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Osseointegration – A Dynamic Process

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ABSTRACT: The efficacious replacement of lost natural teeth by tooth root analogues i.e. implants is a prime attainment in the field of dentistry, this immensely depends on adequate integration of these implants within the bone. This bone-implant integration is known as osseointegration. The science of osseointegration has become an accepted and proven treatment for edentulism. This paper reviews the concept of osseointegration.
KEY WORDS: Implants, osseointegration, bone-implant interface, bone denstity, Implant stability

I. INTRODUCTION

Dental implants are used as treatment modality for missing teeth owing to the fact that they function as artificial roots onto which a prosthesis may be anchored. [1] The utmost compelling and important advancements in dentistry by Professor Per- Ingvar Branemark and his colleagues was the discovery of osseointegration and its application to clinical dentistry.[2] A poorly organized woven bone is formed that have a somewhat low inherent strength at the interface immediately after insertion of an implant. After a period of 3 to 6 months, woven bone is reintegrated by lamellar bone which acquire sufficient strength for load bearing. This bone healing process is termed as osseointegration. Development of this interface is convoluted and involves diverse factors. These incorporate not only implant related factors and surface chemistry but also surgical technique and bone factors.[3]

II. OSSEOINTEGRATION CAN BE DEFINED AS:

"A direct connection between living bone and a load-carrying endosseous implant at the light microscopic level." –Branemark

1. The apparent direct attachment or connection of osseous tissue to an inert, alloplastic material without intervening fibrous connective tissue;
2. The process and resultant apparent direct connection of an exogenous material's surface and the host bone tissues, without intervening fibrous connective tissue present;
3. The interface between alloplastic materials and bone. -G.P.T. 9

III. HEALING OF DIFFERENT BONE DENSITIES[4]:

Bone density	Location	Features	Ideal healing time	Bone-implant contact
D1 bone (Compact cortical bone)	Anterior mandible	The cortical bone requires greater healing time because of poor blood circulation compared with trabecular bone.	3-4 months	80%

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		Healing occurs by formation of lamellar bone interface		
D2 bone (Thick compact to porous cortical bone on the crest and coarse trabecular bone within)	Anterior and posterior mandible	The excellent blood supply of trabecular bone and rigid initial fixation permits adequate bone healing.	4 months	70%
D3 bone **(**Thin porous cortical bone on the crest fine trabecular bone within)	Anterior maxilla	The actual implant interface develops more rapidly than D2 bone.	6 months	50%
D4 bone (Fine trabecular bone)	Posterior maxilla	The healing and progressive bone loading sequence for D4 bone requires more time than any other three types D1, D2 and D3.	months	<25%

IV. THEORY OF OSSEOINTEGRATION

There are two theories concerning the bone-implant interface :

1. **Fibro-osseous integration** proposed up by Linkow (1970), James (1975), and Weiss (1986).[5]
2. **Osseointegration**supported by Branemark(1985).[4] This was first described by Strock in early 1939 and later by Branemark et al in 1952.

V. STAGES OF OSSEOINTEGRATION

Osseointegration is activated by any lesion of the pre-existing bone matrix, as direct bone healing, occurs in defects. Growth factors and non-collagenous proteins are set free when the matrix is exposed to extra cellular fluid and activate bone repair.[6] Osseointegration follows a common, biologically determined program, once activated. Three stages of osseointegration are as follows:

1. Incorporation by woven bone formation;
2. Adaptation of bone mass to load (lamellar and parallel fibered bone deposition);
3. Adaptation of bone structure to load (bone remodeling).

VI. IMPLANT TISSUE INTERFACE

The tissue-titanium-implant interface may be divided into three main zones.

1. **Implant and bone interface**
2. **Implant connective tissue interface**
3. **Implant epithelial interface**

VII.KEY FACTORS FOR SUCCESSFUL IMPLANT OSSEOINTEGRATION (ALBREKTSSON, 1983)[7]:

1)IMPLANT BIOCOMPATIBILITY:	1. Metals like commercially pure (c.p) titanium and possibly tantalum are well accepted in bone as they are self-repairing and corrosion resistant to oxide layer. 2. Metals like cobalt-chrome-molybdenum alloys, stainless steels & titanium alloys are less well tolerated by bone. 3. Ceramics and aluminum oxides due to insufficient documentation and very less clinical trials are less commonly used.
2) IMPLANT DESIGN:	1. Threaded implants provide more functional area for stress distribution than the cylindrical implants and provide better primary anchorage. 2. 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. 3. Longer the length, better the primary stability. 4. Wide diameter implants transmit less stress on crestal bone than narrow implants. 5. Platform-switching concept also preserves the marginal bone loss. This design uses a narrow diameter abutment over a wide diameter implant which provide a biomechanical advantage by shifting the stress concentration area away from the cervical bone-implant interface.
3) IMPLANT SURFACE:	1. Surface topography relates to the orientation of surface irregularities and degree of roughness of the surface. 2. Advantages of increased surface roughness a. Increased surface areas of the implant to bone so increased bone at implant surface. b. Increased biomechanical interaction with bone of the implant. 3. Smooth surfaces result in unacceptable bone cell adhesion and clinical failure.
4) STATE OF THE HOST BED:	1. Previous irradiation: - relative contraindication. However some delay is preferable before implant placement. 2. Low ridge height and resorption and

	Osteoporosis: - an indication for ridge augmentation with bone grafts before / during implant placement. 3. Infection 4. 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:	1. Optimum surgical procedure to promote regenerative type of the bone healing rather than reparative type of the bone healing (Erickson R.A.) 2. Drilling technique – graduated protocol (more drills) 3. Irrigation – copious amount of 0.9 % NaCl a. -To prevent bone tissue necrosis 4. Slow drill speed (less than 2000 rpm with irrigation). 5. A moderate power used at implant insertion

VIII. FACTORS AFFECTING OSSEOINTEGRATION[8]

Factors enhancing osseointegration	**Factors inhibiting osseointegration**
Macrogeometry of the implant body	Excessive implant mobility and micromotion
Titanium coating on Co-Cr metal implant	NSAIDS especially selective COX-2 inhibitors, warfarin and heparins
Laser Lithography	Radiation
Transcription factor Sp7	Rheumatoid arthritis, Osteoporosis
Bone source augment to socket	Smoking
Mechanical stability and loading conditions applied on the implant	Advanced age, nutritional deficiency and renal insufficiency
Effects of drugs such as simvastatin and bisphosphonates	Effects of drugs such as cyclosporin A, methotrexate and cis-platinum

IX. TECHNIQUES FOR SURFACE MODIFICATION OF IMPLANTS

There are numerous methods used to amend the surface topography of dental implants. These may be subtractive or additive processes

Subtractive processes	Additive processes
Acid etching Alkaline etching Sand blasting Sand blasting + Acid etching Grit blasting Titanium blasting Laser lithography	HA coating TCP coating (Tri Calcium Phosphate) Zirconia coating Titanium sintering Titanium plasma spray Anodization Sintered implants

X. METHODS OF EVALUATION OF OSSEOINTEGRATION

Invasive methods - Which interferes with osseointegration process of implant

1. **Histomorphometric**: This is attained from a dyed specimen of the implant and peri-implant bone by evaluating theperi-implant bone quantity and bone-implant contact (BIC).
2. Precise measurement is an advantage, but, it is not desirable for long-term studies. It is used in the nonclinical studies and experiments due to the invasive and destructive procedure.
3. **Tensional test:**It was beforehand measured by detachingthe implant plate from the supporting bone. Bränemark amended it by applying the lateral load to the implant fixture.
4. **Push-out/pull-out test :** It assesses the healing proficiency at the bone implant interface. It estimates interfacial shear strength by applying load parallel to the implant-bone interface. It is assessed during the healing period. The push-out and pull-out tests are at most useful for nonthreaded cylinder type implants, considering that most of clinically available fixtures are of threaded design.
5. **Removal torque analysis :**It is considered stable if the reverse or unscrewing torque of implant is >20 Ncm. Nonetheless, the drawback is that the process of osseointegration may fracture under the applied torque stress at the time of abutment connection implant surface.

Non-invasive methods - which does not interfere with osseointegration process

1. **Percussion test**: An osseointegrated implant produce a ringing sound on percussion while an implant that has undergone fibrous integration makes a dull sound.
2. **Radiographs**
3. **Reverse torque test**: A reverse or unscrewing torque is enforced to examine implant stability at the time of abutment connection. Implants are removed that rotate under the applied torque and are considered failures.
4. **Periotest:** It is a device which is an electrically driven and electronically monitored tapping head that percusses the implant a total of 16 times. The entire measuring procedure takes about 4 s.
5. **Resonance frequency analysis**: It measures implant stability and bone density at distinct time points using vibration and structural principle analysis. The implant stability quotient (ISQ) ranges between 40 and 80, the higher the ISQ, the higher the implant stability.

XI. NEWER METHODS TO ASSESS IMPLANT STABILITY

1. Implatest conventional impulse testing

Conventional impulse testing of an implant requisites fastening an accelerometer with associated wires and connectors to the implant, manifesting it with a calibrated hammer, and then recording and explicating the data.

Implatest is operator independent (independent of the direction or position of test application on the implant) and data can be garnered in seconds. It incorporates all of the characteristics of a conventional impulse test into a compact, portable, self-contained probe.[9]

2. Electro-mechanical impedance method

Analyses the electro-mechanical impedance of piezoelectric materials (work as both sensors and actuators) which is directly associated with the mechanical impedance of the host structure.[10]

Piezoelectric zirconatetitanate (PZT) is combined to the monitored structure and begins to vibrate after applying a voltage in 1 V in the kHz range. Furthermore, transition of structural characteristics such as damping, mass distribution, would impact the reading electrical admittance of PZT as read by impedance analyzer.

3. Micro motion detecting device

A customized loading device which comprise of a digital micrometer and a digital force gauge (range of 10–2500 N) used to regulate implant micromotion. The forces were achieved by turning a dial, which controlled the height ofthe force gauge. This dialed in force was applied to the abutment via a lever. The digital micrometer was placed tangent to the crown of the abutment and detected the displacement after the load application.[11]

XII. EVALAUTION OF SUCCESS OF OSSEOINTEGRATION ALBERKTSSON CRITERIA (1986) [12]

1. On clinical examination the individual unattached implant should be immobile.
2. There should be no evidence of radiolucency on radiographic evaluation.
3. After first year of implant loading there should be less than 0.2 mm vertical bone loss around the fixtures per year.
4. There should not be any signs of pain, infection, violation of mandible canals, sinus drainage and paraesthesia.
5. The success rate should be 85% at the end of 5 year and 80% at the end of 10 years.

XIII. NEW INNOVATIONS TO ENHANCE OSSEOINTEGRATION

1. Use of computer aided radiographic treatment planning & surgical guide fabrication using advanced computer aided design/computer aided manufacturing software
2. Promotion of osteoconduction of new bone growth with hydrophilic properties on implant surfaces
3. Use of recombinant human growth factors as a part of the placement or on the implant surface
4. Use of fluoride modified titanium oxide surface as one of method of surface chemistry modifications to accelerate bone growth.[13]

XVI. CONCLUSION

Osseointegration depicts a direct connection between bone and implant without intervening soft tissue. Nevertheless, bone connection to the implant does not occur wholly. Problems in determining the exact degree of bone attachment for the implant to be termed osseointegrated has led to a definition of osseointegration depend on stability rather than histologic criteria: “A process whereby clinically asymptomatic rigid fixation of alloplastic materials is achieved, and maintained, in bone during functional loading”.

An ultimate aim of the clinical procedure of osseointegration to provide the edentulous patient with occlusal rehabilitation. Long term clinical experience has clearly specified that osseointegrated reconstructions depend on persistent precision in the surgical procedures involved in installing the titanium fixtures.

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