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Osteointegration in Implant-A Review

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Abstract

Osseo-integration of dental implants refers to the process of bone growing right up to the implant surface. No soft tissue connects the bone to the surface of the implant. No scar tissue, cartilage or ligament fibers are present between the bones and implant surface. The direct contact of bone and implant surface can be verified microscopically. When Osseo-integration occurs, the implant is tightly held in place by the bone. The process typically takes four to six months to occur well enough for the implant dentist to complete the restorations. This article provides a comprehensive review of osseo integration in dental implants.

Keyword: Osseo integration, Osseo densification, Implants, Bone

Introduction

Osseo-integration is also defined as: "the formation of a direct interface between an implant and bone, without intervening soft tissue". Osseo integrated implant is a type of implant defined as "an end steal implant containing pores into which osteoblasts and supporting connective tissue can migrate". Applied to oral implantology, this thus refers to bone grown right up to the implant surface without interposed soft tissue layer. No scar tissue, cartilage or ligament fibers are present between the bones and implant surface. The direct contact of bone and implant surface can be verified microscopically.

Osseo integration may also be defined as:

1. Osseous integration, the apparent direct attachment or connection of osseous tissue to an inert alloplastic material without intervening connective tissue.
2. The process and resultant apparent direct connection of the endogenous material surface and the host bone
3. Tissues without intervening connective tissue.
4. The interface between allo plastic material and bone.[1,2]

History

Osseo integration was first observed—albeit not explicitly stated—by Bothe, Beaton, and Davenport in 1940. Bothe et al. were the first researchers to implant titanium in an animal and remarked how it had the tendency to fuse with bone. Bothe et al. reported that due to the elemental nature of the titanium, its strength, and its hardness, it had great potential to be used as future prosthesis material. Osseo integration was later described by Gottlieb Leventhal in 1951. Leventhal pla ced titanium screws in rat femurs and remarked how "At the end of 6 weeks, the screws were slightly tighter than when originally put in; at 12 weeks, the screws were more difficult to remove; and at the end of 16 weeks, the screws were so tight that in one specimen the femur was fractured when an attempt was made to remove the screw. Microscopic examinations of the bone structure revealed no reaction to the implants. The trabeculation appeared to be perfectly normal." The reactions described by Leventhal and Bothe et al. would later be coined into the term "osseo integration" by Per-Ingvar Brånemark of Sweden. In 1952, Brånemark conducted an experiment where he utilized a titanium implant chamber to study blood flow in rabbit bone. At the conclusion of the experiment, when it became time to remove the titanium chambers from the bone, he discovered that the bone had integrated so completely with the implant that the chamber could not be removed. Brånemark called this "osseo integration", and, like Bothe et al. and Leventhal before him, saw the possibilities for human use.(fig.1)

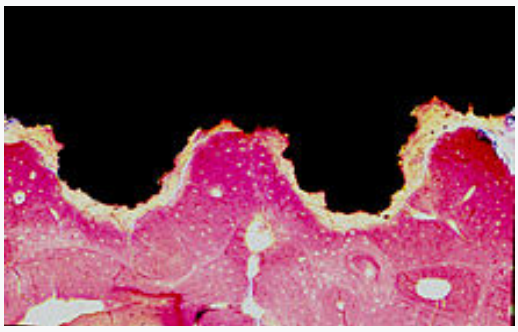


Figure 1: Titanium implant (black) integrated into bone (red): Histological section

In dental medicine the implementation of osseo integration started in the mid-1960s as a result of Brånemark's work. In 1965 Brånemark, who was at the time Professor of Anatomy at the University of Gothenburg, placed dental implants into the first human patient – Gösta Larsson. This patient had a cleft palate defect and required implants to support a palatal obturator. Gösta Larsson died in 2005, with the original implants still in place after 40 years of function.

In the mid-1970s Brånemark entered into a commercial partnership with the Swedish defense company Bofors to manufacture dental implants and the instrumentation required for their placement. Eventually an offshoot of Bofors, Nobel Pharma, was created to concentrate on this product line. Nobel Pharma subsequently became Nobel Biocare.

Brånemark spent almost 30 years fighting the scientific community for acceptance of osseo integration as a viable treatment. In Sweden he was often openly ridiculed at scientific conferences. His university stopped funding for his research, forcing him to open a private clinic to continue the treatment of patients. Eventually an emerging breed of young academics started to notice the work being performed in Sweden. Toronto's George Zarb, a Maltese-born Canadian prosthodontist, was instrumental in bringing the concept of osseointegration to the wider world. The 1983 Toronto Conference is generally considered to be the turning point, when finally the worldwide scientific community accepted Brånemark's work. Today osseointegration is a highly predictable and commonplace treatment modality. More recently since 2010 Al Muderis in Sydney Australia utilized a high tensile strength titanium implant with high prose plasma sprayed surface as an intramedullary prosthesis that is inserted into the bone residuum of amputees and then connect through an opening in the skin to a robotic limb prosthesis. This allows amputees to mobilize with more comfort and less energy consumption. Al Muderis also published the first series of combining osseointegration prosthesis with Joint replacement enabling below knee amputees with knee arthritis or short residual bone to mobilize without the need of a socket prosthesis.[2-6]

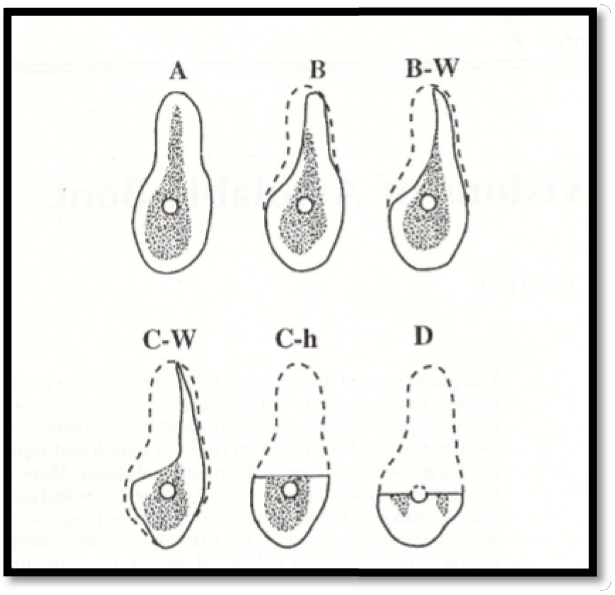
Mechanism

(A) Biological structure creating biologic seal following surgical placement of an implant.

1. Epithelial cell with cell membrane
2. Basal lamina outside cell membrane
   - Lamina Lucida
   - Lamina Densa
   - Sub lamina Lucida
3. Hemidesmosomes on cell membrane
   - Peripheral densities
   - Pyramidal particles
   - Fine filaments
4. Linear body on implant face

(B) Bones are organ because they are functionally related to group of tissues. Each bone has a unique form and function. Specific combination of mineralized tissue types, periosteum, cartilage, marrow, vasculature, nerves, tendons and ligaments fulfill to a particular role in mechanical support and metabolism.

Classification [10]-according to Carl. Meisch (Fig.2).



Osseous tissue is formed in a number of configurations. Depending on age, function and physiologic history, bones are composed of four microscopic tissues types: woven, lamellar, bundle and composite bone.

1. Woven Bone: - is highly cellular osseous tissue that is formed rapidly (30 to40µm/day or more) in response to growth or injury. Compared with mature bone, it has relatively low mineral content, a more random fiber orientation, and mineral strength .It serves a major role in initial healing of end osseous implants.

2. Lamellar Bone: - Lamellar bone is the principal load bearing tissue of the adult skeleton. It is the predominant component of mature corticated trabecular bone. In adults, lamellae are formed relatively slowly (<1.0µm/day), have a highly organized matrix, and a densely mineralized. Lamellar bone is histologically regardless of the age at which it is formed.

3. Bundle Bone:-Is characteristic of ligaments and tendon attachments along bone forming surface. Striations are oriented across the underlying lamellar pattern. These striations are extensions of sharpey's fibers composed of collagen bundles from adjacent connective tissue that insert directly into bone. Bundle bone is well known in dentistry because it is formed adjacent to periodontal ligaments of physiologically drifting teeth.

4. Composite Bone:-Is lamellar bone deposited on woven bone matrix. During rapid growth and wound healing, a highly porous, woven bone lattice grows out and captures blood vessels along an endosteal or periosteal surface. The woven lattice then fills the par vascular space with high quality lamellae, resulting in composite bone with adequate strength for load bearing.[1]

Physiologic Adaptation:

Modeling is a surface-specific activity that produces a net change in the size and/or shape of a bone. It is an uncoupled process, meaning that cell activation (A) proceeds independently to formation (F) or resorption (R).The definition considers compacts and trabecular bone as blocks of the tissue. It refers to a generalized change in overall dimensions of a bone's cortex or spongiosa. Modeling is the fundamental mechanism of growth, atrophy, and reorientation.

Remodeling is defined as turnover or internal restructuring of previously existing bone. It is a coupled tissue level phenomenon. Activation (A) of osseous precursor cells results in a sequence of:

(1). active resorption (R);
(2). quiescence or reversal (Q); and
(3). Formation (F).

The duration of the A R (Q) F remodeling cycle (also referred to as "sigma") is about 6 weeks in rabbits, 12 weeks in dogs, and 17 weeks in human [1].

Bone to Implant Interface

There are two basic theories regarding the bone-implant interface.

I. Fibro-osseous integration supported by Linkow (1970), James (1975), and Weiss (1986) , In 1986, the American Academy of Implant Dentistry defined fibrous integration as “tissue-to-implant contact with healthy dense collage nous tissue between the implant and bone” . In this theory, collagen fibers function similarly to Sharpey’s fibers in natural dentition. The fibers affect bone remodeling where tension is created under optimal loading conditions (Weiss, 1986).

It is not accepted now as no sharpey’s fibers are present between the bones and implant so it is difficult to transmit the loads. Therefore, bone remodeling cannot be expected to occur in fibroosseous integration.

II. Osseo integration supported by Branemark (1985) . This was first described by strock as early as 1939 and more recently by Brenamark et al in 1952. Branemark theorizes that the implant must be protected and completely out of function, as his envis ions a period of healing of at least 1 year, in which new bone is formed close to the immobile resting implant.

Meffert, et al (1987) redefined and subdivided osseo integration into

Adaptive osseointegration: has osseous tissue approximating the surface of the implant without apparent soft tissue interface at the light microscopic level

Biointegration: is a direct biochemical bone surface attachment confirmed at the electron microscopic level. [4-8]

Similar to fracture healing, a bridging callus forms at the preiosteal and endosteal surfaces (Fig.1 and 2).

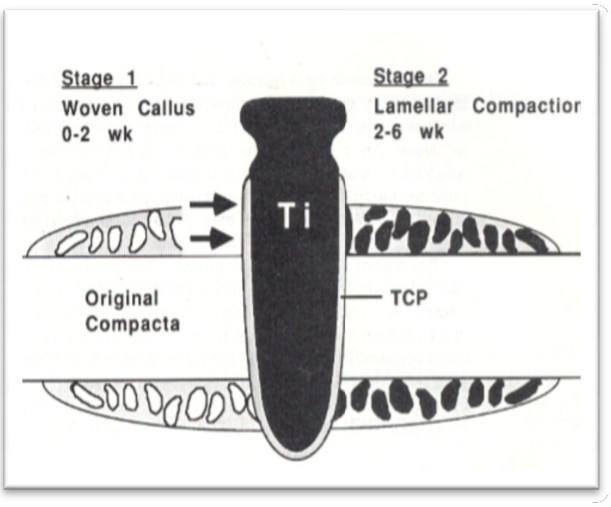


Figure 3: Initial stages of implant healing and interface development are shown in computer generated drawing of tricalcium phosphate (TCP)-coated implant in rabbit compacta. Woven callus being formed during Stage1 (0 to 2 weeks). Stage2 (2 to 6 weeks) is period of lamellar compaction when callus matures and archives sufficient strength for loading. Based on extrapolation from remodeling cycle durations in rabbits, Stages 1 and 2 in humans are completed I 6 to 18 weeks respectively. I Titanium.

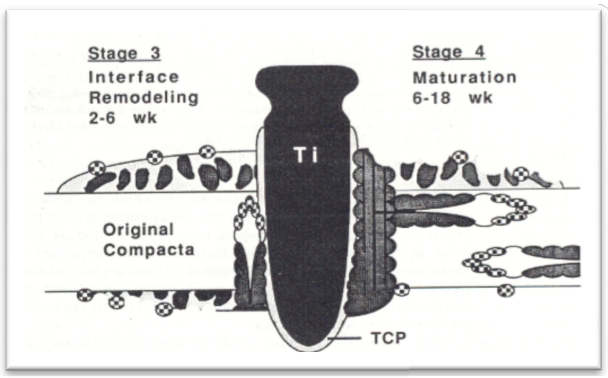


Figure 4:-Stage 3 (2 to 6 weeks) begins at same time callus is completing lamellar compaction (Stage 2), but it is morphologically distinct series of events. Callus starts to resorb and remodeling of devitalized interface begins. In all studies to date, cutting heads penetrate from endosteal surface. During Stage 4 (6 to 18 weeks) compacta matures by series of modeling and remodeling processes: interface remodels; and callus completes resorbtion (modeling).Extrapolation of human equivalents from duration of rabbit remodeling cycle indicates that , in man Stages 3 and 4 are complete in 18 and 54 weeks, respectively. TCP, Tri-calcium Phosphate; Ti, titanium.

Table 1: Time course of interface development for end osseous implants in cortical bone [1]

	RABBIT	HUMAN (3X)
Surface Modeling		
Stage 1: woven callus	2 Week	6 Week
Stage 2: lamellar compaction	6 Week	18 Week
Remodeling, Maturation	6 Week	18 Week
Stage 3: interface remodeling	18 Week	54 Week
Stage 4: compacta maturation		

Factors for Reliable Osseo integration (Albrektsson, 1983):

1) Implant Biocompatibility:

a) Metals like commercially pure (c.p) titanium, niobium and possibly tantalum are most well accepted in bone as they are covered with a very adherent, self-repairing and corrosion resistant oxide layer.

b) Metals like cobalt-chrome-molybdenum alloys, stainless steels & titanium alloys are less well tolerated by bone.

c) Ceramics like calcium phosphate hydroxyapatite (HA) and various types of aluminum oxides are proved to be biocompatible but due to insufficient documentation and very less clinical trials, they are less commonly used.

2) Implant Design

a. Threaded implants provide more functional area for stress distribution than the cylindrical implants and provide better primary anchorage.

b. V-shaped threads transfer the vertical forces in an angulated path, and thus may not be as efficient in stress distribution as the square shaped threads.

c. Longer the length, better the primary stability. Shorter implants (10 mm or less) are associated with increased bone loss.

d. Wide diameter implants exert less stress on crestal bone as compared to narrow implants.

e. Providing micro threads in implant neck, helps to maintain marginal bone as these threads anchor in the bone. Whereas a smooth machined neck is associated with greater bone loss.

f. Platform-switching concept also preserves the crestal bone and prevents bone loss. This design uses a narrow diameter abutment over a wide diameter implant.

g. Advantages of one-piece implant over two-piece implants are elimination of Implant-abutment junction maximizes strength, eliminates micro movement, and also eliminates the bacterial penetration which might occur at the implant-abutment junction in 2-piece implants.

h. Providing a Morse taper in 2-piece implant systems has reduced the potential bacterial penetration at the junction.

3) Implant Surface

a) Surface topography relates to degree of roughness of the surface and the orientation of surface irregularities

b) Advantages of increased surface roughness

c) Increased surface areas of the implant to bone so in- creased bone at implant surface.

d) Increased biomechanical interaction of the implant with bone.

e) Smooth surfaces do not result in an acceptable bone cell adhesion and clinical failure would be prone to occur.

4) State of the Host Bed

a) Poor bone bed because of

I. Previous irradiation: - not an absolute contraindication implants. However some delay is preferable before implant placement.
II. Low ridge height and resorption and Osteoporosis: - an indication for ridge augmentation with bone grafts before / during implant placement.
III. Infection
IV. Poor bone quality: - As stated by Branemark et al. and Misch, D1 and D2 bone densities shows good initial stability and better osseointegration while D3 and D4 shows poor prognosis.

5) Surgical Considerations

a) Optimum surgical technique to promote regenerative type of the bone healing rather than reparative type of the bone healing (Erickson R.A)
b) Use of well-sharpened and graded series of drills.
c) Adequate cooling. Critical time / temperature relation- ship for bone tissue necrosis is around 470C applied for one minute.
d) Slow drill speed (less than 2000 rpm and tapping at a speed of 15 rpm with irrigation).
e) A moderate power used at implant insertion

6) **Loading Conditions**

a. Premature loading will lead to soft tissue anchorage and poor long-term function, whereas postponing the loading by using a two stage surgery will result in bone healing and positive long term function.

Some Other Factors Affecting the Osseo integration

1. **Uncontrolled diabetes:-** delayed wound healing in these patients inhibit osseointegration

2. **Smoking:-** associated with more bone loss and the risk of failure is increased by almost 250% (Wilson and Nunn)

3. **Extremes of age:-**

a. Advanced age is a potential risk factor

b. In too young, the ankylosed devices introduce problems in growing jaws.[5-10]

Success Criteria for Osseo integrated Implants

Smith D.E et al. Examined the possible criteria for implant success in the light of available supporting studies for implant success

Consideration should be given to evaluating the following criteria:

a. Durability
b. Bone loss
c. Gingival health
d. Pocket depth
e. Effect of adjacent teeth
f. Function
g. Esthetics
h. Presence of infection, discomfort, paresthesia or anesthesia
i. Intrusion on the mandibuar canal
j. Patient emotional and psychological attitude

Revised criteria for implant success

1. Individual unattached implant is immobile when tested clinically.

2. No evidence of per implant radiolucency is present as assessed on an undistorted radiograph.

3. Mean vertical bone loss is less than 0.2 mm after 1st year of service.

4. No persistent pain, discomfort or infection.

5. A success rate of 85% at the end of a 5-year observation period and 80% at the end of a 10-year period are minimum levels of success.[3-4]

Conclusion

Physiologic principles govern all aspects of implant healing and long term function. An understanding of fundamental bone physiology, metabolism, and biomechanics is essential for clinicians placing and restoring these devices. A thorough physiologic assessment of the patient and the implantation site is an important part of the diagnostic process. Basic science information regarding the healing mechanism of bone in response to implantation is well known. However, definitive studies evaluating the long-term dynamic response of bone to various implant materials and designs are necessary. In particular, a carefully controlled study is needed in which biomechanical and biomaterial properties can be compared with the histogic response resulting from basic from basic differences in implant design and composition. Finally, studies manipulating the remodeling rate of bone are needed to investigate the underlying role of this process in maintaining a vital bone-to-implant interface.

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