Evaluation of the Effect of Pulsed Electromagnetic Fields on Dental Implants Osseo-integration in Fresh Extraction Sockets: A Clinical Study

A thesis Submitted to the Faculty of Dentistry, Ain Shams University in partial fulfillment of the requirements of Master degree in Oral and Maxillofacial Surgery

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B.D.S. 2006

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2014

Dedication

This work is dedicated to

My Dear parents

The light that leads my way

My beloved wife

My true friends and colleagues for their encouragement and cooperation

Acknowledgment

I would like to express my special thanks and gratitude to **Dr. Zyad El Sayed**

Endodontics specialist

For his effort and unlimited willingness for help.

I would also like to express my deep gratitude to

Doaa Adel

Ass. Lecturer of Oral medicine, Ain shams university

For her support and help

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LIPUS	: Low intensity pulsed ultrasounds
PEMFs	: Pulsed electromagnetic fields
RFA	: Resonance frequency analysis
ISQ	: Implant stability quotient
COX-2	: Cyclo-oxygenaze 2 enzyme
BMP	: Bone morphogenic protein
IGF	: Insulin like growth factor
TGF	: Transforming growth factor
LLLT	: Low level laser therapy
IR	: Infra-red
PRF	: Pulsed radiofrequency fields
DC	: Direct current
EMF	: Electro-magnetic fields
IL	: Interleukin
VEGF	: Vascular endothelial growth factor
FGF	: Fibroblast growth factor
SLA	: Sandblasted and acid etched
RVG	: Digital radiovisiography
XCP	: Extension cone paralleling technique
SPSS	: Statistical package for Social Science
SD	: Standard deviation
NS	: Non-significant
S	: Significant
HS	: Highly significant
ELF-PEMFs	: Extremely low frequency pulsed electromagnetic fields

Introduction

One of the main goals in dental and maxillofacial surgery and a pre-requisite for clinical success is to achieve good and fast bone implant Osseo-integration as it would provide early fixation with long-term implant stability.

Despite the ongoing improvement in implant characteristics, adjuvant therapies are required to stimulate the bone intrinsic potential for regeneration.

For this purpose various pharmacological, biological or biophysical modalities have been developed, such as bone grafting materials, pharmacological agents, growth factors and bone morphogenetic proteins.

Biophysical stimulation of Osseo-integration includes three non-invasive and safe methods that have been initially developed to enhance fracture healing: pulsed electromagnetic fields (PEMFs), low intensity pulsed ultrasounds (LIPUS) and low-level laser therapy (LLLT), for which most experimental studies confirm their beneficial effects.

Several animal and human studies have been published, discussing the effect of PEMFs stimulation on orthopedic implant Osseo-integration with most of them proving its beneficial effect. So far there are only few studies on the efficacy of PEMFs stimulation on dental implant Osseo-integration.

Nearly 50 years ago, the advent of implant dentistry changed our ideas about tooth replacement therapy for our patients. Branemark discovered that fully edentulous patients could be dentally rehabilitated using machined screws made of commercially pure titanium, which Osseo-integrated to the jawbone, enabling the attachment of a fixed prosthesis.[1]

Since then, endosseous dental implants of various shapes and surface textures have been used in partially edentulous patients, achieving a measured rate of success of 96.7% at 8 years.[2] To achieve this safe, predictable, and cost-effective mechanism of rehabilitation, Branemark and coworkers developed a list of clinical recommendations regarding treatment protocols. According to one of the recommendations, a waiting time of 12 months was necessary following tooth extraction before an endosseous dental implant could be installed.[1, 3] The rationale for this reasoning was to allow resolution of any hard or soft tissue pathology in a proposed recipient site.

Several investigations have evaluated the effects of tooth extraction on the dimensional changes observed with both the hard and soft tissue. These changes in the healing extraction sockets have been evaluated by means of cephalometric analysis [4, 5], study cast assessments [6, 7], subtraction radiography [8], and direct measurements made at surgical reentry.[9, 10] Diagnostic casts have the ability to evaluate morphologic changes in the bone and overlying mucosa in a noninvasive fashion. During the first 4 months of healing, according to observations and measurements, the bucco-lingual dimension of the ridge undergoes a reduction of approximately 5 to 7 mm [5, 9] with a 2 to 4.5 mm loss of vertical bone height.[8, 11] Several studies have observed greater apico-coronal changes when comparing multiple adjacent extraction sites to single sites.[9,11,12] Recently, a study measured dimensional changes intraoperatively in 46 healing sockets in 46 patients, confined to only the premolars and molars in both arches. They reported a reduction in bucco-lingual width of nearly 50% over an observation period of 12 months. They noted that two thirds of the change occurred within the first 3 months following tooth extraction, with greatest changes observed in the molar sites. [12]

Noting that this post-extraction resorption could adversely affect the availability of bone for implant placement, clinicians began to insert dental implants immediately following tooth extraction. The first reported case was described in 1976 using a polycrystalline aluminum surface. [13] Since then, numerous clinical case reports have been published. [14-17]

Literature reviews delineated the advantages of immediate versus delayed implant placement as follows: treatment time is reduced, number of surgeries is reduced, width and height of the alveolar bone are preserved, ideal implant location can be achieved provided that the extracted tooth has a desirable alignment and there is maximum soft tissue support. As an adjunct to these advantages, there are several other benefits including less surgical morbidity, a reduction in treatment expense, if additional regenerative techniques (bone grafts and membrane use) are not applied and better patient acceptance of the treatment plan. [18]

The biologic advantage often mentioned in the immediate implant literature is that the implant will prevent postsurgical bone resorption seen following tooth extraction as a normal part of the socket healing. However, a study that measured the bucco-lingual dimension of the bone at the time of immediate implant placement (15 implants in 15 patients) and again at second-stage surgery 6 months later found that in spite of the implant being immediately placed, the mean distance in the bucco-lingual direction decreased from an average of 10.5 mm (± 1.54) to 6.8 mm (± 1.33). [19]

A more recent article compared bucco-lingual bone resorption in cases of immediate versus delayed implant placement; the results demonstrated that less resorption occurred in sockets receiving the immediate implants than in sockets allowed to heal naturally. [20]

Although reduced by immediate implant placement, this degree of horizontal resorption may present problems, especially in the esthetic zone. [19, 20]

Regardless the timing of implant placement whether immediate or delayed, the success of endosseous implants depends essentially on Osseo-integration which refers to a direct bone to metal interface without interposition of non-bone tissue. This concept has been described by Branemark, as consisting of a highly differentiated tissue making "a direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant.[21,22] Through his initial observations on Osseo-integration, Branemark showed that titanium implants could become permanently incorporated within bone that is, the living bone could become so fused with the titanium oxide layer of the implant that the two could not be separated without fracture.[21] From this discovery in experiments focusing on observing the micro-movements of bone, through its laboratory development and initial application in the dental sciences, Osseo-integration has become a realized phenomenon of importance. [22]

Since Branemark's initial observations, the concept of Osseo-integration has been defined at multiple levels such as clinically, [3] anatomically, [22] histologically and ultra-structurally.[23] In vivo and in vitro researches have also been performed to evaluate the biology of the healing response to the implant surface and how the material's characteristics, such as surface preparations, chemical composition, coatings and sterilization procedures may affect the short- and long-term stability of the metallo-biological interface.[24, 25]

Bone healing around implants involves a cascade of cellular and extracellular biological events that take place at the bone-implant interface until the implant surface appears finally covered with a newly formed bone. [26]

These biological events include the activation of Osteo-genetic processes similar to those of the bone healing process, at least in terms of initial host response. [27-29] This cascade of biological events is regulated by growth and differentiation factors released by the activated blood cells at the bone-implant interface. [30]

The response of the skeleton to trauma has been well studied mechanically and histologically with increasing interest in the molecular biology of this phenomenon. The host response after implantation is modified by the presence of the implant and its characteristics, the stability of the fixation and the intraoperative heating injuries that include death of osteocytes extending 100-500 μm into the host bone. [26-29]

The first biological component to come into contact with an endosseous implant is blood. Blood cells including red cells, platelets, and inflammatory cells such as polymorphonuclear granulocytes and monocytes emigrate from post-capillary venues, and migrate into the tissue surrounding the implant. The blood cells entrapped at the implant interface are activated and release cytokines and other soluble, growth and differentiation factors. [30]

Initial interactions of blood cells with the implant influence clot formation. Platelets undergo morphological and biochemical changes as a response to the foreign surface including adhesion, spreading, aggregation, and intracellular biochemical changes such as induction of phosphotyrosine, intracellular calcium increase, and hydrolysis of phospholipids. [30, 31]

The formed fibrin matrix acts as a scaffold (Osteo-conduction) for the migration of osteogenic cells and eventual differentiation (Osteo-induction) of these cells in the healing compartment. Osteogenic cells form osteoid tissue and new trabecular bone that eventually remodels into lamellar bone in direct contact with most of the implant surface (Osseo-integration). [30, 31]

Osteoblasts and mesenchymal cells seem to migrate and attach to the implant surface from day one after implantation, depositing bone-related proteins and creating a non-collagenous matrix layer on the implant surface that regulates cell adhesion and binding of minerals. This matrix is an early-formed calcified afibrillar layer on the implant surface, involving poorly mineralized osteoid similar to the bone cement lines and that forms a continuous, 0.5 mm thick layer that is rich in calcium, phosphorus, osteopontin and bone sialoprotein. [31, 32]

Peri-implant Osteo-genesis then proceeds, it can be in distance and in contact from the host bone. Distance Osteo-genesis refers to the newly formed peri-implant bone trabeculae that develop from the host bone cavity towards the implant surface. In contrast, contact Osteo-genesis refers to the newly formed peri-implant bone that develops from the implant to the healing bone. [30]

Initially, rapid woven bone formation occurs on implants to restore continuity, even though its mechanical competence is lower compared to lamellar bone based on the random orientation of its collagen fibers. Woven and trabecular bone fill the initial gap at the implant-bone interface. Arranged in a three-dimensional regular network, it offers a high resistance to early implant loading. [30, 33, 34]