

By what forces a dental implant retains (for newcomers to implant practice)

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ABSTRACT

By inflammatory response acutely to osteotomy, chronically to persistence of foreign body, and finally by healing in osseous deposits, implant retention concerns the tissue component bonded to the metal component, made possible by the matrix mediated like the bonding agent. Following implant insertion, beginning with the initial fibrinous union sealing off oral fluids, strengthened next by fibrous union, and finalized in osseous union condensed by mineralization, the progressive stages of implant-taking process might be trailed with the knowledge of physiologic wound healing taken place in the alveolar bone marrow. In terms of retaining forces such as adhesion, adaptation and chelation, chelators in the matrix are apparently the most important agents for bonding the two components.

KEYWORDS

adhesion; matrix; titanium cat-ions; chelation; fibrin platelet network; fibrinous union; fibroblasts; fibrous union; promonocytes; tissue component; metal component; osseochelation.

INTRODUCTION

Nature has long proven retaining in the tissues buried foreign bodies like bullets and splinters. Quite differently, however, a dental implant

sticking out into the oral cavity is continually bathed in oral fluids and destined to sustain repeated loads of stress. For the longevity of dental implants therefore, they must be sealed from infection, persevere under stress, and most purposefully, be durably retained in the jaw.

Union of dental implant to osseous tissues is generally known "osseointegration" referring to the state of the bonded condition, with an indication, however, of any force accountable for the cause, such as molecular forces of attraction are for 'adhesion'.

Other than adhesion between titanium surface and the tissues, and the mechanical retention by adaptation, the dental implant is retained by dissolution of titanium cat-ions into the osseous matrix. It is into the molecular structure of organic compounds in the matrix that the titanium cat-ions are dissolved, retaining the implant by binding forces referred to as "chelation". For each of the forces, adhesion, adaptation, and chelation, reasonably all three in combination, the matrix is mediated; and apparent from the nature of binding, chelation is possibly the strongest force, the most operative, yet least considered. Apart from these three, there are no other possibilities for binding metal to tissues, physically or chemically.

Adhesion: the electromagnetic intermolecular

force of attraction between dissimilar molecules is the result of difference in surface-tension which is the free potential energy on the surface due to forces of cohesion drawing from beneath.

Chelating agents are soluble organic compounds that form complexes by binding oppositely charged metal ions into their molecular structure, some used to treat metal poisoning; polysaccharides and polypeptides are typical chelators.

IMPLANT-TAKING PHYSIOLOGY

With response to any of injury, characteristic of mammalian tissue, implant-taking outcome is the end result of inflammatory response followed by physiologic wound healing around the foreign body. The whole picture is in essence a tissue reaction, acutely to osteotomy, and chronically to the planted foreign body, to be completed by a physiologic healing process taken result in the osseous tissues of the jaw. Being now taking place in the bone marrow, instead of fibroblasts elsewhere, it is here the osteoblasts that are to be differentiated and proliferated predominantly.

Acutely, following osteotomy the response sets in with the initial vasoconstriction of duration depending upon the nature of trauma. Bleeding and extravasation of neutrophils and platelets along with fibrinogen in plasma ensue as local features.

Chronically, the implant as a foreign body, by its persistent nature would provoke a chronic picture of inflammation in the alveolar bone marrow; and with repeated episodes of response, recurrence of granulations and progressive deposits of osteoblasts, the successful implant is durably retained in spite of the continual stress in the oral cavity.

The physiologic response by differentiation of osteogenic mesenchymal precursor cells from the vicinity in the alveolar bone marrow is a replacement by parenchymal cells designated as "regeneration", to be contrasted from "repair"

where healing is a replacement by connective tissues [1].

Of the three types of cells in the body: labile, stable and permanent, bone marrow cells belong to the labile type with the most favourable capacity for physiologic regeneration throughout life. Regeneration by replacement with labile type of parenchymal cells is by nature very energetic and much faster than repair by non-specialized connective tissue cells in fibrosis or scarring [1].

THE BIOCHEMICAL PICTURE

From the beginning of implantation, neutrophils and platelets clump around the implant. By a series of clotting factors and calcium ions, chemical changes turn platelet thromboplastin into prothrombin and thrombin which acting upon fibrinogen in plasma forms fibrin, meshing up the implant in the fibrin platelet network in fibrinous exudate.

The fibrinous exudate and network containing neutrophils and added macrophages provide the most important front line for promptly sealing the osteotomy wound against oral fluids and infection. This earliest inflammatory response resulting in the fibrinous union is also of particular value for affording the initial implant retention. Of even more significance for implant retention, the network of fibrin provides the scaffold for the in-growth of fibroblasts and buds of endothelial cells by which the acute inflammatory picture prepares to overlap with the onset of the incipient healing process.

As a regular feature, in preparation for healing, cleaning of necrotic debris and fibrin scaffold begins by dissolution with proteolytic and fibrinolytic enzymes from degranulating neutrophils, and the remains phagocytosed by macrophages.

The significance of fibroblasts should deserve some attention. Like all connective tissue cells including those of specialized connective tissues such as bone, cartilage and blood, fibroblasts

are derived from primitive mesenchyme. Fibroblasts synthesize collagen. The protoplasmic prolongations of fibroblasts unlike the cytoplasmic extensions in dendrites, are to be severed into independent collagen fibres which grow in size to form mature collagen fibres; the growth in bulk cramping and clutching into crevices and catches on the implant surface. Concurrent with the laying down of collagen fibers, buds of endothelial cells grow into the young fibrous mesh for the making up of the young vascular connective tissue or granulation. The reticulum of matured collagen fibres in the granulation furnishes the fibrous union more secure than the fibrinous union for effectively sealing the transmucosal junction, as well as for stronger implant retention by early chelation. Polypeptides (collagen), enzyme, clotting factors, growth factors, fibrin, all of them proteins, including other amino acids and polysaccharides in the tissue fluid are noteworthy chelators affording excellent ligands for titanium cat-ions [2,3,4,5]. Fibroblasts also produce glycoproteins and polysaccharides for the ground substance, a gel-like material that surrounds collagen fibres forming the "extracellular matrix". Initially, the collagen fibrils lie indiscriminately but later become oriented along lines of stress to provide maximal strength [1]. Collagen fibers were thus found to be laid parallel to the implant surface, the alignment of the HA crystals in the collagenous matrix being also parallel to the collagen fibres [6].

THE OSSEOUS GRANULATION

As much as fibroblasts are mesenchymal and primary for tissue repair, so also are osteoblasts mesenchymal and repairing cells in the bone marrow. In the present case of implant taking, by regeneration with pro-osteoblasts in the marrow healing is taken place in the osteoblast granulation in place of fibrous granulation, so that retention of implant is resulted in osseous union in place of fibrous union.

The granulation tissue typically composed of

endothelial cells, macrophages and fibroblasts in the regular picture, now taking place in the bone marrow, is predominated by osteoblasts additional to fibroblasts. It could be the promonocytes in the bone marrow, those primitive mesenchymal cells which are the precursors of different cells like histiocytes, Kupffer cells, and other several variants of tissue macrophages, as well as for the mesenchymal cells in the genesis of new bone on the implant surface. Settling according to the requirements in the varying tissues, embryonic precursor cells or stem cells for pro-osteoblasts, apparently, have no other more appropriate origin.

Pro-osteoblasts, pre-osteoblast, osteogenic cells, osteoblasts progenitors and mesenchymal stem cells, inferred as precursor cells are apparently all intended and implied for the procreation of osteoblasts. For regeneration around the implant, there is no total dependence upon such cells to be migrated from afar; local alveolar marrow cells in the immediate vicinity are rapidly proliferated and differentiated in urgent response to meet the emergency demand by mitosis and lateral extensions (or thigmotaxis).

MACROPHAGE TAKEN PART IN EARLY CHELATION

By acute inflammatory response to osteotomy, due to active amines (like histamine) and polypeptides (e.g.: bradykinin) released particularly from cytoplasmic granules of mast cells most prevalent in the oral mucosa [7], the neutrophils are the earliest to extravasate to be closely followed and dominated by the macrophages in directional locomotion known as chemotaxis.

As early as the initial fibrinous retention by chelating proteins in the fibrin platelet network, macrophages have been recognized to be extensively involved around the implant, presumably by virtue of their surface proteins chelating with titanium cat-ions, this bonding property being interpreted as extensive adhesions of macrophages to retrieved implant surface [8].

In nature, virtually all biochemicals exhibit the ability to dissolve certain metal cat-ions [2,3,4,5]. Organic compounds such as collagen, glycoproteins, polypeptides, enzymes, and all other extracellular proteins are typical chelators for the titanium surface, for which property the surface characteristics have been taken to be promoted by "adhesive proteins" [9,10].

THE TREND:

The tissue-component of the interface being thus naturally favorable with its labile parenchymal cells and the chelating matrix, attention has now turned upon treating the metal component of the interface. Other than the various elaborations on designs, the interface particularly has been modified to become rougher and broader, additional to the various treatments to promote the surface properties [9, 10, 11, 12, 13].

Implant- Matrix-Osteoblast Bond

For all the three forces retaining the dental implant, adhesion, adaptation and chelation, the matrix is essentially mediated. Put in the simplest comparison, it is like the bonding agent between the tooth and the composite filling material.

Once the osteoblasts have differentiated in the matrix, the scaffold of vascular granulation regresses, the healing process sets in, and the osseous matrix begins to condense by mineralization with calcium phosphates in the presence of alkaline phosphatase.

The osteoblasts now organically integrated with the mineralized matrix constitute the osseous matrix, establishing the tissue component of interface to be chelated, adapted, or adheased to the metal component of the implant. Entangled contact between the mineralized bone tissue and the laser-modified surface exhibiting calcium, phosphorous, titanium and oxygen in coexistence [6], might be taken as a clear depiction of chelation.

Conclusion and expectations

Virtually all biochemical have been said to display the ability to dissolve certain metal cat-ions. It is the proteins in the matrix that afford excellent ligands in chelating the titanium surface, as well as mediate for adhesion and adaptation. For each of the properties of all three forces of retention to become more versatile, the metal components of the interface remains to be modified. Whilst the surface topography is for all the three forces a deciding factor, the chemical properties in the surface are apparently of particular concerns for chelation. To this end the titanium surface have undergone various elaborations beginning with etching, blasting, pitting, beading, coating, spraying, although as yet not able to conclude which combination should be the best. With awareness or not, all attempts are apparently in the direction to promote the metal cat-ions on the interface to enhance the bonding of ligands.

Chelation (Greek chele = claw) or clawing apparently is the strongest force for implant retention; manifest in the findings, **osseointegration** is the basically a phenomenon of osseochelation. In support for this claim, the following finding should be most noteworthy across the implant literature. It was found that platelet adhesion was higher with smoother surfaces, but reduced with rougher surfaces, while most significantly, their degranulation was reduced with smoother but near 100% with roughened surfaces [14]. In spite of the lesser adhesion by rougher surfaces, the well established superior retention of blasted/etched implants then must possibly be due to the highly elevated production of chelators by the nearly 100% platelet degranulation. The broadened surface area afforded by roughening procedures, besides promoting adhesion and adaptation, would also most effectively extend a wider access for greater dissolution of titanium cat-ions. Three dimensional images have clearly depicted the bonding [15]. Effort might be appropriately put more in this direction for elaborating the titanium interface to promote

chelation. Short courses on dental implantology, in vogue these days, additional to focusing on know-how techniques and products, should count in certain of such basic sciences for their fundamentals contributory to perceiving how implants are taken and how they remain retained so that new comers as well might be encouraged to pursue what areas to elaborate upon.

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