→ NONE for "Zirconium" implants

THE ISSUE OF CORROSION IN DENTAL IMPLANTS: A REVIEW

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ABSTRACT

Pure titanium or titanium alloys, and to a lesser extent, zirconium, are metals that are often used in direct contact with host tissues. These metallic biomaterials are highly reactive, and on exposure to fluid media or air, quickly develop a layer of titanium dioxide (TiO_2) or zirconium dioxide (ZrO_2). This layer of dioxide forms a boundary at the interface between the biological medium and the metal structure, determining the degree of biocompatibility and the biological response of the implant. Corrosion is the deterioration a metal undergoes as a result of the surrounding medium (electrochemical attack), which causes the release of ions into the microenvironment. No metal or alloy is entirely inert in vivo. Corrosion phenomena at the interface are particularly important in the evolution of both dental and orthopedic implants and one of the possible causes of implant failure after initial success. This paper comprises a review of literature and presents results of our laboratory experiments related to the study of corrosion, with special emphasis on dental implants.

In situ *degradation of a metallic implant is undesirable because it alters the structural integrity of the implant. The issue of corrosion is not limited to a local problem because the particles produced as a result could migrate to distant sites, whose evolution would require further studies.*

Key words: corrosion, dental implants, macrophages, failures.

LA PROBLEMÁTICA DE LA CORROSION EN IMPLANTES ODONTOLOGICOS

RESUMEN

El titanio puro o en aleación, y en menor grado el circonio, son los metales más utilizados en contacto directo con los tejidos del huésped. Estos biomateriales metálicos son muy reactivos y al exponerse a medios líquidos o al aire, desarrollan rápidamente una capa de dióxido de titanio (TiO_2) ó de dióxido de circonio (ZrO_2). Esta capa de dióxido limita la interfase entre el medio biológico y la estructura metálica, determinando el grado de biocompatibilidad y la respuesta biológica del implante. La corrosión es el deterioro que sufre un metal debido al medio que lo rodea (ataque electroquímico) y que produce como consecuencia la liberación de iones en el microambiente. In vivo *ningún metal o aleación es completamente inerte. Los fenómenos de corrosión, en la zona de la interfase, son de especial importancia en la evolución de los implantes tanto odontológicos como ortopédicos y constituyen una de las posibles causas de fracaso de un implante luego del éxito inicial. El presente trabajo comprende una revisión bibliográfica y la presentación de resultados de las experiencias de nuestro laboratorio en relación al estudio de la corrosión con especial énfasis en los implantes odontológicos. La degradación "in situ" de un implante metálico es un hecho no deseable ya que altera la integridad estructural del implante. La problemática de la corrosión no se limitaría a un problema local dado que las partículas resultantes de este proceso podrían migrar a sitios alejados al sitio del implante, cuya evolución plantea interrogantes para futuros estudios.*

Palabras clave: corrosión, implantes odontológicos, macrófagos, fracasos.

INTRODUCTION

The discovery of relatively inert metallic and alloy biomaterials has led to their use in the field of biomedical applications such as orthopedics and dentistry. They are being increasingly used due to their physical-chemical properties and compatibility with biological surroundings[1].

Pure titanium or titanium alloys, and to a lesser extent, zirconium, are the metals that are most often used in direct contact with host tissues. These metal-

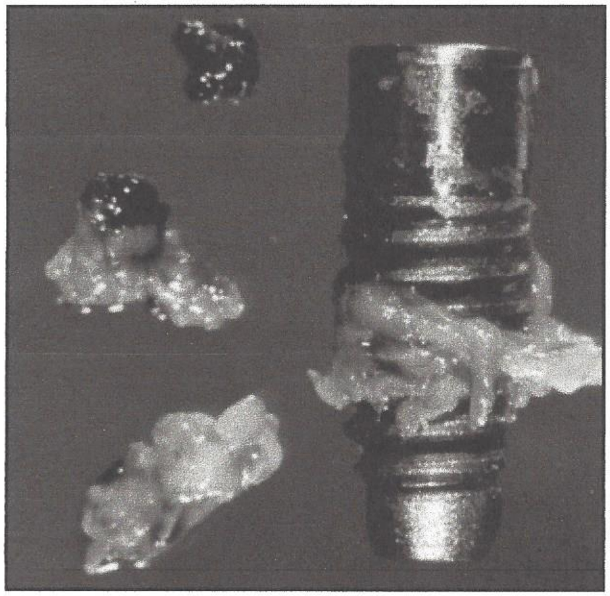

Fig. 1A: Failed human dental implant showing tissue in contact with the metallic surface and tissue fragments obtained by curettage of the surgical bed.

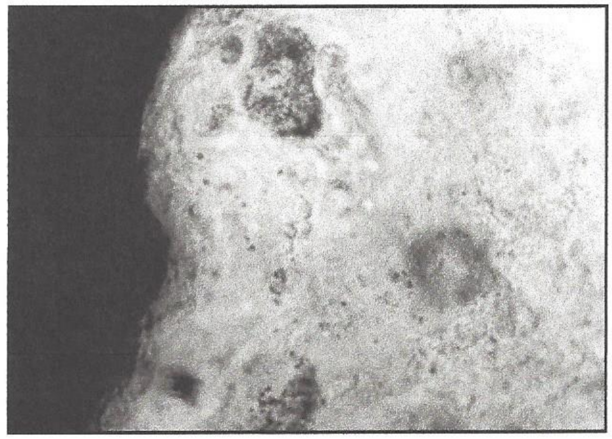

Fig. 1B: Photomicrograph of macrophages near the surface of the implant. Note the presence of particles in their cytoplasm. Ground section. Orig. Mag. X1000.

produced by this kind of corrosion and observed in this study suggest caution in the use of titanium plates and grids as permanent fixation structures.

Corrosion phenomena at the interface are especially important in the evolution of both dental and orthopedic implants.

The issue of corrosion may not be limited to a local problem because particles produced as a result of corrosion may migrate to sites far from the implant. This subject is of particular interest in studies of biocompatibility.

DISSEMINATION OF TITANIUM TO OTHER BIOLOGICAL COMPARTMENTS

The local effect of corrosion with the consequent passage of metal particles to the peri-implant biological medium may also compromise other biological compartments.

In the field of orthopedics there are data that state that titanium ions pass into the surrounding tissues, reach the inner medium and are excreted in urine[17].

Different researchers have found metal ions in body fluids and organs. Galante et al.[17] studied osseointegrated coxofemoral prostheses made from titanium 90% - aluminum 6% - vanadium 4%, showing that ions of all three metals pass into the plasma and are excreted in urine. In autopsies, Urban et al. found metal and plastic particles from coxofemoral prostheses and knee replacements in organs such as liver, spleen and lymph nodes[18].

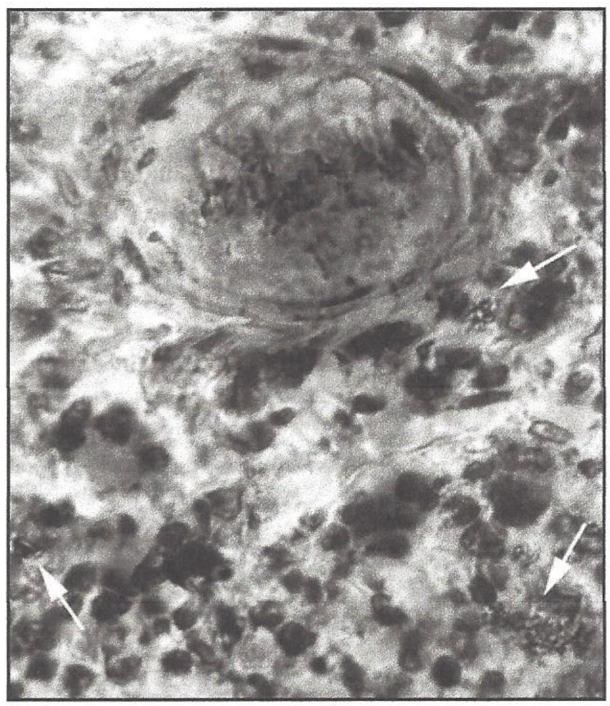

Fig. 2: Blood vessel in the bone marrow near an experimental implant surface and products of corrosion (→) in the vicinity. Ground section. Orig. Mag. X1000.

As previously described, titanium and zirconium implants have a protective surface layer of dioxide (TiO_2 or ZrO_2). This layer is responsible for biocompatibility and forms a boundary of the interface between the biological medium and the implant, reducing its reactivity and partially preventing corrosion[3,4,7].

With the aim of assessing the pathways of the dissemination of corrosion products and estimating the images showed depressions and irregularities on the surface of metal caps. It would be interesting to relate possible biological action of these particles with the evolution of the implant[36].

The products of corrosion of the metal implant may behave as haptenes, generating a hypersensitivity reaction with release of inflammatory mediators known as cytokines and macrophage recruitment[37-39]. It has not yet been proved whether hypersensitivity to metal is the cause of implant failure or vice versa[37]. Similarly controversial is the issue of whether an inflammatory process is responsible for corrosion, or corrosion triggers an inflammatory process.

Furthermore, metal corrosion can affect the close contact between the implant and the bone tissue. Metal particles from coxofemoral prostheses can be ingested by macrophages, stimulating the release of cytokines that contribute to bone reabsorption by activating osteoclasts. In addition to increasing bone reabsorption, these particles can suppress the osteoblast function, reducing bone formation and contributing to osteolysis[40,41].

Titanium toxicology is a subject currently under discussion. According to epidemiological studies, inhalation of environmental dust containing titanium does not have a deleterious effect on lungs[42,43] but other studies have suggested the association of titanium particles with pleural pathologies[44], granulomatous diseases and malignant lung neoplasm[45]. The accumulation of metal particles in the liver might compromise its function, as described by Urban et al. in a study where the presence of titanium particles in a patient was associated to granulomatous reactions and hepatomegaly[18]. In experimental models, we have observed the presence of a considerable amount of titanium particles not only in macrophages but also in hepatocytes[28].

It has been reported that some of the metals currently used most often in the manufacture of implants, particularly in the field of orthopedics (titanium, aluminum, vanadium, cobalt, chrome, nickel) are potentially toxic[46-51]. Their carcinogenic potential has been assessed in experimental studies on animals[52-54]. Nevertheless, there are few reports on the possible development of malignant tumors associated to prosthetic structures in humans[2,55,56]. In this regard, our work group has reported one case of sarcomatous degeneration in the proximity of a stainless steel metal prosthesis, with the aim of contributing with the pool of information to help define more certainly the potential toxicity and risks associated to the use of metallic implants[57]. It is interesting to note that the International Agency for Research on Cancer (IARC) has recently classified TiO_2 as a possible human carcinogen[58].

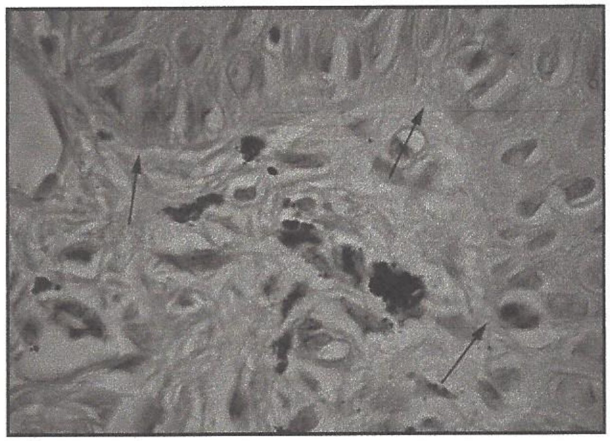

Fig. 5: Human oral mucosa that covered an implant closure screw. Note the presence of free titanium particles or particles phagocytosed by macrophages at the epithelium-chorion interface (→). H-E. Orig. Mag. X1000.

"In situ" degradation of a metallic implant is undesirable because it alters the structural integrity of the implant. Implant manufacturing prospects aim at developing methods that will help reduce the passage of ions/particles from implants to tissues, in order to minimize the adverse effects of corrosion.

We believe that further studies are needed, in particular long-term studies, to continue defining the factors involved in implant corrosion and to establish the basic conditions for their use in clinical implantology.

It is important to stress that the adverse effects of corrosion described in this paper do not always occur in patients with implants, because the biological response varies among individuals.

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