3):165-72

OBJECTIVES: As the success of implants leads to their increasing use in restorative dentistry, attention should be devoted to the galvanic combination of restorative materials with titanium. This paper used continuous corrosion potential monitoring in conjunction with zero- resistance ammetry to obtain galvanic corrosion properties of restorative and implant materials coupled with titanium (ASTM F67-Grade II). METHODS: Direct coupling or galvanic experiments were conducted on eight restorative and implant materials coupled to titanium. Deaerated artificial saliva solution in a specifically designed corrosion cell simulated an oral crevice situation. Open circuit potentials (Eo.c.) of each material in the couple, coupled corrosion potentials (Ecouple corr), coupled corrosion current density (Icouple corr) and the resultant charge transfer were monitored. The results were analyzed using single factor ANOVA and Duncan's multiple range tests. RESULTS: Noble restorative (Au-, Ag-, and Pd-based) alloys coupled to titanium were found to be least susceptible to galvanic corrosion. Co-Cr-Mo, Ni-Cr and Fe-based alloys coupled to tatanium were found to be moderately susceptible to galvanic corrosion due to mechanical-electrochemical interaction. Ni- Cr-Be alloy coupled to titanium was found to be highly susceptible to galvanic corrosion. The in vitro test results for the titanium/Disperalloy combination does not concur with the published clinical performance of this combination, and thus warrants further investigation. SIGNIFICANCE: From the data obtained in this study and current literature profiles, acceptable restorative couples were developed for use as clinical guidelines in restorative dentistry.

Corrosion of coupled metals in a dental magnetic attachment system.

Iimuro FT Yoneyama T Okuno O Dent Mater J (1993 Dec) 12(2):136-44

Implants and magnetic attachments are becoming widespread in dental treatment. Their associated use, implants and magnetic attachments, can be seen often too. In those cases, it is difficult to avoid coupling of different metals. The corrosion behavior of the metals is expected to be different depending on whether it is found in an isolated or a coupled condition. Potential corrosion couples in a dental magnetic attachment system among titanium, ferromagnetic stainless steel, gold alloy type

IV, and gold-silver-palladium alloy were studied by an immersion test in 1% lactic acid for 7 days and potential/current density curves were measured. Corrosion of titanium and ferromagnetic stainless steel seemed to be accelerated by coupling with gold alloys or gold-silver-palladium alloys. On the other hand, the corrosion amount of gold alloy and gold- silver- palladium alloys were attenuated by coupling.____________________

Polymetallism and osseointegration in oral implantology: pilot study on primate. Foti B Tavitian P Tosello A Bonfil JJ Franquin JC J Oral Rehabil (1999 Jun) 26(6):495-502

In oral implantology, successful results in osseointegration are obtained in the medium term (6-12 months) with commercially pure titanium implants. However, current superstructures can be of a different nature (precious metal or titanium) and of different manufacture (cast or machine-produced). Polymetallism between the implant and the superstructure may lead to conditions of galvanic corrosion, and influence osseointegration. The study described establishes, on the one hand, the procedures of animal experimentation in primates and on the other, the techniques of analysis of histological sections. The first technique of analysis is based on histomorphometry and leads to the definition of an osseointegration index. The second technique of analysis consists of X spectrometry by dispersion of energy which enables a spectral analysis of selected points below the crestal neck of the implant (vulnerable area in the case of corrosive attack) to be obtained. It is noted that after 6months, two of which were of activation, osseointegration did not vary according to the nature of the superstructure (precious alloy or titanium). After 2 months, the presence of a precious alloy superstructure lead to titanium migration towards the area around the cervical region of the implant (10-50 microm). This phenomenon did not occur with a titanium implant. It can therefore be presumed that polymetallism leads to detectable corrosion after 2 months but without apparent modification of osseointegration.

Corrosion current and pH rise around titanium coupled to dental alloys.

Ravnholt G Scand J Dent Res (1988 Oct) 96(5):466-72

Corrosion reactions around titanium, usually considered biologically inert, might be provoked by coupling it galvanically with more corrodible dental alloys. Experiments in vitro simulating the conditions of a titanium dental implant or root canal post coupled to an amalgam filling, demonstrated corrosion current densities up to 31 microA/cm2, anodic pH values around the amalgam down to 2, and cathodic pH values around the titanium up to 10. The amounts of tin released by the enhanced corrosion of amalgam might contribute measurably to the daily intake of this element; the corrosion current generated reached values known to cause taste sensations. If the buffer systems of adjacent tissues in vivo are not able to cope with the high pH generated around the titanium, local tissue damage may ensue; this relationship is liable to be overlooked, as it leaves no evidence in the form of corrosion products.

On electric current creation in patients treated with osseointegrated dental bridges.

Nilner K Lekholm U Swed Dent J Suppl (1985) 28:85-92

Electric currents are created when metals or metal alloys are immersed and make contact with each other in an electrolyte. As such metallic contacts are created in the oral cavity also at treatments with osseointegrated fixed bridges ad modum Br anemark, the generated currents were studied in vivo. In four subjects, all wearing osseointegrated mandibular dental bridges and complete maxillary acrylic dentures, the bridges were removed leaving the osseointegrated titanium abutments exposed in the oral cavity. Potentials and polarizations were determined independently for all the titanium abutments and gold alloy bridges and from the obtained data the maximum electric currents generated at contact between the materials were calculated. The results of this study showed that, generally speaking, in the oral cavity dental gold alloy was electrochemically more noble than titanium implants. The mean potential difference between the two metallic systems was found to be 73 mV and the mean generated maximum electric currents was in the magnitude of 26 microA at oral contacts between titanium and dental gold alloy.

In vivo corrosion behavior of gold-plated versus titanium dental retention pins.
Palaghias G Eliades G Vougiouklakis G J Prosthet Dent (1992 Feb) 67(2):194-8

Two types of titanium dental retention pins and a gold-plated stainless steel pin were tested for their in vivo corrosion behavior. Six paired samples of titanium and gold-plated pins were placed in box preparations of 12 periodontally involved premolars. Half of the samples were restored with a high copper admixed type amalgam while the rest were restored with a BisGMA-POCl2 bonding resin and a hybrid visible light-cured composite resin. After 3 months in vivo, the teeth were extracted, and the pins were removed and examined with an electron microprobe. The surface of the titanium pins was found to be smooth and without defects. Only traces of Ca and P could be identified from dentin. The gold-plated pins demonstrated cracks and pores, especially at the outer part of the serrations, resulting in disruption of the electroplated film. Traces of Hg, Sn, Cu, S, Zn, Ca, K, Cl, P, and S were detected at the gold-plated pin/amalgam interface, while Cl and P were found at the gold-plated pin/composite resin interface.

Influence of fluoride on titanium in an acidic environment measured by polarization resistance technique. B oere, G. J Appl Biomater, 6(4):283-8, 1995.

Abstract: The effect of sodium fluoride on the polarization resistance of titanium was investigated. Titanium plates were exposed to sodium chloride solutions with increasing fluoride concentrations. This was done at pH 7 and 4 at 37 degrees C. The polarization resistance technique was chosen because it is the only electrochemical corrosion test procedure that allows sequential measurements of the same specimen and provides a quantitative basis to estimate corrosion currents unlike measurements of the potential.

The results showed a large decrease in polarization resistance with increasing fluoride concentration at pH 4. The polarization resistance at pH 7 remained constant after a slight decrease at a very high value, even with a high fluoride concentration. The results clearly confirm that titanium is attacked by fluoride in an acidic environment. The clinical implications are that fluoride rinses or fluoride gels must have a neutral pH if there is a titanium containing device in the oral environment despite the less prophylactic effectiveness.

Heavy Metal: Titanium Implant Safety Under Scrutiny

Yoana Nuevo-Ordóñez, M. Montes-Bayón, E. Blanco-González, J. Paz-Aparicio, J. Diánez Raimundez, J. M. Tejerina, M. A. Peña, A. Sanz-Medel. Titanium release in serum of patients with different bone fixation implants and its interaction with serum biomolecules at physiological levels. Analytical and Bioanalytical Chemistry, 2011;
DOI: 10.1007/s00216-011-5232-8

It has recently been shown that titanium-based implants both corrode and degrade, generating metallic debris.
titanium concentrations were significantly higher for all the patients with implants.

The more invasive implants shed more metallic debris into the blood than the external, superficial designs. The work also identified how the titanium from the implants is transported in the bloodstream and potentially distributed and accumulated.

Corrosion in titanium dental implants: literature review

Journal of the Indian Prosthodontic Association 2005 Vol 5 Iss 3 P126-131
Adya N, Alam M, Ravindranath T, Mubeen A, Saluja B Institute of Nuclear Medicine & Allied Sciences, DRDO, Min of Defence, Delhi, India

These are excerpts of statements form this paper:

The aim of the study is to evaluate galvanic corrosion current around indigenously developed Titanium Dental Implant when coupled to a Base metal Alloy.

Corrosion, the gradual degradation of materials by electrochemical attack is a concern particularly when a metallic implant is placed in the hostile electrolytic environment provided by the human body. [8] The term corrosion is defined as the process of interaction between a solid material and its chemical environment, which leads to a loss of substance from the material, a change in its structural characteristics, or loss of structural integrity. During corrosion, casting alloys release elements into the body over the short-term (days) and long term (months). The corrosion of biomaterials depends on geometric, metallurgical and solution chemistry parameters.

Yokoyama et al [11] studied the delayed fracture of titanium dental implant. It was concluded that titanium in a biological environment absorbs hydrogen and this may be the reason for delayed fracture of a titanium implant.

'Olmedo et al reported from his study that presence of macrophages in peri-implant soft tissue induced by a corrosion process play an important role in implant failure. [12] These processes lead to local osteolysis and loss of clinical stability of the implant. Macrophages loaded with titanium particles as revealed by EDX analysis were associated with the process of metal corrosion. … The presence of metallic particles that result from the process of corrosion may directly inhibit osteoblast function. In this way both an increase in bone resorption and an inhibition in bone formation may occur eventually resulting in osteolysis.

The corrosion products have been implicated in causing local pain or swelling in the region of the implant in the absence of infection. [17]

Hexavalent chromium ions are released from implant materials, …. Hexavalent chromium causes several cytotoxic responses including decrease in some enzyme activities, interference with biochemical pathways, carcinogenicity, and mutagenicity. [19],[20],[21],[22],[23]

When the acidity of the milieu increases with time the passive layer of the alloy dissolves and it accelerates local corrosion process. [25]

The most common form of corrosion, which is generally present in dental implants, is galvanic corrosion. … galvanic coupling of titanium to other metallic restorative materials may generate corrosion. … Galvanic corrosion occurs when dissimilar alloys are placed in direct contact within the oral cavity or within the tissues. …. An in vivo galvanic cell is formed and the galvanic current causes acceleration of corrosion of the less noble metal. The galvanic current passes through metal/metal junction and also through tissues, which cause pain. The current flows through two electrolytes, saliva or other liquids in the mouth and the bone and tissue fluids. … The less noble metal alloy forms the anode and the more noble titanium forms the cathode. Electrons are transferred through metallic contact, and the circuit is completed by ion transport through saliva, mucosa and tissue fluid

increasing evidence is found that titanium is released into and accumulated in tissue adjacent to titanium implants. [37], [38], [39]

… indicated increased release of metal ions from the amalgam and gallium alloy samples coupled to titanium …

… revealed from his study a relation between the fluoride concentrations and pH values at which Ti corrosion occurred …[45]

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multiple failed implants may result in considerably more titanium release which can track through the regional lymph nodes.

subsequent transport into local blood vessels and to distant organs is also likely.

The titanium levels in the lungs of the animals with failed implants was elevated,

The draining lymph nodes were significantly enlarged in the case of both failed implants.

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