Osseointegration- The Backbone of Implant Dentistry

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Introduction

The ideal goal of modern dentistry is to restore the patient to normal contour and function.Implant dentistry is unique because of its ability to achieve this goal regardless of the stomatognathic system. The primary function of an implant is to act as an abutment for prosthetic device and the present surge in the use of implants was initiated by Branemark (1952)which was coined as the term Osseointegration, (Fig No. 1)The word osseointegration consists of "os", the latin word for bone and "integration", the latin word for the state of being combined into a complete whole.

History & Definition

The concept of osseointegration was developed and the term was coined by Dr. Per-Ingvar Branemark, 1952.Professor at the institute for Applied Biotechnology, University of Goteborg, Sweden.Initial concept of osseointegration stemmed from vital microscopic studies of microcirculation in bone repair mechanisms in 1952, implant clinical studies in humans began in 1965, were followed for 10 years and were reported in 1977.[1]

The term Osseointegration (rather than bone fusing or ankylosis)as defined by Brånemarkis a direct contact of living bone with the surface of an implant at the light microscopic level of magnification.[2]The terms bone fusing, ankylosis and osseointegration may be interchangeable and may address the microscopic bone-implant interface. American Academy of Implant Dentistry (1986) defined it as "contact established without interposition of non bone tissue between normal remodeled bone and on implant entailing a sustained transfer and distribution of load from the implant to and within bone tissue".

Albrektssonet al. (1981)[3] suggested that this was "a direct functional and structural connection between living bone and the surface of a load carrying implant". Clinical definition was provided by Zarb and Albrektsson (1991)[4] who proposed that osseointegrationwas "a process whereby clinically asymptomatic rigid fi xation of alloplastic materials is achieved and maintained in bone during functional loading".Schroeder et al. (1995)[5] used the term "functional ankylosis" to describe the rigid fixation of the implant to the jaw bone, and stated that "new bone is laid down directly upon the implant surface, provided that the rules for atraumatic implant placement are followed (rotation of the cutting instrument and less than 800 rpm, cooling with sterile physiologic saline solution) and the implant exhibits primary stability".

Development of the Concept of Osseointegration

Based on the foundation for Osseo integration, the Branemark implant system was established in 1952.Studies on humans were conducted by means of an implant optical titanium chamber in a twin pedicle skin tube on the inside of the left upper arm of volunteers.[6] Tissue reactions were studied in long term experiments and all this lead to the treatment of first edentulous patient in 1965.

The implant material (Titanium) is an important factor for Osseo integration to occur at the bone to implant interface. Two basic theories were proposed as a result of this

- Fibro-osseous integration (Fig No 2) by Linkow(1970), James(1975)& Weiss (1986)[7]
- Osseointegration by Branemark 1952[8]

American Academy of implant dentistry (1986) defined fibrous integration as tissue to implant contact with healthy dense collagenous tissue between the implant and bone.The fibers are arranged irregularly, parallel to the implant body, when forces are applied they are not transmitted through the fibers.So no bone remodeling expected in fibro-integration. A direct bone implant interface occurs when an implant is allowed to heal in bone undisturbed which will result in Osseointegration.

Biological Process of Implant Osseo-integration

The healing process of implant system is similar to primary bone healing.Titanium dental implants show three stages of healing.[9]

- OSTEOPHYLLIC STAGE
- OSTEOCONDUCTIVE STAGE
- OSTEOADAPTATIVE STAGE

Osteophyllic Stage

When a implant is placed into the cancellous marrow space blood is initially present between implant and bone.Only a small amount of bone is in contact with the implant surface; the rest is exposed to extracellular fluids. By the end of first week, inflammatory cells are responding to foreign antigens. Vascular ingrowth from the surrounding vital tissues begins by third day.A mature vascular network forms by 3 weeks. Ossification also begins during the first week and the initial response observed in the migration of osteoblasts from the trabacular bone which can be due to the release of BMP's.

The osteophyllic phase lasts about 1 month.

Osteoconductive Phase

Once they reach the implant, the bone cells spread along the metal surface laying down osteoid. Initially this is an immature connective tissue matrix and bone deposited is a thin layer of woven bone called foot plate.Fibro-cartilaginous callus is eventually remodeled into bone callus.

This process occurs during the next 3 months

Four months after implant placement the maximum surface area is covered by bone.

Osteoadaptive Phase

The final phase begins approximately 4 months after implant placement. Once loaded implants do not gain or loose bone contact but the foot plates thicken in response and some reorientation of the vascular pattern may be seen.Grafted bone integrates to a higher degree than the natural host bone to the implant.

To achieve optimal results an osseointegration period of 4 months is recommended for implants in graft bone and 4 to 8 months for implant placed in normal bone.

Osseointegration- communication of cells

The molecular and cellular events duringthe healing of an osseous wound after installation of a dental implant with special emphasis on the process of osseointegrationhas been studied in dogs and in humans.The concept of the four phases of a healing soft tissue wound was transferred to a bone wound after insertion of a dental implant: haemostasis, inflammatory phase, proliferative phase and remodelling phase.[10] Wound healing throughout these phases is the result of a coordinated action of different cell types (erythrocytes, inflammatory cells, fibroblasts, osteoblasts, osteoclasts) which communicate with each other by their interaction using signalling molecules like cytokines, extracellular matrix proteins and hormones like prostaglandin, steroid hormones and histamines. A regular sequence of cell types controlled byadequate concentrations of signalling molecules results in undisturbed healing. Disturbed healing is associated with a continuation of the early inflammatory phase and the development of a toxic wound environment.[11]The latter is characterized by high counts of polymorphnuclear cells, high concentrations of toxic radicals and proteolytic enzymes and low concentrations of growth factors and extracellular matrix molecules.

Factors affecting osseointegration

Various factors may enhance or inhibit osseointegration. Among them implant design, early loading, biomaterial and its biocompatibility, surface treatment of implants and systemic diseases are pivotal.

Factors enhancing osseointegration

Factors enhancing osseointegration include implant-related factors such as implant design and chemical composition,topography of the implant surface, material, shape, length, diameter, implant

surface treatment and coatings[12], the status of the host bone bed and its intrinsic healing potential, the mechanical stability and loading conditions applied on the implant, the use of adjuvant treatments such as bone grafting, osteogenic biological coatings and biophysical stimulation[13], and pharmacological agents such as simvastatin and bisphosphonates.

Factors inhibiting osseointegration

Factors inhibiting osseointegration include excessive implant mobility and micromotion, inappropriate porosity of the porous coating of the implant, radiation therapyand pharmacological agents such as cyclosporin A,methotrexate and cis-platinum, warfarin and low molecular weight heparins, non-steroid anti-inflammatory drugs especially selective COX-2 inhibitors41,42, and patients' related factors such as osteoporosis, rheumatoid arthritis, advanced age, nutritional deficiency, smoking and renal insufficiency.[13]

Implant design

The implant body design is responsible for transmitting the occlusal stress of the prosthesis to the supporting bone.There are more than 90 dental implant body designs available. An implant has a macroscopic and microscopic body design to implant design. The former is important during initial implant healing and the initial loading period and the latter during early loading and mature loading period. Implants may be cylindrical or screw shaped. They may be threaded or nonthreaded.(Fig No.3) Bone resorption has been associated with the use of press fit or cylindrical implants primarily due to micromovements that occur during their use. This problem is more or less eliminated when screw shaped implants are used. Threaded implants have a long documentation of successful use in dentistry. The advantage of threaded implants is that they provide more functional surface area for better load distribution. Furthermore, there is lesser micromovement seen in association with these implants.[14]

Early loading

An implant within normal limits appear to be in rigid fixation but may fail shortly after it has initially 'integrated' to the bone once the implant is loaded within 6 to 18 months, this is called early loading failure by Misch and Jividen2000,[15] early loading failure is related to the amount of force applied to the prosthesis and the density of the bone around the implant and it affects 15% of the implant restorations Early loading failure from biomechanical overload, as high as 40% has been reported in the softest bone types.results from animal model studies concluded that biomechanical occlusal stress was a greater risk factor for early implant failure than the biological component of bacterial plaque.[16]

Biomaterial and its biocompatibility

Titanium is a metal that is

- Low weight
- High strength/weight ratio
- Low modulus of elasticity
- Increased corrosion resistance
- Easy to shape and finish

It has been stated that osseointegration of titanium does not result due to a positive tissue reaction, instead it occurs in the absence of a negative tissue response.[17]Therefore, the bioinert character of titanium is the main reason of its enhanced bone bonding behaviour. Now, osseointegrationof titanium is widely accepted as the prerequisite for dental implant success in dentistry.Success rates are higher than 90% in controlled clinical trials.[18]The surface is composed of an oxide layer with a reported nonstoichiometric composition of TiO2, TiO, and Ti2O3 depending on the methods of preparation.Therefore the biocompatibility of titanium is therefore the result of the chemical stability and corrosion resistance of its dense and protective oxide film.

Surface treatments of implant

It is thought that cp Ti owes its ability to form an osseointegrated interface to the tough and relatively inert oxide layer, which forms very rapidly on its surface. This surface has been described as osseoconductive, that is, conducive to bone formation. Other substrates also have this property and may also stimulate bone formation, a property known as osseoinduction. The surface of a titanium implant plays a crucial role in determining the biological response of the host bone. For enhancing the biomechanical anchorage of the implant and for promoting osseointegration at the histological level, the modification of surface topography or the coating of titanium with bioactive materials has captured the interest of many scientists, clinicians, and manufacturers as well (Oshida, 2007).[19] Commonly used techniques to alter surface properties of titanium are: Sand-Blasting, Acidetching,Plasma Spraying, Electropolishing, Hydroxylapatite (HA), Calcium Phosphate (Cap) and Oxidation, coatings.

Radiographic assessment of osseointegration

Evaluation of osseointegration can be made by use of clinically and histologically, radio graphically and by RFA

- OPG
- CT
- Denta-Scan
- RFA(Resonance Frequency Analysis)

Clinically observed osseointegration corresponds to 60-80% of bony contact histologically (Albrektsson et al 1993).[20]The proportion of bone to metal contact varies with the material and design of the implant, the state of the host, the surgical technique, the loading conditions, and time. In practice the degree of osseointegration histologically cannot be determined so assessment is based on the clinical stability of the implant and radiographic evaluation.Loss of osseointegration is manifested as implant mobility and peri-implant radiolucency. In the post operative radiographs the marginal bone level is compared with radiographs taken immediately following implant placement (baseline). A thin perifixtural radiolucency surrounding the entire implant, suggests an absence of direct bone-implant contact. Increased marginal bone loss or "saucerization" can also be a sign of failure (Esposito et al 1998).[21]

Resonance Frequency Analysis

Meredith et al. (1997)[22]used Resonance Frequency Analysis to assess bone formation around an implant. In this technique a transducer is attached to the implant fixture. The resonance frequency reflects the stiffness in relation to the surrounding bone, amplifying with the increased height of the bone around the implant. Thus, the resonance frequencies are a function of the interface biology and implant stability, and not a true function of osseointegration per se.

Conclusion and future aspects

The interaction between the osseointegrated fixture bone tissue, receptor systems and nervous system has been studied.The identification of osseoperception as a phenomenon of osseointegration was the result of work carried out in the dental sciences by TorgnyHaraldson. In 1979, T Haraldson[23] characterized the sensory feedback in patients with osseointegrated bridges and concluded, "Patients with osseointegrated bridges have been restored to a level of functional capacity of the masticatory system equal to that in individuals with a natural but reduced dentition of the same extension as in the osseointegration group." Implant osseointegration is probably one of the most pivotal molecular and functional aspect in successful implant therapy which involes the role of various cell interaction and factors enhancing the bone implant contact to provide an osseo-integrated structure.Future studies can utilize the cell culture environment to investigate the mechanisms by which topographic cues influence adherent cell behavior related to the process of osseointegration.

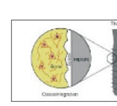

FIG. 1

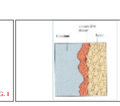

FIG. 2

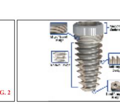

FIG. 3

Reference

References are available on request at **editor@healtalkht.com**