REVIEW ARTICLE

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Osseointegration- A Review

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ABSTRACT:

Comprehensive changes in the practice of implantology have been made possible through a more exhaustive understanding of the essential requirements of specific case treatment planning, surgical procedures, and the evolution of the design and architecture of the modern day implants. However, the most fundamental process that is the basis to any implant treatment is osseointegration. In the recent times, the concept of osseointegration has undergone a most extensive understanding and research. Osseointegration has been defined as the direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant. Nowadays, an implant is considered as osseointegrated when there is no progressive relative movement between the implant and the bone surface. It has thus been postulated that osseointegration is not the result of an advantageous biological tissue response but rather the lack of a negative tissue response. A thorough knowledge of the mechanism of osseointegration and the various factors influencing it, will go a long way in optimizing the results obtained during implant therapy. This article aims to throw light on the mechanism of osseointegration and the factors affecting it.

Keywords: Bone, Implant-bone interface implants, Implant surface, Matrix, Osseointegration.

INTRODUCTION

The high success rates of the dental rehabilitation of patients with endosseous implants have evolved from several comprehensive research methodologies with the aim of increasing and accelerating bone anchorage to the implant, thereby providing maximum support for the intraoral prosthetic devices. Nowadays it is widely accepted by the scientific community that osseointegration is an absolute requirement for successful implant-supported dental prosthesis. Osseointegrated implants are used widely in the dental, maxillofacial, and ear nose throat fields and, although not as frequently, also in orthopaedic surgery. Osseointegration comes from the Greek ‘osteon’ meaning bone, and the Latin word ‘integrare’, meaning to make whole. Osseointegration is defined as a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant.

Several techniques of surface treatments have been considered and enforced to enhance biological surface properties, to optimise the mechanism of osseointegration to promote faster and stronger bone formation for better functional stability of the load bearing implant.

HISTORICAL ASPECTS

In 1952, Per-Ingvar Brånemark[1] of Sweden conducted an experiment to study blood flow in rabbit bone using a titanium implant chamber. At the conclusion of the experiment, he found that the bone had integrated so completely with the implant that the chamber could not be removed. Brånemark named this phenomenon as "osseointegration," and saw the possibilities for human use. Osseointegration was first observed in animals by Bothe, Beaton, and Davenport[2] in

1940. They used titanium implants in an animal and remarked how it had the tendency to fuse with bone and reported that it had an enormous potential to be used as future prosthesis material due to the elemental nature of titanium, its high strength, and its durability. Osseointegration was later described by Gottlieb Leventhal[3] in 1951, who placed titanium screws in rat femurs.

OSTEOINDUCTION, OSTEOCONDUCTION AND OSSEOINTEGRATION

Osseointegration is not considered as a separate entity, but rather has been known to depend on osteoconduction and osteoinduction. Osteoinduction, osteoconduction and osseointegration are interrelated, but not identical phenomena. Osteoinduction is the process of induction of osteogenesis and is generally seen in all types of bone healing processes. Osteoinduction refers to the recruitment of immature cells and the stimulation of these cells to develop into preosteoblasts. In a bone healing situation such as a fracture, the majority of bone healing is dependent on osteoinduction. Osteoconduction implies that the bone grows on a surface and is regularly seen in the case of bone implants. Implant materials of low biocompatibility such as copper, silver and bone cement show minimal or no osteoconduction. Osteoconduction and osseointegration both depend not only on biological factors, but also on the response to foreign materials. The osteoconductive response may be rather short lived, but successful osseointegration maintains its bone anchorage over a long period. Thus materials that are too toxic to allow osteoconduction will not be osseointegrated either.[4]

IMPLANT-BONE INTERFACE

It is highly dynamic in nature and can change from time to time. The tissue to implant contact may be either fibro-osseointegrated or osseointegrated.

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". In this theory, collagen fibers function similarly to Sharpey's fibers in natural dentition. The fibers affect bone remodelling where tension is created under optimal loading conditions. This concept of Fibro-osseous integration was supported by Linkow (1970), James (1975), and Weiss (1986).[5]

The role of osseointegration in bone healing was first described by Strock as early as 1939 and more recently by Branemark et al in 1952. Branemark theorized that the implant must be protected and completely out of function, as he envisioned a healing period of almost an year when new bone is formed close to the immobile resting implant.[6] Meffert et al (1987) redefined and subdivided osseointegration[7] into: Adaptive osseointegration that has osseous tissue approximating the surface of the implant without supposed soft tissue interface as seen under a light microscope and Biointegration which is a direct biochemical bone surface attachment confirmed at the electron microscopic level.

STAGES OF OSSEOINTEGRATION

Bone healing is certainly a fascinating biological accomplishment of the skeletal tissues and one of the rare examples in which regenerative processes fully restore the original structure and function. Bone regeneration follows similar pathways: in direct (or primary) healing, a scaffold of woven bone, closely associated with an expanding vascular net, invades the granulation tissue that organizes the initially formed blood clot. In in-direct (or secondary) healing, connective tissue and/or fibrocartilage differentiates within the fracture gaps and is replaced by bone as in endochondral ossification.[8] Osseointegration belongs to the category of direct or primary healing. Originally, it was defined as direct bone deposition or functional ankylosis. Comparisons have been made with direct fracture healing where the fragment ends become united by bone, without the formation

of an interposing fibrous tissue or fibrocartilage. An important difference, however, exists as in osseointegration bone is united not to bone, but to an implant surface(a foreign material). Thus the material is thought to play a fundamental role for this union.

Direct bone healing occuring in defects, primary fracture healing and in osseointegration is activated by the pre-existing bone matrix. When the matrix is exposed to extracellular fluid, noncollagenous proteins and growth factors are set free and activate bone repair. Osteoprogenitor cells from the bone marrow and the endocortical and periosteal bone envelopes migrate into the site attracted by chemotaxis. These cells then proliferate and differentiate into osteoblast precursors and osteoblasts and start bone deposition on the walls of the defect, the fragment ends and presumably on the implant surface. At this stage, the osteoclasts are rarely seen and supposedly uninvolved in the process of activation.[8] Once activated, osseointegration follows a biologically determined program that is subdivided into 3 stages:

Stage I- Incorporation by woven bone formation- Woven bone generally begins to grow from the surrounding bone towards the implant, except in narrow gaps, where it is simultaneously deposited upon the implant surface. Woven bone formation clearly dominates the scene within the first 4 to 6 weeks after surgery.[9]

Stage II- Adaptation of bone mass to load (lamellar and parallel-fibered bone deposition)- beginning in the second month, the microscopic structure of freshly formed bone changes, either towards the more notable lamellar bone, or towards an equally needed but lesser known modification called parallel-fibered bone. Lamellar bone is certainly the most elaborate type of bone tissue. Arrangement of these collagen fibrils into parallel layers showing alternating course (comparable to plywood) gives it the highest ultimate strength. Parallel-fibered bone is a transition between woven and lamellar bone: the collagen fibrils are seen parallel to the surface but without a preferential orientation in that plane.[9]

Stage III- Adaptation of bone structure to load (bone remodeling) - Bone remodeling characterizes the last stage of osseointegration. It starts around the third month and, after various weeks of increasingly high activity, slows down again, but continues for the rest of life. In cortical, as well as in cancellous bone, remodeling occurs in distinct units, often referred to as a bone multicellular unit, as proposed by **Frost 1963**. Remodeling of the bone begins with osteoclastic resorption, followed by lamellar bone deposition. Resorption and formation are coupled in space and time. In cortical bone, a bone multicellular unit consists of a band of osteoclasts (cutting cone) forming a drill-head and producing a cylindrical resorption canal with a diameter equal to an osteon, that is, 150-200 pm. After 2-4 months, the new osteon is completed.[9]

OSTEOGENESIS

Osborn and Newsley[10], described the phenomenon by which bone can become juxtaposed to an implant surface. They described that this could occur via two means: *Contact osteogenesis and Distance osteogenesis*. In contact osteogenesis, new bone forms first on the implant surface. The implant surface has to be colonized by bone cells before the beginning of bone matrix formation. Thus, distance osteogenesis results in bone approximating the implant surface while contact osteogenesis results in bone apposition to the implant surface.

In contrast, In distance osteogenesis, new bone is formed on the surfaces of old bone in the peri-implant site. The bone surfaces now provide a community of osteogenic cells that lay down a new matrix that impinges on the implant. The new bone is not forming on the implant, but the latter does become surrounded by bone. Thus, in these circumstances, the implant surface is always partially obscured from bone by intervening cells.

FACTORS AFFECTING OSSEO-INTEGRATION

According to Albrektsson *et al*. (1981),[11] the different factors responsible for osseointegration are design, biocompatibility, surface conditions, the surgical technique ,the status of the host bed, and the loading conditions applied afterward.

Several different materials have been used to manufacture the implants to date. However, use has mostly been restricted to metals, polymers and more recently, ceramics. Among the metals, titanium and its alloys has been the mainstay for implant manufacture. Tantalum and niobium have also been used although it has been reported that they elicit an exaggerated macrophage response. The popularity of titanium has been attributed to its chemical purity and its ability to form an adherent, passivating oxide film which forms at the rate of 100 Å per minute.[12] Different techniques of surface treatments have been studied and applied to enhance the biological surface properties to increase osseointegration.

The imminent targets of these implant surface modifications are to improve the clinical performance in areas with poor quantity and quality of bone, to increase bone healing and thus allowing immediate or early loading protocols and also stimulating bone growth in order to permit implant placement in sites that lack sufficient residual alveolar ridge.

Implant morphology also influences bone metabolism: rougher surfaces enhance differentiation and attachment of bone cells, and increase mineralization; also, the degree of roughness is important. The main methods that can be employed to increase implant roughness are acid etching, sandblasting, titanium plasma spraying and hydroxyapatite (HA) coating. A recent penchant is the manufacturing of implants with micro and submicro (nano) topography. The biofunctionalization of implants surfaces has also been lately investigated by adding various substances to improve its biological characteristics. Implant design refers to the three dimensional structure of the implant. Implants may be cylindrical or screw shaped. They may be threaded or non-threaded. 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 huge 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.[13]

The major patient factors which need to be considered during implant placement with regards to health of the patient are: Age, Previous irradiation and History of smoking. Extremes in age are relative contraindications to implant placement although old age has shown no poorer results. In children, placement of implants could lead to an infra positioning of the implant following growth and needs to be considered during implant surgery. Early placement of implants may be required in cases which use bone anchored hearing aids. Previously irradiated bone is a relative contraindication to implant placement. It has been seen that success rates are 10- 15% lesser in irradiated patients as opposed to non-irradiated patients. If the patient has been irradiated before implant surgery, the higher the dose, the poorer the results. The longer the time from radiotherapy, the poorer the results.[14] Mean failure rates are twice as high in smokers as in non-smokers. History of smoking affects the healing response in osseointegration adversely. Smoking causes vasoconstriction, a reduced bone density and impaired cellular function and thereby interferes with healing following implant surgery.[15]

Surgical considerations:[7]

a) Most favourable surgical technique should be employed to encourage regenerative bone healing rather than reparative type of the bone healing.

b) Use of well-sharpened drills should be highlighted.
c) Adequate cooling should be allowed.
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.

LOADING CONDITIONS[7]

Premature loading may cause soft tissue anchorage and poor long-term function, while postponing the loading by using a two stage surgery often results in better bone healing and a positive long term function.

OTHER FACTORS

Lasers and bioactive molecule have provided a broader margin for clinicians to amplify osseointegration. Some practices that have proven valuable are the local administration of osteogenic factors and systemic administration of Parathormone. Several systemic diseases can adversely affect the osseointegration in dental implant such as osteoporosis, rheumatoid arthritis, advanced age, nutritional deficiency, smoking and renal insufficiency and these should be given due consideration during the procedure.[16] Factors enhancing osseointegration include the status of the host bone bed and its intrinsic healing potential, the use of adjuvant treatments such as bone grafting, osteogenic biological coatings and biophysical stimulation,[16,17] and pharmaco-logical agents such as simvastatin and bisphosphonates.[18] Factors inhibiting osseo-integration include excessive implant mobility, inappropriate porosity of the porous coating of the implant, radiation therapy[19] and pharmacological agents such as cyclosporin A, methotrexate and cis-platinum,[20] warfarin and low molecular weight heparins, non-steroid anti-inflammatory drugs especially selective COX-2 inhibitors, and patient factors such as age, nutritional deficiency, smoking and renal insufficiency.[21]

CONCLUSION

Implant osseointegration is probably one of the most critical aspects in implant therapy. It is mandatory that osseointegration be successful in order that the implant treatment achieves its most important goal - the restoration of missing natural tissue. A better understanding of the complex biological events occurring at the bone-implant interface will ultimately lead to improved biologically-driven design strategies for endosseous implants.

REFERENCES

1. Branemark R, Branemark PI, Rydevik B, Myers RR. Osseointegration in skeletal reconstruction and rehabilitation: A review. JRRD 2001;38(2):175-81.
2. Bothe RT, Beaton LE, Davenport HA. Reaction of bone to multiple metallic implants. Surg Gynecol Obstet 1940;71:598-602.
3. Leventhal GS. Titanium, a Metal for Surgery. Journal of Bone and Joint Surgery 1951;33A:473-4.
4. Albrektsson T & Johansson C. Osteoinduction, osteoconduction and osseointegration. European Spine Journal 2001;10(2):96-101.
5. Linkow LI. Implant dentistry today: a multidisciplinary approach, Volume III. Italy: Piccin Padua. 1990;1513-18.
6. Misch CE. Contemporary Implant Dentistry. 2nd ed. USA: Mosby publication. 1999;239-250.
7. Nandal S, Ghalaut P, Shekhawat H, Nagar P. Osseointegration in Dental Implants: A Literature Review. Ind J App Res 2014; 7(4):411-13.
8. Johansson C, Lausmaa I, Ask M, et al. Ultrastructural differences of the interface zone berween bone and TÍ-6AI- 4V or commercially pure titanium. Binmed Eng 1989;11:3-8.
9. Schenk RK, Buser D. Osseointegration: a reality. Periodontology 2000 1998;17:22-35.
10. Osborn JF, Newesely H. Dynamic aspects of the implant bone interface. In: Heimke G, ed. Dental implants: materials and systems. München. Carl Hanser Verlag 1980:111-23.
11. Albrektsson T, Brânemark PI, Hansson HA, et al. Ultrastructural analysis of the

interface zone of titanium and gold implants. Adv Biomat 1982:4:167-77.
12. Gottlander, Albrektsson. Histomorphometric studies of hydroxyapatite coated and uncoated cp titanium implants in bone. Int J Oral Maxillo fac Implants 1991;6:399-404.
13. Harshakumar K, Ravichandran R, Nair V V, Krishnan A. Osseointegration. Ind J Dent Sciences 2014;6(1):123-5.
14. Gösta Granströ. Osseointegration in Irradiated Cancer Patients: An Analysis With Respect to Implant Failures. J Oral Maxillofac Surg 2005;63:579-85.
15. Schwartz-Arad D, Samet N, Samet N, Mamlider A. Smoking and complications of endosseous dental implants. J Periodontol 2002;73:153-7.
16. Khan SN, Cammisa FP Jr, Sandhu HS, Diwan AD, Girardi FP, Lane JM. The biology of bone grafting. J Am Acad Orthop Surg 2005;13:77-86.
17. Younger EM, Chapman MW. Morbidity at bone graft donor sites. J Orthop Trauma 1989;3:192-5.
18. Eberhardt C, Habermann B, Müller S, Schwarz M, Bauss F, Kurth AH. The bisphosphonate ibandronate accelerates osseointegration of hydroxyapatite-coated cementless implants in an animal model. J Orthop Sci 2007;12:61-6.
19. Kudo M, Matsui Y, Ohno K, Michi K. A histomorphometric study of the tissue reaction around hydroxyapatite implants irradiated after placement. J Oral Maxillofac Surg 2001;59:293-300.
20. Sakakura CE, Marcantonio E Jr, Wenzel A, Scaf G. Influence of cyclosporin A on quality of bone around integrated dental implants: a radiographic study in rabbits. Clin Oral Implants Res 2007;8:34-9.
21. Rosenqvist R, Bylander B, Knutson K, Rydholm U, Rooser B, Egund N, Lidgren L. Loosening of the porous coating of bicompartmental prostheses in patients with rheumatoid arthritis. J Bone Joint Surg Am 1986;68:538-42.

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