THE CONCEPT OF OSSEOINTEGRATION IN IMPLANTOLOGY

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Abstract: *Branemark & Col were the first to suggest the possibility of a direct contact between the haversian bone and a loaded implant that they called "osseointegration". The current definition of osseointegration is the "direct anatomical and functional junction between the reshuffled bone and the surface of the implant that was loaded." In light of the clinical studies published by Branemark, the concepts of the nature of the bone-implant interface have evolved considerably. The interposition of a fibrous connective tissue represented the classical concept, but the excellent results published by the Swedish show that in case of a bone-implant direct contact, osseointegration is more viable on the long term.*

Cuvinte cheie: *osteointegrare, implant, sarcină, implant*

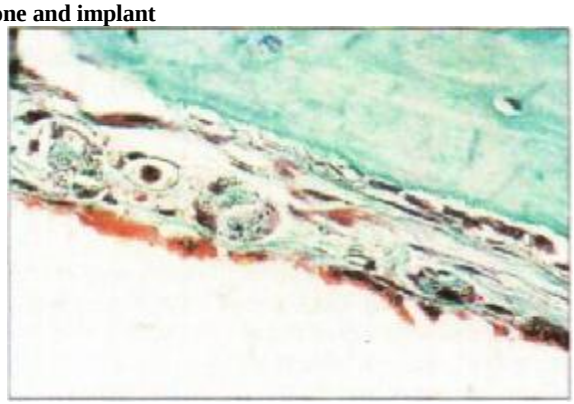
Rezumat: *Branemark & Col au fost primii care au sugerat posibilitatea unui contact direct între osul haversian şi un implant care a fost pus în sarcină pe care au numit-o " osteointegrare". Definiţia actuală a osteointegrării este «jonctiunea anatomică şi functională directă între osul remaniat şi suprafaţa implantului care a fost pus în sarcină». În lumina studiilor clinice publicate de Branemark, conceptele asupra naturii interfeţei os-implant au evoluat considerabil. Interpunerea unui ţesut fibro-conjunctiv era conceptul clasic, dar rezultatele excelente publicate de suedezi arată că în cazul unui contact direct os-implant, osteointegrarea, este mai viabilă pe termen lung.*

Biological process of osseointegration

Fibre-integration

The first histological studies on titanium blade type implants (Manderson 1972, James 1974; Doms 1974) showed that the implant was separated by the bone by one or more layers of fibrous tissue of connective origin.

Figure no. 1. Fibrous connective tissue interposed between bone and implant



This tissue described as being highly organized is supposed to have a cushion role the same way as desmodontium has around the tooth. Thus the fibro-integration concept has also been defined and justified.

The published studies on fibrous integration (Bert 1981, 1985 and 1986) show that the results are not stable on the medium and long term, failures increase with time, faster at the cheek bone level and slower at jaw level. After 15 years of study, the results clearly showed that the long-term maintenance of implants placed after the interposition concept of fibrous tissue between implant and bone, leads to failure.

The interposition of a fibrous tissue between bone and implant, which is the implant classic traditional concept, does not enable a good anchorage to the prosthetic elements.

Osseointegration

The direct contact between bone and implant show much improved clinical outcomes compared with the previous concept.

Clinically, osseointegration is translated by ankylosis that is the absence of implant lack of mobility. The surgical and prosthetic principles should obey the bone physiology imperatives in order to achieve and maintain osseointegration.

This requires knowledge of the phenomena of healing, tissue repair and reworking.

The bone is reformed along the turns of a screw implant, invading the implant pores. This bone is of the same quality and quantity with the bone formed in the absence of the implant.

The success criteria used by Alberektsson & Col (1986) are the following:

- clinically: immobility, clear sound at percussion, absence of painful infectious syndrome, absence of permanent paresthesias;
- radiologically: no clear radio periimplantar space, lower bone loss at 0.2 mm/year after the first year.

Determinants of osseointegration

The ability of an implant to be osseointegrated depends on several factors:

A) Factors related to the patient

Relative or absolute contraindications are related to diseases for which surgery is risky or interferes with bone

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healing, thus presenting a potential risk for osseointegration.

a) Patient's age

The advanced age is not a contraindication for dental implants; the failure rate does not increase in the elderly patients. In children or adolescents, various studies have shown that implants act like an ankylosed tooth which does not aim at the vertical increase of the jaws. It is therefore imperative to wait for the end of the growth of the jaws to provide a therapeutic implant in a teenager.

b) Gender:

No clinical study demonstrates any correlation between implant failure rate and patient's gender. This factor was mentioned mainly in relation to postmenopausal osteoporosis.

c) Severe cardiovascular disease is a risk for implant procedures. The mentioned pathologies are: cardiomyopathy, pericarditis, coronary disease, hypertension and cardiac arrhythmias. In the patients presenting a high risk for such diseases, dental implants are contraindicated.

d) Metabolic bone diseases: osteoporosis, osteomalacia, hyperparathyroidism, Paget's disease, multiple myeloma - can influence the osseointegration of the implant.

e) Endocrine disorders: diabetes, Cushing's syndrome, hyperparathyroidism. Diabetes increases the risk of impaired wound healing and postoperative infection. This risk is higher in insulin dependent diabetics.

Hyperparathyroidism is characterized by an increased production of parathyroid hormones. This hormone intervenes in regulating the extracellular calcium concentration. In its severe form, hyperparathyroidism brings about renal, intestinal and bone pathologies. Jaw bones are affected, alveoliosis can lead to total edentulism. This pathology is a contraindication for implant surgery.

f) Rheumatic disorders

Rheumatoid arthritis, Sjogren's syndrome, lupus erythematosus do not represent a contraindication for implant surgery.

g) Smoking – is considered a factor for implant failure.

h) Alcoholism can lead to impaired healing and may be the origin of osteopenia.

Local factors

The integrity of the soft tissue covering the implant site, osteogenesis and bone reshaping are key factors for osseointegration.

a) Mucous status

All dermatoses such as oral thrush, eczema, lichen planus, leukoplakia should be treated before putting the implants.

b) Bone quantity and quality

Implant site must be well vascularised. The success rate increases with the available volume of bone and quality. Implantation in a type IV spongy bone increases the risks for treatment failure.

c) Implant primary stability

Stability is largely obtained at the level of the marginal and apical parts of the implant engaged in the cortical bone. The spongy bone should ideally have a large proportion of trabeculae to help support the implant. Empty or fatty marrow areas should be avoided, as well as the sites with a low rate of trabeculae / bone marrow.

d) Resorption rate

Edentulous alveolar processes are subject to continuous resorption, the pressure exerted by a second prosthesis, poorly adapted may increase resorption. A severe resorption of the mandible implies that residual basal bone consists of a poorly vascularised bone essentially compact.

e) Periodontal diseases

In partially edentulous persons, periodontal pathology present in the natural teeth may colonize the peri-implant sulcus. The risk for peri-implant infections is higher in the patients who have particularly aggressive forms of periodontitis. It is recommended to treat these diseases before the therapeutic implant.

f) Congenital defects

The regions with dental agenesis have frequently insufficient bone volume. Also, the maxillary bone adjacent to a palatine cleft is generally less dense and with a limited volume.

B) Factors related to the implant

1) *Biocompatibility of the implant material*

Titanium used by Branemark, considered as "purely commercial" with impurities at a rate less than 0.25%, is considered as having the best biological tolerance.

Biological tolerance of pure titanium has been demonstrated since 1951 by Lever and by Beder & Col. No cancer action has been found.

Also, titanium is highly resistant to liquid attacks because it is covered by a very thin layer of tenacious and protective oxide.

The observations made with scanning electron microscope showed that at the level of the bone/implant interface, there is no fibrous tissue, the two structures are actually separated by a layer of proteoglycans partially calcified.

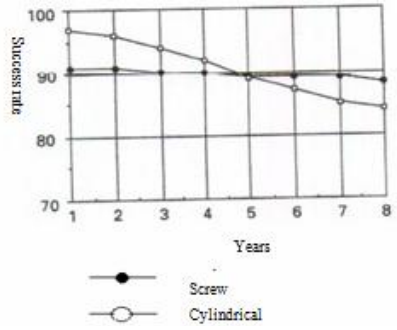
Ceramics such as hydroxyapatite are biocompatible on the long term. Bone unaccomplishment at the level of bone/implant interface is rapid during the first months but, along with the times, this clinical benefit is compromised by a frequent dissociation between the layer of hydroxyapatite and titanium surface. Hydroxyapatite layer can be little by little reabsorbed.

Since the early 80's, different hydroxyapatite coated implants have been sold. For some authors, these materials with osteoconductive characteristics should facilitate the obtainment of osseointegration. Long term studies have shown many complications with this type of surface.

2) Form of the implant

There are different types of implants: screws, cylindrical blade. The most used today are the screw implants. Comparative studies have shown that at mandible level, screw implant systematically gives the best results. At maxillary level, although the cylindrical implant seems to give good results, it has been demonstrated that on long term, screw implants were more stable. The picture below demonstrates this on a comparative study between the screw implant and the cylindrical implant for a period of 8 years.

Figure no. 2. Comparative study between the screw implant and the cylindrical implant (on a period of 8 years)



3) Implant surface status

The surface condition of a material influences the ability to be osseointegrated. Titanium presents an oxide layer

considered as being fully capable of incorporating neutral ions such as calcium and phosphorus, the basic components of the bone. Osseointegration is not only a direct contact between bone and implant but also a biochemical reaction between bone and titanium oxide that creates a link quite difficult to destroy. Titanium must not come in contact with any pollutants such as the talc powder from the surgical gloves, other metals or saline.
Smooth surfaces do not allow any bone/implant adhesion, resulting in a fibrous encapsulation regardless of the implant material used. Some irregularity of the surface appears to be necessary to allow a proper cell adhesion.

C) Surgical and prosthetic imperatives

1) Aseptic surgery is a prerequisite to prevent any bacterial contamination.

2) Bone site preparation

The conditions for the preparation of the recipient bone site have an influence on its healing. Regardless of any surgical precautions taken, an area of necrosis will inevitably occur as a result of trauma the bone has been submitted to. It seems that the main factor hindering the normal healing is the heat of the rotary instruments during the preparation of the recipient bone site.

Table no. 1. Maximum temperature should not exceed 470° C for one minute

^{0}C + time	Effect	
	Immediately	On long term
50^0 1 min	Important hyperaemia	Replacement of bone by fibrous tissue
47^0 5 min	Mild hyperaemia	Marrow fibrosis with occasional osteogenesis
47^0 1 min	-	Normal bone remodelling

A temperature higher to 47° causes a permanent stop blood flow, so there will be an area of necrosis that seems not to be repaired 100 days after the implant. The instruments used must be in good condition because the use of any used tools involves an increase of the local temperature. The rotation speed of the instruments influences the temperature released during the bone preparation. For the initial drilling, a rotation speed of 1500 rev/min. is acceptable, provided that the bit be removed from neoalveola as often as possible in order to be cooled with saline. The drills with internal irrigation seem to no longer meet the quality criteria of a rotary tool. The perfect cleaning of the internal channel is impossible to do, which turns these tools in real bacterial reservoirs.

3) Implant insertion

The pressure to insert the implant must be such as to allow its good stability. Too large insertion forces can cause peri-implant bone resorption.

4) Repartition of the occlusal forces

Surgical and prosthetic imperatives aim at achieving and maintaining the osseointegration. Bone-implant contact area largely determines the ability to withstand the occlusal forces.

Maintenance of osseointegration

Osseointegration durability depends on the health of the peri-implant tissues and of the control of the occlusal forces. Any inflammation of the peri-implant tissues due to bacterial infection may be the origin of a marginal bone resorption.
A bone loss of 1.5 mm one year after its emplacement, then of 0.2 mm/year is normal.

Complications and failures of osseointegration

It is important to distinguish between failure and complication, the latter being most often temporary and reversible. Any implant failure occurred before or during the second stage of implant surgery is considered a primary failure.

Bone-integrated implant prognosis is closely related to its length, bone quality and surgical technique mastery.

Intraoperative technical complication leads to a poor primary implant stability. A mobile implant at the end of the surgery risks not being osseointegrated. It is advisable to foresee the failure and be immediately replaced by an appropriate implant with a corresponding length and diameter.

Postoperative infectious problems are very rare in implants due to the pre-and postoperative antibiotic therapy. The infection may nevertheless be secondary to an intrasurgical contamination. The etiologic diagnosis of the absence of osseointegration is often difficult to accomplish: bacterial contamination, poor bone quality or quantity, traumatic surgery or the presence of excessive compressive forces on the implant during the healing bone stage.

Occlusal overload can result in the loss of osseointegration or rarely, in implant fracture. An improper adaptation or an incomplete screwing of the implant pillar can be a source of localized complications. The hiatus between the two components allows the proliferation of granulation tissue compromising osseointegration.

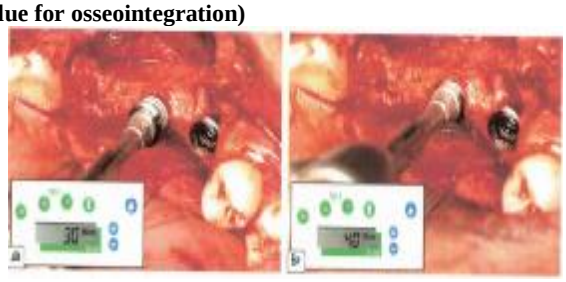
Most failures occur within six months before emplacement through spontaneous expulsion or during the implant loading when a certain mobility of the implant can be noticed. Putting a provisional prosthesis allows, among others, testing this fundamental stage of the prosthetic reconstruction. After this period of time, failures are exceptional.

Strategies for osseointegration optimization

Optimisation of the primary stability

Implants are subject to biochemical constraints from the time of their emplacement and all conditions must be met in order to maintain the amplitude of the micro movements at the interface below the tolerance level. This becomes very important for the implant prognosis, so much the more as it undergoes a formal charge. To objectively determine the primary stability, it is required an objective method, by determining the limit values at which stability is considered sufficient to achieve osseointegration. The simplest method is the maximum Torq applied for the final placing of the implant. Values of 20-50 Ncm are normal to obtain implant stability.

Figure no. 3. Biochemical constraints of the implants and the determination of the primary stability (obtaining a limit value for osseointegration)



It is a measurement method using the periotest that measures the “shock reaction” of the bone-implant entity by using an electromechanical device. Arbitrary measurements may vary between -8 and + 50. The negative values indicate a good stability of the implant, and the value +9 corresponds to implant mobility, so a failure.

The method with the help of Osstell is similar in principles with Periotestuf, except that the shock wave that measured the “shock resistance” of the bone-implant entity is generated electronically. The bone-implant entity enters in vibrations and the resonance frequency is analyzed, and the higher the frequency is the rigid the system is, so we may speak about a stable one.

Figure no. 4. "Shock resistance" measurement of the bone-implant entity with the help of the periotest connected to an electromechanical device

Figure no. 5. The three axes of rotation of the abutments (longitudinal, medio-distal, vestibulo-lingual), according to the pressure applied at the level of prostheses in certain moments

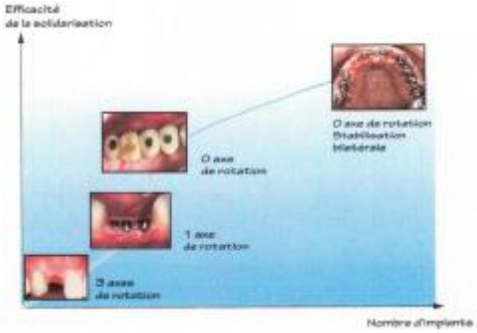


Figure no. 6. "Shock resistance" measurement of the bone-implant entity with the help of Osstell. Analysis of resonance frequency by bone-implant entity vibration

Influence of the implant

Implant must have a length generally between 10-15 mm. Implants with a diameter larger do not necessarily provide a better primary stability. Bearing surface of the tooth to replace is a reference for choosing the implant size. Also, the type of implant is important in the sense that tapered implants provide a better primary stability than the cylindrical ones.

Recipient site influence

The insufficient bone quantity and a bone density (bone density of type I) provides a better primary stability. Also, when the implant does not fill out the socket, a drilling of 3-6 mm will be performed beyond the apical limit to increase the primary stability. The use of a sonic or flared implant allows a better integration of the implant in the socket geometry.

Minimizing the forces exerted on the bone-implant interface

After the optimization of the primary stability, a second manner to reduce the movements consists of the minimization of the forces exercised at bone-implant interface. In this respect, the distribution of implants per arch serves to minimize the pressures on the implant. The forces trained in implant axis are better tolerated by the bone. The abutments with a tilt of 15° or more, train forces that are outside the implant axis, giving rise to important rotation movements. These abutments can be tolerated only if the insertion torque is superior to 40 Ncm and if the other factors in the interface are optimized. The pressure applied at prosthesis' level in certain movements occurs in three ways: around its longitudinal axis, around the mesio-distal axis and around the vestibulo-lingual axis. To optimize implant osseointegration, despite the pressure exercised during bone healing, it is needed that the amplitude of the movements at the interface level be kept below the critical threshold, to reduce the intensity of the forces and of the movements exercised on the implants, which is achieved through solidarity implants.

Implant's solidarity has a double purpose: to reduce the pressure on the interface of each implant, the pressures are distributed according to the number of implants; neutralizing the rotation movement (those three types of movements).

The purpose of an implant is to restore the oral function of the tooth it replaces. The implant and the prosthesis were designed, implemented and balanced in order to optimally resist the forces developed during the occlusal function.

The biomechanical characteristics of the implant-prosthesis complex depend on many parameters: characteristics of osseointegrated implants; choice of implant according to the type of PS and bone quality; implant position and orientation; prosthetic construction and the occlusal concept applied to restoration;

Implants specificity is given by a number of elements: absence of periodontal mechanoreceptors that reduce the proprioceptive ability of the implant; presence of excessive occlusal contacts and an improper adjustment of the prosthesis as the main factors responsible for bone loss and implant mechanical failure; absorbing the forces exerted on the axis of the implant - in the sense that they are better absorbed by the implant than those non-axial;presence of natural teeth with significant mobility that increases the non-axial and axial load supported by two-stage implants; lack of the ligament leads to a linear elastic response of the implant during the application of the occlusal forces.

These phenomena cause a large area of stress at the bone crest in the interface bone.

In most cases, after failure of an implant and after a healing of about 6 weeks, it is possible to place an implant in the same place, and experience shows that the second time the attempt seems to be a successful one, with little chances of failure. Understanding all the principles that lead to a good osseointegration is indispensable for obtaining a predictable success in implantology.

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