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Osseointegration in Dental Implants: A Literature Review

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ABSTRACT *Osseointegration 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 Osseointegration 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 osseointegration in dental implants*

INTRODUCTION:
The word osseointegration consists of "os" the Latin word for bone and "integration" derived from the Latin words meaning the state of being combined into a complete whole. The successful management of implant dentistry depends on the meticulous diagnostic, planning and surgical skills of the operator.

HISTORY:
Professor Per-Ingvar Branemark (1952) working in the laboratory of the vital microscopy, University of Goteberg, Sweden, accidentally discovered that titanium bonded well with bone; a phenomenon which was later termed as osseointegration [1]. Branemark defined it "as a direct contact between the bone and metallic implants, without interposed soft tissues layers" (1969). Later it was modified "as a direct structural and functional connection between ordered, living bone and the surface of a load carrying implant" [2, 3].

In 1970s, there were no methods available to section intact bone to metal specimens [2]. Therefore, the histologic evidence of osseointegration remained indirect. The first investigator to clearly demonstrate osseointegration was Schroeder from Switzerland [2, 4] by using new techniques to section bone-implant specimens. They termed this union as functional ankylosis.

Adell et al in 1981 [3] reported a success rate of 80-100 per cent after a fifteen-year study of osseointegrated implants in the treatment of edentulous jaws.

Misch Bone Density Classification (1988)[5] [Figure 1]
- D1: Dense cortical bone
- D2: Thick dense to porous cortical bone on crest & coarse trabecular bone within.
- D3: Thin porous cortical bone on the crest and fine trabecular bone within.
- D4: Fine trabecular bone
- D5: Immature, non-mineralized bone.

Studies of the Branemark System over the last 20 years have shown a 10% higher implant failure rate in soft maxillary bone in comparison to the dense bone of the mandible [4].

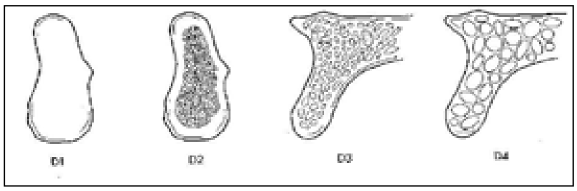

Figure 1:- Misch bone density classification

HEALING OF DIFFERENT BONE DENSITIES [5]:

1. D1 bone:
a. D1 bone is usually found in anterior mandible.
b. Because of poor blood circulation, the cortical bone requires greater healing time compared with trabecular bone.
c. Healing occurs by formation of lamellar bone interface (forms slowly at 0.6 microns per day) rather than woven bone (forms rapidly at 80 to 50µm/day) after the initial trauma. Therefore, for complete regeneration of vital bone in this dense structure, 5 months healing time may be required.
d. However because of the load bearing capability of bone and the excellent bone implant contact, prosthetic loading of D1 bone start at very early stage.
e. Bone-implant contact (BIC) =80%.

2. D2 bone
a. Usually found in anterior and posterior mandible.
b. The excellent blood supply of trabecular bone and rigid initial fixation permits adequate bone healing within four months.
c. BIC = 70%

3. D3 bone:-
a. Usually found in anterior maxilla
b. The time frame for automatic healing is approximately 6 months. The actual implant interface develops more rapidly than D2 bone; however the extended time permits the regional acceleratory phenomenon (RAP) from implant surgery to stimulate the formation of more trabecular bone. More advanced bone mineralization in extra 2 months also increases its strength before loading.

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c. BIC = 50%

4. D4 bone
a. Usually found in posterior maxilla
b. The healing and progressive bone loading sequence for D4 bone requires more time than any other three types D1, D2 and D3. Time is needed not only to allow the bone to remodel at the surface but also required for more advanced bone mineralization and increased strength. Hence eight months of undisturbed healing period is suggested.

Fugazzotto P. A et al. [6], demonstrated the efficacy of cylinder implant used in D4 bone. It was documented that implant success rates were much lower in D4 bone than in D1, D2 and D3.

Early Tissue Response To Osseointegrated Implants:
The various steps used in the surgical procedure cause mechanical insults & injury to both the mucosa and the bone tissue [7]. The damage to the soft and hard tissue initiates the process of wound healing which ultimately allows the implant to become "ankylotic" with the bone, i.e. osseointegrated.

Lioubavina N et al [8] investigated the influence of initial implant stability on osseointegration between titanium dental implants and new bone generated by GTR and found that no osseointegration was observed between the newly formed bone and the non-stabilized implants at any observation time.

IMPLANT-BONE INTERFACE
There are two basic theories regarding the bone-implant interface

I. Fibro-osseous integration supported by Linkow (1970), James (1975), and Weiss (1986) [9].
In 1986, the American Academy of Implant Dentistry defined fibrous integration as "tissue-to-implant contact with healthy dense collagenous tissue between the implant and bone" [4]. 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 fibro-osseous integration.

II. Osseointegration supported by Branemark (1985) [5].
This was first described by strock as early as 1939 and more recently by Brenamark et al [2] in 1952. Branemark theorizes that the implant must be protected and completely out of function, as he envisions 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 osseointegration 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.

Factors For Reliable Osseointegration (Albrektsson, 1983) [10]:
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
i. Increased surface areas of the implant to bone so increased bone at implant surface.
ii. Increased biomechanical interaction of the implant with bone.
c. 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 [Figure 2]:
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.

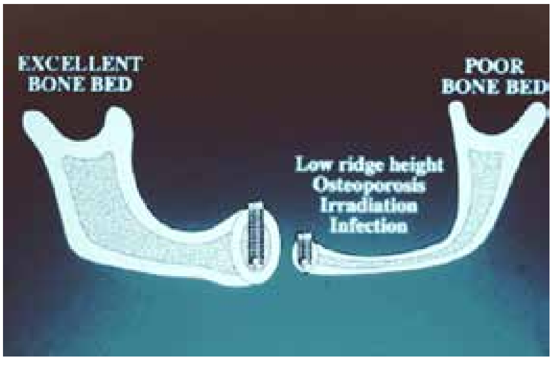

Figure 2:- State of host bed

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5) SURGICAL CONSIDERATIONS [Figure 3]:

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 relationship for bone tissue necrosis is around 47^0C 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

Figure 3:- The optimum surgical technique

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 Osseointegration

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.

SUCCESS CRITERIA FOR OSSEOINTEGRAETD IMPLANTS

Smith D.E et al. [11] 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 [11]:

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 [12]

1. Individual unattached implant is immobile when tested clinically.
2. No evidence of peri implant radiolucency is present as assessed on an undistorted radiograph.
3. Mean vertical bone loss is less than 0.2 mm after 1^{st} 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.

CONCLUSION:

"Osseointegration" is a multifactorial entity. It is because of the attention to training, research & clinical studies that osseointegration has now become an accepted part of the treatment regime in many countries worldwide and no longer regarded as the last resort when all else has failed but often as a treatment of choice.

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