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Immediate Versus Delayed Loading of Two Implants Supporting A Locator Retained Mandibular Overdenture. A Randomized Controlled Study.

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**Immediate Versus Delayed Loading of Two Implants
Supporting A Locator Retained Mandibular Overdenture.
A Randomized Controlled Study.**

Sejal Thacker

D.D.S., Columbia University College of Dental Medicine, 2009

A Thesis

Submitted in Partial Fulfillment of The

Requirements for the Degree of

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APPROVAL PAGE

Master of Dental Science Thesis

**Immediate Versus Delayed Loading of Two Implants
Supporting A Locator Retained Mandibular Overdenture.
A Randomized Controlled Study.**

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I also thank my mother and my father who pray for me everyday, dream big for me every night and whose eyes tear in happiness at my smallest achievements.

DEDICATION

I would like to dedicate this thesis to the three most important people in my life.

My late grand mother, my best friend, my “Ba”, Ms Zaverben Thacker. She made me the person that I am today. She was a epitome of self confidence and independance. She will always be alive in my heart and continue to inspire me through the thick and thin of life.

My beloved husband, Ajay Dhingra. He is my pillar of strength and the love of my life. His love, care and support make it possible to live life to the fullest and to realize my dreams.

My little baby, Krish. His twinkling eyes and dimpled smiles makes life worthwhile.

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1. Introduction

Progressive bone resorption of the edentulous ridge is a major concern when rehabilitation of the edentulous mandible with a complete denture is considered [1-3]. Complete dentures seem insufficient in re-establishing oral function, chewing efficacy and bite force [4, 5]. The introduction of implant-retained overdenture prostheses has led to a paradigm shift in the management of complete edentulism. The long-term efficacy, clinical efficiency and patient satisfaction with these prostheses have been successfully established in many retrospective and longitudinal trials [6-11].

As per traditional knowledge, when making implant overdentures, the matrices of the bar or the solitary attachments are connected three to six months after implant placement (delayed loading), when the process of osseointegration is considered completed. For a long time, immediate loading of dental implants was considered detrimental for osseointegration. But this *dogma* of delayed loading was based on empirical data and these recommendations were made predominantly for the machined surfaced implants. Evolution in implant systems, designs and surfaces have made it possible to shorten the healing time without jeopardizing osseointegration and implant success rate [12].

A search through literature shows that there is high level of scientific and clinical evidence for conventional loading with mandibular implant retained overdentures but insufficient scientific validation for immediate loading protocols [13]. Hence, a randomized controlled clinical trial was designed to compare the performance of two implants supporting a mandibular overdenture, using either an immediate or a delayed loading protocol.

2. Background and Significance

2.1 Dental Implants

2.1.1 Introduction of implants in dentistry

Dental implants are prosthetic devices, made of alloplastic materials that are inserted into the oral cavity to provide retention and support to removable and fixed dental prostheses [12, 14]. The concept of using implants to replace teeth is age old. In fact, in ancient history thousands of years ago, ivory teeth were used as implants in Egyptian mummies. However, the era of modern dental implantology began much later, in the 1940's, with the discovery of screw type implants by *Formiggini et al* [15, 16]. The introduction of the concept and the biology of osseointegration, by *Branemark et al* (1952), added another milestone in the history of dental implantology [17]. Over the years, this field has significantly evolved and emerged as an extensively used treatment modality for oral rehabilitation.

2.1.2 The Concept of Osseointegration and Healing Around Implants

Osseointegration, as defined by Branemark and his colleagues, is a direct structural and functional connection of a load-carrying implant and consists of direct histological bone-implant contact, without an intervening layer of fibrous tissue [17, 18]. Osseointegration results from a complex series of molecular processes ultimately leading to the formation of a functional bone – implant interface. In order to better understand the concept of osseointegration, it is important to know the healing of the peri-implant space following implant insertion into a pre drilled bone cavity.

The first clinical outcome of surgical procedure is the primary stability of the implant. Primary stability is rigid fixation and lack of micro motion of the implant into the bone cavity [12, 18, 19]. Absence of stability can lead to excessive mobility and cause fibrous tissue formation around the implants inhibiting osseointegration [19-21]. Primary stability depends on the surgical technique, implant design and the implant site [22-24].

At a microscopic level, healing begins with bleeding, induced by surgical trauma from the osteotomy preparation. When blood comes in contact with the implant surface, triggers a cascade of biological events leading to protein adsorption and coagulation [19]. The blood clot, thus formed, serves as a mechanical scaffold and provides the biochemical components for osseointegration. Osseointegration, as described by *Davies et al* (2003), is the recruitment and migration of osteogenic

cells [25]. Mesenchymal cells migrate through the preliminary matrix of the fibrin clot toward the implant surface [25]. As these cells move to the implant surface, signaling molecules and certain transcription factors cause the cells to differentiate into the osteoblastic lineage. The osteoblasts lay down bone on the old bone surface or on the implant surface itself. When new bone is formed on the surface of the old bone, it is called distant osteogenesis [25]. In contrast, *de novo* bone formation on the implant surface is termed as contact osteogenesis [25]. As healing proceeds, bone formed through distant and contact osteogenesis grows and unites.

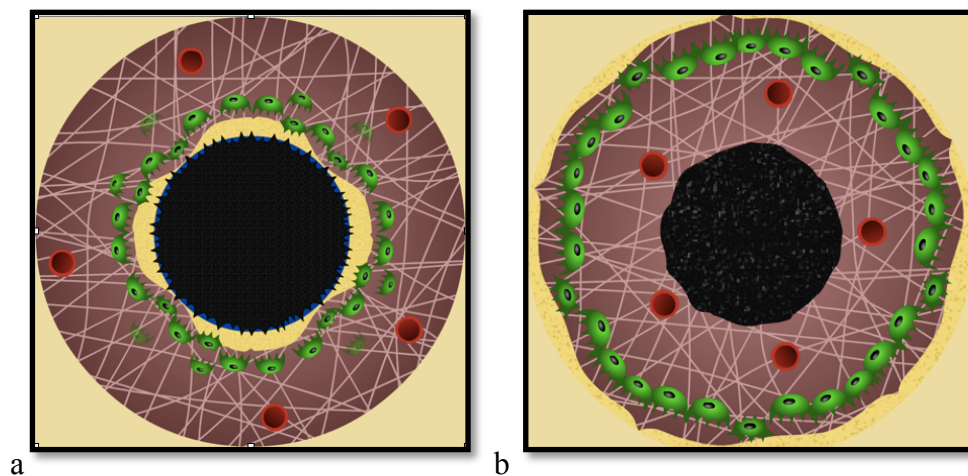


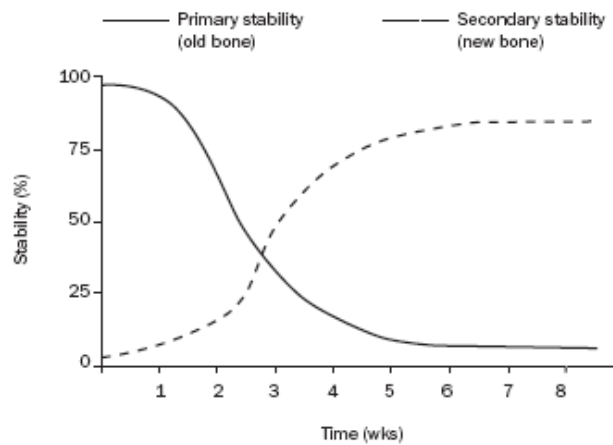
Fig 1: Osteogenesis during healing of bone around an implant

a. Contact osteogenesis: de novo bone formation along the implant surface

b. Distance osteogenesis: bone formation on the surface of old bone

Immature bone formed through osteogenesis results in gradual increase in secondary stability of the implant. At the same time, remodeling and osteoclastic resorption of bone that was initially in direct contact with the implant, causes a

decline in primary stability [26]. The immature bone eventually mineralizes, matures and remodels.



[26]

Fig 2: Gradual shift from primary to secondary stability

The above-mentioned healing process was well illustrated by *Berglundh et al* (2003) in an animal model. Twenty dogs had one hundred and sixty surface modified implants placed and wound healing was evaluated, via bone chambers and ground sections, from two hours to twelve weeks. The healing began with coagulum formation followed by in growth of granulation tissue, which was eventually replaced by a provisional matrix. The process of bone formation started as early as the first week following implantation. Both, contact and distance osteogenesis were seen. Between one and two weeks, bone tissue immediately lateral to the pitch region, that was responsible for primary stability, was resorbed and replaced by newly formed viable bone. Despite this temporary loss of hard tissue, implants remained clinically stable at all time. Thus, it can be

said that osseointegration represents a dynamic process, both during its establishment and its maintenance [27].

Albrektsson et al (1986) summarized the factors affecting this healing process by stating that implant osseointegration and success is dependent on the interrelationship of various components of an equation that includes:

(1) Biocompatibility of the implant material (2) The quality of bone in the implant site (3) Macroscopic nature of the implant design (4) Microscopic nature of the implant, the surface treatments and characterizations (5) Undisturbed healing phase (6) Prosthetic design and loading [28]

2.1.2.1 Biocompatibility of implant material

Commercially pure titanium and titanium – aluminum alloys are the most commonly used dental implant materials. The popularity of titanium as an implant material is attributed to its well proven biocompatibility. A biocompatible material can be defined as a foreign body that does not cause chemical, physiological or mechanical insult to the living tissue. Studies on the use of titanium as an implant material have shown [29]:

1. Titanium is resistant to corrosion -

Corrosion is visible destruction of the metal with rupture of structure, leaching of byproducts and loss of mechanical properties.

When titanium gets exposed to oxygen, it leads to the formation of titanium dioxide. This reaction converts the base metal into a ceramic

material that electrically and chemically passivates the implant surface [30]. Corrosion resistance of the implant is accredited to this surface oxide layer because it acts as a potent barrier against dissolution of the metal [29].

2. Titanium is bio-inert-

In vivo polarization studies, by *Steineman et al* (1985), have shown that titanium and its alloys belong to a bio-inert class incapable of causing a chemical insult to the body [29].

The titanium oxide layer around the implant surface grows through a specific mechanism wherein the oxygen ions migrate towards the metal and react with the titanium at the base of the oxide. This unique mechanism of oxide growth has a positive effect that no metal ion will leach out onto the surface and be released into the electrolyte [29]

3. Titanium is non toxic –

Rae et al (1975) in an animal study have shown that titanium alloys do not cause toxicity to macrophages or fibroblasts and do not cause an inflammatory response in peri-implant tissues [19, 31-34]

It can thus be established that, titanium is biologically safe. Furthermore, titanium has been shown to be capable of achieving osseointegration. The titanium dioxide layer gets hydroxylated when water comes in contact with it. This hydroxylated surface possesses an amphoteric nature, i.e., it has an electrical double layer which adsorbs blood proteins and cells which eventually result in bone formation [30].

The titanium oxide layer is amenable to modification by addition of ions such as magnesium and fluorides [35, 36]. These ionic supplementations in the bioceramic strata seem to enhance osseointegration as shown in some *in vitro* studies. For example, *Zreiqat et al* (2002) reported that magnesium increased adhesion of human bone derived cells and significantly enhanced levels of key signaling proteins and extracellular matrix protein collagen type I [37]. Fluorides have been shown to enhance the incorporation of newly formed collagen into the bone matrix, increase the seeding of apatite crystals, increase trabecular bone density and stimulate osteoprogenitor cell numbers [38, 39].

2.1.2.2 Quality of bone in implant site

Bone tissue is arranged in two macro architectural forms, trabecular or cancellous and cortical or compact. *Leckholm and Zarb* (1985) have classified bone types in the oral cavity, depending on the relative proportions of cancellous and cortical bone:

- Class I: predominantly cortical
- Class II: thick layer of compact bone surrounding a dense cancellous core
- Class III: thin layer of compact bone surrounding a cancellous core
- Class IV: very thin compact layer around a low density trabecular bone

Sennerby et al (1992) compared implants placed in rabbit cortical versus cancellous bone and established that cortical bone has a higher modulus of elasticity, is harder to deform and provides greater resistance to motion [40].

Hence, Class I and Class II bone would facilitate higher primary stability.

2.1.2.3 Macroscopic nature of implant design

Macroscopic features of the implant design encompass the implant shape, implant threads and the neck design at the implant abutment interface.

O'Sullivan (2000) compared the initial stability of implants with different designs in human cadavers and concluded that a tapered implant provides a wedging effect and offers greater primary stability than a cylindrical implant [41]. Similarly, a threaded implant increases the surface area for implant-bone interaction and provides mechanical interlocking, thus ensuring secure fixation [12, 19]. Instead, a smooth non-threaded implant would rely purely on press fit and frictional forces for initial stability.

Furthermore, *Orsini et al* (2012) showed that the pitch of the implant threads also seem to influence the osseointegration process. The smaller the pitch, the higher the bone to implant contact and greater the stability [42]. When such a micro-threaded modification is made to extend all the way to the neck of the implant, greater resistance to marginal bone loss and maintenance of bone levels have been observed in clinical trials done by *Shin et al* (2006) and *Bratu et al* (2009) [43, 44]. A microthread configuration is hence, now commonly used in many implant designs.

2.1.2.4 Microscopic nature of implant design

The first osseointegrated implant surface was produced by industrial machining of a bulk titanium implant, which lead to a minimally rough surface with some residual periodic microgrooves [45]. These surfaces showed a longitudinal success rate of 96% - 99%, over five years, in the mandible [46]. However, a study by *Jaffin et al* (1991) failed to replicate such a high degree of success in the maxilla. In fact, they showed a failure rate of 35% using machined Branemark implants [47]. This difference in success on the posterior maxillary arch when compared to mandibular arch can be attributed to difference in bone quality. The maxilla, being predominated by Class IV bone (mostly cancellous), seems to predispose to low implant stability and, many a time, lack of osseointegration.

To overcome this problem, implant surface modifications were developed. These modifications were aimed at accelerating bone healing and improving bone anchorage to the implant. Implant characterizations resulted in a biologically interactive implant surface with high surface energy, capable of improving matrix protein adsorption, bone cell migration, proliferation and finally osseointegration [45, 48]. Owing to these interactions, the newer rough implant surfaces promote both distance and contact osteogenesis, whereas machined surface seemed to heal only by distance osteogenesis [25]. A combination of distance and contact osteogenesis allowed for faster bone healing, higher success rates even in Class IV bone and shortened treatment time.

In fact, *Albrektsson et al* (2004) proposed that some of these modifications (namely coatings with calcium phosphate and fluorides) were capable of converting the bioinert turned surface into a bioactive / osteo-attractive surface [49]. Where a turned surface was essentially anchored in bone via a biomechanical bond, a bioactive modification allowed the implant to biochemically bond with living tissues. This can be exemplified by an experiment done by *Ellingsen et al* (2004), who reported significantly greater bone to implant contact and higher removal torques with fluoridated surfaces, in a rabbit study [36]. The same group of authors recently (2010) investigated the biologic factors involved in the improved retention of these implants. They observed a significant increase in genes responsible for mineralization of bone (osteocalcin and tartrate-resistant acid phosphatase – TRAP), in cortical bones alongside titanium implants treated with hydrofluoric acid using a cathodic reduction method [50].

Furthermore, surface treatments seems to help increase surface micro-roughness leading to an increase in surface area for mechanical interlocking and, hence, permitting higher primary stability, greater removal torque and enhanced bone to implant contact [51].

Another notable effect of these modified surface topographies and micro-roughness is their influence on cellular attachment and proliferation, extracellular matrix synthesis, growth factor release and cytokine production. *Schneider et al* (2003), reported increases in Runx2 and osteocalcin gene expression in cells

cultured on rough and grooved implant micro-topographies [52]. *Boyan et al* (1996), analyzed the role of surfaces in regulating bone cell response and concluded that surface micro-topography determines the pattern of cell adsorption, attachment and alignment along the implant surfaces [53]. A recent systematic review by *Wennerberg and Albrektsson*, concluded that smooth ($S_a < 0.5 \mu\text{m}$) and minimally rough ($S_a = 0.5\text{--}1 \mu\text{m}$) surfaces showed less strong responses than moderately rough ($S_a = 1 - 2 \mu\text{m}$) surfaces [54]. Consequently, a review of literature seems to suggest that in the early period of peri-implant healing, a micro-roughened surface stimulates osteogenesis, bone turnover and bone maturation [55].

Some biochemical surface modifications induced specific cell and tissue response by incorporation of organic molecules such as proteins, enzymes and peptides into the titanium oxide layer [45, 48, 56-59].

Besides this, attempts have been made to increase the hydrophilicity of surfaces by altering surface charges because hydrophilic surfaces are more desirable for interactions with biologic fluids, cells and tissues. *Buser et al* (2004), in an animal model, showed that increase in hydrophilicity yielded higher bone to implant contact [60, 61]. An *in vitro* study, comparing hydrophilic and hydrophobic surfaces, demonstrated that the expression level of bone-associated genes (alkaline phosphatase, *Onc*, type I collagen, osteoprotegerin and glyceraldehyde 3 phosphate dehydrogenase) was higher on hydrophilic surfaces [62]. Increases in

wettability and surface energy have been shown to possess higher potency to promote differentiation of osteoblasts by higher expression of cell differentiation and cell activity markers such as alkaline phosphatase and transglutaminase II [63]. Thus, with the available data, it can be concluded that wettability and surface energy influence the rate of protein adsorption and osteoblast adhesion on implant surfaces.

Today, more than one thousand three hundred types of implants varying in surface properties are commercially available [61, 64]. Various physicochemical, biochemical and morphological techniques have been developed. Surface modifications can be broadly classified as -

1. Surface deletions - which help increase roughness, and
2. Surface additions - various coatings, which enhance the biologic behavior

The following table summarizes some of these modification strategies [61, 65] –

Surface deletions	Surface additions
<ol style="list-style-type: none"> 1. Blasting <ol style="list-style-type: none"> a. Silica b. Alumina c. Titanium oxide 2. Acid Etching <ol style="list-style-type: none"> a. Hydrofluoric acid b. Nitric acid c. Sulfuric acid 3. Anodization 	<ol style="list-style-type: none"> 1. Calcium phosphate / Hydroxyapatite <ol style="list-style-type: none"> a. Plasma Spraying b. Sputtering (Magnetron and Radiofrequency Sputtering) c. Pulsed Laser Deposition d. Ion Beam Assisted Deposition e. Electrostatic Spray Deposition f. Biomimetic Deposition g. Discrete Crystalline Deposition 2. Biomolecule coatings <ol style="list-style-type: none"> a. Amino Acid Sequence RGD b. Collagen and Collagen Mimetic Peptides c. Collagen and Chondroitin sulfate d. Collagen Calcium Phosphate Composite Coatings e. Growth Factors <ol style="list-style-type: none"> i. Bone Morphogenetic Protein ii. Growth Factor iii. Platelet Derived Growth Factor iv. Fibroblast Growth Factor 3. Antibiotics <ol style="list-style-type: none"> a. Tetracycline b. Gentamycin

Table 1: Overview of some of the surface modifications done on implants

Some of these surface modifications have been tested in animal and human models but many are experimental and several others are being constantly developed.

2.1.2.5 Healing and loading

The original protocol for loading, as described by Branemark, involved waiting for three months (for mandible) to six months (for maxilla) after implant placement. Such a delayed loading protocol was aimed at allowing undisturbed healing and complete osseointegration before implants could be loaded. For a long time it was assumed that premature loading would limit peri-implant osteogenesis and induce fibrous tissue formation [19, 66].

However, over the last few decades, significant development in implant systems, surfaces and surgical techniques, have led to the evolution of alternative loading protocols, such as immediate and early loading. Recent studies, done at an ultrastructural level, have proven that the newer implant designs permit the use of immediate and early loading without disturbing the biological osseointegration process [12].

Schnitman et al (1990) introduced the concept of immediate loading, which has been described as attachment of the prostheses within twenty-four hours to one week after implant placement [67-71]. Some of the advantages of immediate loading are shortened treatment time and early functional, physiological and psychological rehabilitation of the patient. In addition, there have been some claims made about a biologic advantage in the form of enhanced osteoblastogenesis with immediate loading. An *in-vivo* study by *Qi et al* (2009), evaluated the response of mesenchymal stem cells to mechanical strain and their consequent gene expression patterns [72]. Their results suggested that mechanical strain might act as a stimulator to induce differentiation of stem cells into osteoblasts [72]. Indeed, cyclic tensile strain has been shown to increase osteoprotegerin synthesis and decrease soluble receptor activator of nuclear factor kappa-B ligand (RANKL), thus favoring bone formation [73]. This theory was tested in an rabbit model by *Duyck et al* (2007), who concluded that mechanical loading stimulated bone formation and led to a higher bone fraction [74-79].

Though there is limited evidence to substantiate this belief, the concept of preferential osteoblast differentiation during remodeling of bone around implants, via immediate loading, seems intriguing.

It seems plausible, from the literature, that the immediate loading principle provides significant benefits over delayed loading. But the question still remains whether there is enough evidence, in humans, for this modality of treatment to be used safely in all patients.

2.2 Complete Edentulism and its Treatment

2.2.1 Causes, Incidence and Effects of Complete Edentulism

Edentulism has been described as the loss of all permanent teeth [14]. Loss of teeth is a multi-factorial process that can be caused by the combination of biologic and non-biologic factors. Biologic factors may include caries, periodontal disease, pulpal pathology, trauma and oral cancer. On the other hand, non biologic factors may encompass access to care, treatment options and patient preferences [80]. The incidence of complete edentulism varies significantly among countries and has been estimated to be between 7% and 69% internationally [81]. Despite the decrease in edentulism prevalence during the last decades, there is still a considerable proportion of edentulous patients in the ageing society worldwide [82]. In fact, an oral health survey conducted in 2010 showed that 26% of the US population between the ages of 65 years and 74 years were completely edentulous [80].

Loss of natural dentition has multi-level effects among the geriatric population, with both physiologic and psychological implications [1]. Physiological impairment can be exemplified by residual ridge resorption, which has been considered one of the most important sequelae of edentulism [1, 2, 80]. It is well established that this resorption progresses at a much higher rate in the mandible versus the maxilla [3, 80, 83]. In addition, temporo-mandibular disorders, poor dietary intake and nutritional deficiencies have been shown to be significantly associated with edentulism [1, 84, 85]. A negative impact on social life, depression and personality changes are established psychological effects of loss of teeth [86-88]. Casual, but not causal, correlations has been made between complete edentulism and certain systemic diseases such as coronary artery plaque formation, diabetes and rheumatoid arthritis [80]. Thus, it is justified to say that people with no teeth are in a way “handicapped” or “disabled” and that edentulism is a part of general health problems in geriatric patients [80, 82, 89].

2.2.2 Traditional Treatment of Edentulism: Complete Dentures

Traditionally, complete dentures have been used for centuries to treat complete edentulism. Complete dentures are removable dental prostheses that replace the entire dentition and associated structures of the maxilla and the mandible [14]. Over the years, improved dental materials and better impression techniques have been developed and employed in the fabrication of complete dentures, resulting in more functional and stable prostheses. Despite these improvements, complete

dentures still present limitations in the reestablishment of chewing efficacy and bite forces [4, 5]. For instance, the chewing efficiency of denture wearers has been shown to be less than one sixth of those with natural teeth [90-92]. Moreover, patients with complete dentures are able to generate no more than 15% of bite force compared to dentate counterparts [93]. Some of the other shortcomings of complete denture prostheses are continuous residual ridge resorption, malnutrition, muscular deformation and articular alterations [5, 83, 94]. In addition, even well fabricated complete dentures are unable to uplift patient confidence and quality of life [5, 95]. Overall it is evident that complete dentures fail to successfully manage psychophysiological morbidities associated with complete edentulism.

2.2.3 Paradigm Shift in Treatment of Complete Edentulism: Implant Overdentures

An overdenture is defined as any dental prosthesis that covers and rests on one or more remaining natural teeth, the roots of natural teeth, and / or dental implants [14]. The concept of overdentures is age old. Ledger as early as 1856, suggested utilizing natural teeth to stabilize removable prostheses and after a whole century Miller introduced the concept of tooth retained overdentures [96]. The downside of these prostheses was frequent failure of abutments caused by periodontal disease, periapical lesions, caries and fracture of teeth [97].

The introduction of osseointegrated implants and implant-retained prostheses led to a paradigm shift for the management of edentulism. This is true especially for mandibular edentulism, where the problem of advanced alveolar resorption and difficulty in providing stable, retentive and functionally comfortable prostheses seemed to represent a major challenge [98].

A number of randomized controlled trials have demonstrated increased patient satisfaction and reduced negative impact on quality of life with implant retained overdentures as opposed to conventional dentures in the mandible [99]. Other studies have reported an improvement in chewing ability, bite force and in serum nutritional and anthropometric parameters (such as skin fold thickness, waist hip ratio and body mass index) [7-9]. The long-term efficacy of implant-supported overdentures has been established in many retrospective and longitudinal trials [6, 10, 11].

Implant overdentures are used in conjunction with attachments and there are many different attachments provided by a large number of manufacturers around the world. The attachments currently available can be broadly divided into two major categories:

- Splinted / Bar Attachments- Dolder bar and hader bar are examples of splinted attachments
- Non-splinted / Solitary / Stud Attachments - Ball attachments, magnets and locators exemplify solitary attachments.

The choice of attachment depends on the clinical situation at hand [100]. For example, splinted bars cannot be used in cases where the inter-occlusal space is limited. On the other hand, non-splinted solitary attachments require less inter-arch space, need minimal to no laboratory support, are less technique sensitive and can be fabricated at a lower cost.

However, implant success rate and marginal bone loss seem to be independent of the type of attachment used [100-102].

2.2.4 Loading of Implant Overdentures

A fairly recent systematic review by *Gallucci et al* (2009), presented the strength of evidence available for different loading protocols (conventional, early and immediate loading) in completely edentulous patients. Their search led to a conclusion that the highest level of scientific and clinical validation was available for conventional loading with mandibular overdentures. However, immediate loading of mandibular dentures was clinically well documented but not scientifically validated [13].

Clinical documentation of immediate loading can be exemplified by various prospective trials that have been conducted using this protocol for mandibular dentures. For example, a longitudinal study with 3-8 years of follow up by *Chiapasco et al* (2003), looked at success and survival of immediately loaded implants supporting a mandibular overdenture. Four implants were placed per patient, connected by a splinted bar attachment. A cumulative success rate of 88.2%

and survival rate of 96.1% was seen after a mean follow up period of 62 months. The authors concluded that, for about 3 years after immediately loading the implants, the success and survival were the same as that documented for delayed loading. However, with a longer follow up it became evident that immediately loaded implants had a moderate decrease in success rate [103]. Similar results were reported by *Kronstrom et al* (2010), wherein he advised caution in using immediate loading due to a low survival rate of 81.8% at 1 year follow up [104].

Other investigators have, however, reported higher rates of success and survival using an immediate loading protocol. A cohort study by *Gatti et al* (2002) has shown a cumulative survival rate of 100% and minimal bone level changes (0.5 - 0.9 mm) around immediately loaded implants [105]. *Alfadda et al* (2009) used historical controls with delayed loading in a prospective cohort study and compared it to immediate loading. At 5 years, they found identical success, survival, satisfaction and impact on quality of life between the two groups [106].

Randomized clinical controlled trials (RCT) are considered as the most reliable (Level I) form of validation in the hierarchy of scientific evidence, essentially because they reduce spurious causality and bias. In order to prove the efficacy and safety of an immediate loading protocol *Chiapasco et al* (2001), performed a RCT comparing an immediate and a delayed protocol for four splinted implants supporting a mandibular overdenture. They found no difference in cumulative

survival rate, bone loss, clinical and radiographic parameters at 2 years between the two groups [107].

Review paper by *Gallucci et al* (2009) and a 10 years clinical trial by *Meijer et al* (2009), among many others, have shown that there is no difference in the clinical and radiographic performance of two or four implants supporting a mandibular overdenture [11, 13]. Hence, having established that immediately loaded four implants supporting a mandibular overdentures are comparable to delayed loaded implants, it would be interesting to see if these results can be replicated when two implants were used in conjunction with unsplinted attachments such as locators.

3. Aims, Hypothesis and Objectives

3.1 Aims

The aim of this study was to evaluate, clinically and radiographically, immediate versus delayed loading of OsseoSpeed™ implants, six months post-surgery, supporting a locator retained mandibular overdenture.

3.2 Hypothesis

There is no difference in implant outcome as related to the timing of loading.

3.3 Objectives

3.3.1 Primary objectives

The primary objective is to evaluate implant bone remodelling using radiographic bone level changes as the variable, from baseline to six months, between the test and the control groups.

3.3.2 Secondary objectives

The secondary objectives include evaluation of:

- Implant survival at six months
- The nature and the frequency of surgical and prosthetic complications between test and control group
- Correlation between implant length and insertion torque on marginal bone level changes

4. Study Design and Procedures

4.1 Study Design

The study was designed to be a randomized controlled trial, whereby each patient received two implants supporting a locator retained mandibular overdenture. The patients were randomly assigned to either one of the following groups:

- Test group - immediately loaded, or
- Control group - submerged during implant surgery and loaded after three months of healing

4.2 Patient Selection

The Institutional Review Board, at the University of Connecticut, approved the research protocol and subjects were recruited from among patients seeking implant-retained overdentures at the University of Connecticut Health Center Dental Clinics.

An initial evaluation was conducted to determine whether the patient met the study inclusion criteria. This evaluation consisted of a medical history questionnaire, a clinical exam and radiographic assessment. An orthopantomogram was done for all patients and in some cases a Cone Beam Computerized Tomography was performed due to severe bone resorption. During this preliminary screening visit, a preoperative prosthetic evaluation of the existing prostheses was made to establish their quality and the need for a new set of complete dentures before the implant placement. Once the patient was deemed eligible, he/she signed an informed consent form and HIPAA waiver form. The mandibular denture was duplicated and used as a radiographic and a surgical guide.

4.2.1 Inclusion Criteria

Patients that were included in the study had to fulfill the following inclusion criteria:

- (1) Males or females ≥ 21 years of age
- (2) Ability to provide informed consent
- (3) Totally edentulous arch requiring or wearing mandibular complete denture
- (4)

Teeth in the implant sites have been extracted at least four months prior to implant placement (5) Adequate bone support to insert an implant that is 8 mm in length and 4 mm in diameter, without encroaching on vital structures (6) Insertion torque $\geq 20\text{Ncm}$, and (7) No need for major bone augmentation procedures

4.2.2 Exclusion criteria

Patients with the following systemic and local conditions were deemed ineligible:

- Systemic conditions

(1) Conditions that would prevent completion of study participation (2) Conditions requiring chronic routine use of antibiotics or requiring prolonged use of steroids (3) History of leukocyte dysfunction or deficiencies, bleeding disorders, neoplastic disease requiring radiation or chemotherapy, metabolic bone disorder, uncontrolled endocrine disorders, HIV infection (4) Use of investigational drugs or devices within 30 days of study period (5) Alcoholism or drug abuse and heavy smokers > 10 cigarettes a day (6) Simultaneous participation in other studies, and (7) Pregnancy

- Local conditions

(1) Untreated periodontitis (2) Erosive lichen planus (3) Local irradiation history (4) Osseous lesion (5) Unhealed extraction socket (6) Intraoral infection (7) Lack of primary stability, and (8) Inadequate oral hygiene

4.3 Study Procedures

4.3.1 Randomization and Allocation

Every patient was given a subject identification number. A blinded investigator (one who was not involved in the screening, treatment, follow up, data collection or analysis) used computer software to randomize the subject identification numbers into one of the two groups. This information was concealed in sealed envelopes, which were opened at visit 2 after Stage I implant surgery. Neither the surgeon, nor the patient was aware of the group assignment until the implants were in place.

4.3.2 Surgical Treatment

Stage I Surgery: Implant Placement (For Control and Test Group)-

The same experienced operator performed all the surgeries. Two implants (OsseoSpeed™, Astra Tech) per subject were inserted under local anesthesia, following administration of prophylactic antibiotic medications consisting of 2 grams of amoxicillin one hour before the surgical procedure. After making a crestal incision, a full thickness flap was elevated. The osteotomy site was prepared following the drilling sequence provided by the manufacturers surgical manual. The implant site was underprepared in relation to bone quality. The 3.2 and 3.7 mm twist drills were used as the final drill for Class III –IV and I – II quality bone respectively. The implant position was decided based on the radiographic/surgical guide. The implant was placed and the maximum value of

insertion torque (peak of insertion torque, IT) was measured during the seating of the most coronal implant threads by means of the surgical unit (W&H, Burmoos, Austria) and recorded as 20, 30, 40, 50 Ncm, >50Ncm. In case IT was lower than 20 Ncm the implants were submerged, the patient was excluded from the study and the implant treatment completed following the standard delayed protocol. For the control group a cover screw was placed and the implants were submerged under the oral mucosa. For the test group, Locator abutments were secured on the implant at 20 Ncm torque and the flaps sutured. Primary closure was achieved using 5-0 monosoft, interrupted sutures. Patients of the control group were not allowed to wear the denture for 14 days whereas those in the test group were instructed not to remove the denture for 7 days. As post-surgical instructions, the patients were asked not to brush the operated areas and to rinse instead with 0.12% chlorhexidine solution twice a day, for one minute for fourteen days. Pain control was provided with 400 mg Ibuprofen, as needed. Sutures were removed after two weeks.

Stage II Surgery: Un-coverry (Control Group Only)-

Subjects in the control group were seen at twelve weeks for second stage surgery. All control subjects were anesthetized and the crest was sounded to locate the cover screws. On localization, a minimal crestal incision was made and a conservative full thickness flap elevation done. Cover screws were replaced with the locator abutment and the flaps sutured with resorbable 5-0 chromic gut interrupted sutures.

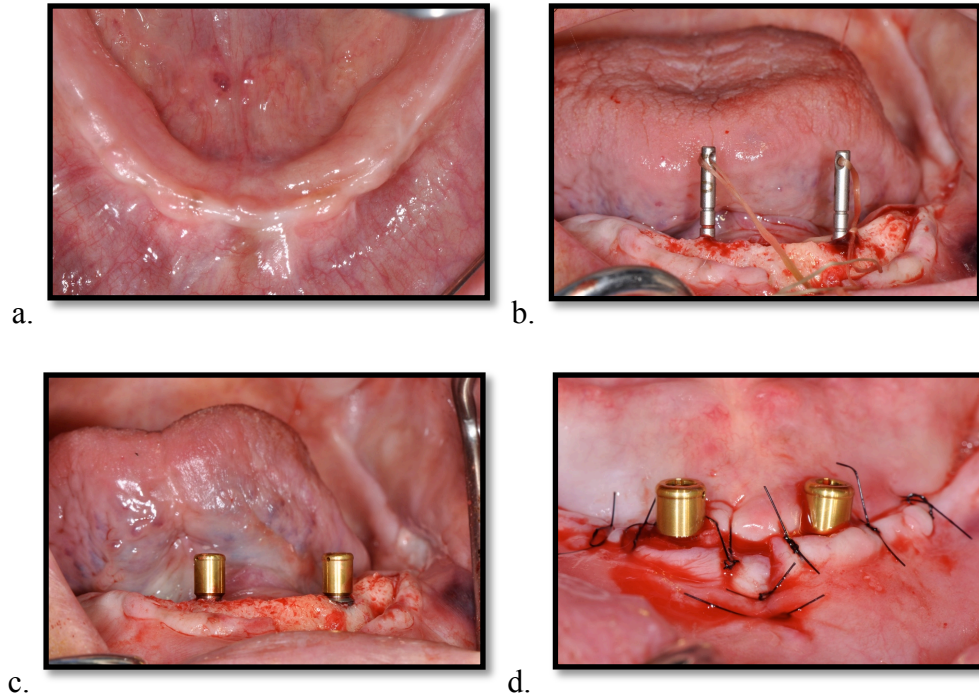


Figure 3: Clinical pictures of a patient who received immediate loading
a. Preoperative picture, b. Direction indicators after use of pilot drills, c. Abutments attached, d. Interrupted suturing using 5-0 monosoft

4.3.3 Prosthetic Treatment

1. Test Group

For the immediate loading group, the denture was immediately connected to the implants after Stage I surgery. The Locator cap attachments were picked up intraorally using cold curing resin. To avoid contact of the resin with the sutures and the surgical wound, a circular portion of a sterile rubber dam sheet was adapted on the cap attachment once placed on the Locator abutment during the pickup procedure. Occlusion and the adaptation on the residual ridges was then

checked and adjusted if necessary and the patient dismissed. No limitations to chewing function were given.

2. Control group

The subjects in the control group resumed the use of the denture 2 weeks post Stage I surgery. The dentures were used with soft reliner until the implants were uncovered. Uncovery / Stage II surgery and denture connection to the implants were done at 12 weeks

4.3.4 Follow – Up Visits

Patients were recalled at 1, 2 and 24 (+/- 1 week) weeks after surgery. At the post-operative visit occlusion, stability, and retention of the prostheses were evaluated and adjusted as required.

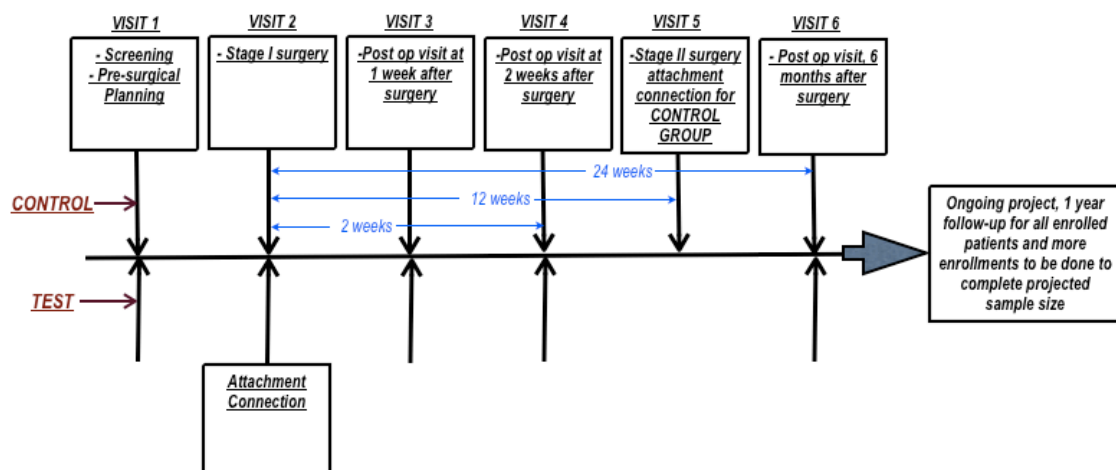


Figure 4: Study design for control and test group

4.4 Data Collection and Analysis

4.4.1 Radiographic Evaluation

Periapical radiographs were taken at the implant placement visit after surgery and at six months using the paralleling technique using a Rinn® (Dentsply Rinn, Elgin, Illinois, USA) film holder. The film holder was indexed on the Locator attachment so that the film position could be reproduced for the follow up radiographs.

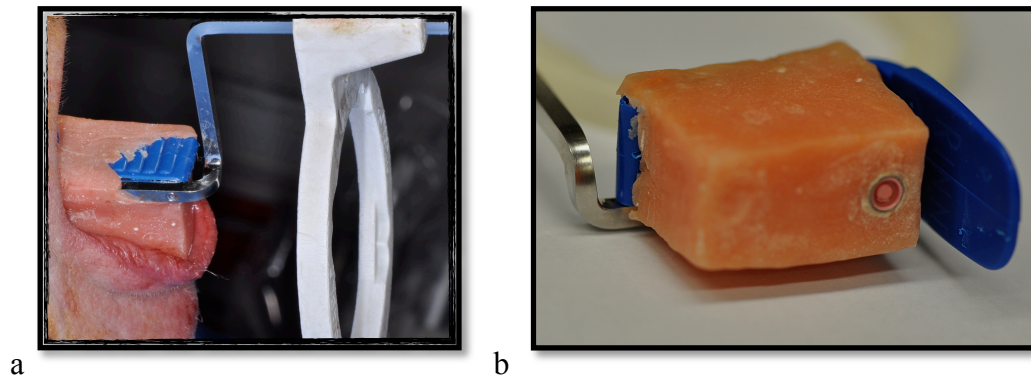
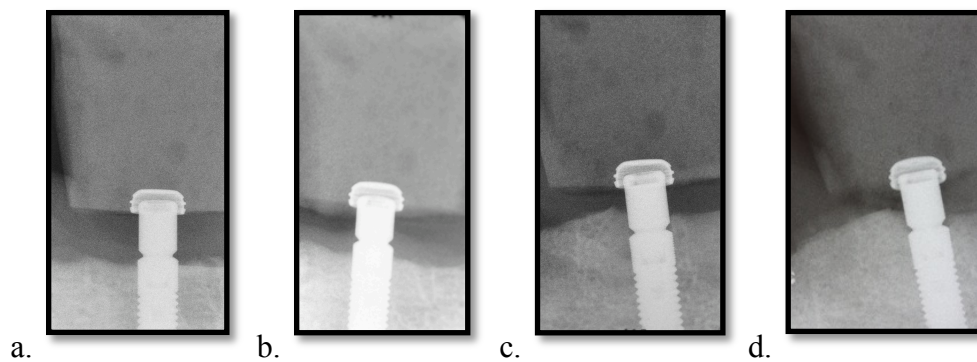
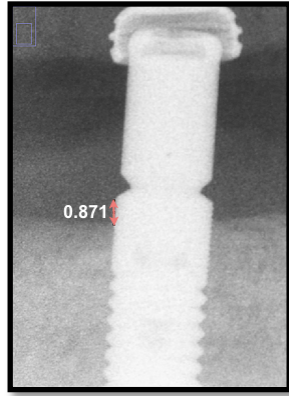


Figure 5: Indexed film holder used to standardize periapical radiographs





e.

Figure 6: Radiographs at baseline and at 6 months follow up visit

*a,c. Baseline radiographs for right and left implants
b,d. Radiographs at 6 months follow up for right and left implants
e. RBL as measured by a blinded examiner using Image J software*

4.4.2 Prosthetic Evaluation

A record of the number of extra visits made by every patient was maintained. The reason for the visit, nature of complaint, measures taken to manage the issue were all noted in the patient's chart.

4.4.3 Evaluation of Primary and Secondary Outcome Variables

As outcome variables the following clinical parameters were evaluated:

- Independent Variables

1. Patient demographics
2. Implant length
3. Implant insertion torque

- Dependent Variables:

1. Implant failure/success –

The success criteria for the implants were,

- a. No radiolucency around the implant,

- b. No mobility,
- c. No suppuration, pain or on-going pathologic process

Implants that did not fulfil the success criteria were considered as failed. The failed implants were removed and replaced with another implant after a minimum of eight weeks of healing of the implant site. The replaced implants were loaded after three months of undisturbed healing.

2. Radiographic bone level change –

Radiographic bone level change (RBL) was measured on standardized periapical radiographs. Radiographs were scanned in Tiff format at 800 dpi, were coded and read using an image analysis software (Image J, v 1.42., NIH, Bethesda Maryland.). A blinded examiner, who was unaware of the treatment protocol rendered, made the bone height measurements. The distance between the implant platform and the most coronal level of the bone deemed to be in contact with the implant surface was evaluated. Mesial and distal bone height measurements were averaged for each implant. The measurements of the bone level at implant placement were considered as baseline. The RBL change was calculated as the difference between the reading at six months and the baseline value.

3. Prosthetic complications -

The number and nature of prosthetic complications between the two groups were compared.

4.4.4 Statistical Analysis and Data Presentation

An implant and patient level analysis was done. The radiographic bone level change (RBL) was the main response variable used to evaluate the clinical performance of the two implant protocols. A RBL of 0.4 mm is considered to be of clinical relevance [108]. Sample size analysis was calculated based on an α error of 5% and a power of 80%. A minimum sample size of 16 subjects (32 implants) for each group was determined to be necessary to detect a difference of 0.4 mm with a standard deviation of the change of 0.5 mm (Primer of Biostatistic 5.0, Statistical package). The RBL was reported as mean \pm SD for each group and the means of the two groups were compared using a non-parametric test at patient level and at implant level. Data relative to patient demographics, number of extra visits, prosthetic complications and implant failure rates were considered as nominal data and presented with descriptive statistics. Correlations between peak insertion torque (IT) and implant length to RBL were evaluated using one-way ANOVA.

5. Results

5.1 Patient Enrollment and Randomization

Twenty-five patients were screened and seventeen were enrolled. Five of the enrolled patients were females and twelve males. Two of these eligible patients withdrew before the surgical phase, due to personal reasons while one was discontinued owing to non-compliance. Every patient received two implants in

the mandibular arch in the inter-foraminal space approximately in the lateral incisor – canine position. A total of twenty-eight implants were placed supporting fourteen complete dentures. All patients participated till the end of the study.

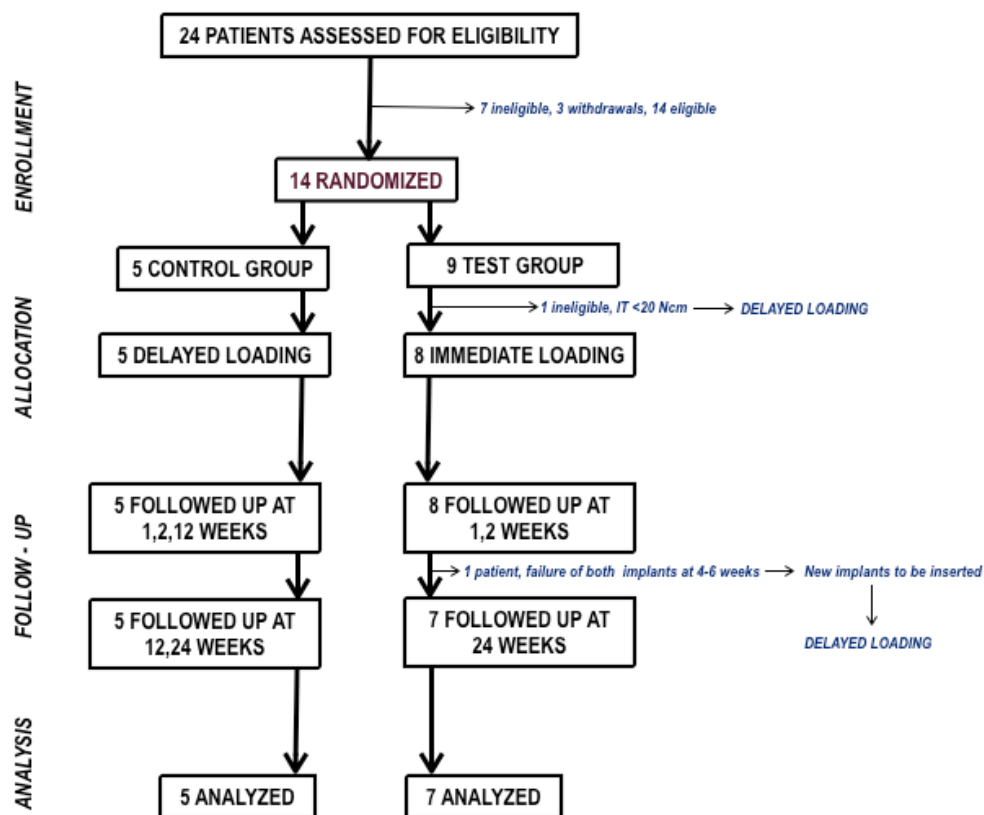


Figure 7: Flow chart of enrollment, allocation, follow-up and analysis

Ten implants (5 patients) of the total placed implants were loaded as per the delayed loading protocol. Eighteen implants (9 patients) were allocated to the immediate loading group. In one of these test group patients both implants had an insertion torque of <20 Ncm and therefore both the implants were submerged and

the patient was made ineligible for the study. Both implants were loaded at 12 weeks following the delayed loading protocol.

However, the projected sample size of 32 patients has not yet been met. Data that are being presented here are hence, an interim report of this on-going study.

5.2 Insertion Torque Distribution

IT distribution is reported in Table 2. The maximum insertion torque in the control group was >50 Ncm (40%) and the minimum was 30 Ncm (50%). In the test group the maximum and minimum torques were >50 Ncm (31.25%) and 20 Ncm (25%), respectively. No statistical difference was observed in the peak insertion torques in the two groups ($p=0.136$, *Mann Whitney Rank Sum Test*).

ALL PATIENTS					
PEAK IT (Ncm)	20	30	40	50	>50
NO. OF IMPLANTS	4 (15.3%)	3 (11.53%)	9 (34.6%)	1 (3.8%)	9 (34.6%)

CONTROL GROUP - DELAYED LOADING					
PEAK IT (Ncm)	20	30	40	50	>50
NO. OF IMPLANTS	0	1 (10%)	5 (50%)	0	4 (40%)

TEST GROUP - IMMEDIATE LOADING					
PEAK IT (Ncm)	20	30	40	50	>50
NO. OF IMPLANTS	4 (25%)	2 (12.5%)	4 (25%)	1 (6.25%)	5 (31.25%)

Table 2: Distribution of peak insertion torque (IT) at implant placement

5.3 Implant Length Distribution

Implant length distribution is reported in Table 3. Implants varying from 8-13 mm in length were used. In most cases (61.5%), 13 mm implants were placed. No statistical difference was observed between the implant lengths in the two groups ($p=0.063$, *Mann Whitney Rank Sum Test*).

ALL PATIENTS			
IMPLANT LENGTH	8 mm	11 mm	13 mm
NO. OF IMPLANTS	2 (7.6%)	8 (30.7%)	16 (61.5%)

CONTROL GROUP - DELAYED LOADING			
IMPLANT LENGTH	8 mm	11 mm	13 mm
NO. OF IMPLANTS	0	2 (20%)	8 (80%)

TEST GROUP - IMMEDIATE LOADING			
IMPLANT LENGTH	8 mm	11 mm	13 mm
NO. OF IMPLANTS	2 (12.5%)	6 (37.5%)	8 (50%)

Table 3: Implant length distribution

5.3 Implant Success and Failures

All patients healed with minimal discomfort and no swelling. There was 100% success in the control (delayed loading) group. However, one patient in the immediate loading group reported with continuous dull pain of one of his implants 4 weeks after surgical placement. This patient had no contributory medical history, was a non-smoker and had high primary stability (IT > 50 N cm) of the implants at insertion. He presented with no signs of post-operative infection but did report a history of implant failure in his maxillary arch. On clinical examination there was suppuration and mobility in relation to the implant. The implant was explanted at 4 weeks. The same patient reported 2 weeks later with a

similar complaint in the second implant. The second implant was explanted at 6 weeks after surgical insertion. Taking these failures into account, the success rate in the test group was 87.5%.

5.4 Prosthetic Outcome

Prosthetic maintenance was required in 7 (58.3%) out of 12 patients (one with implant failure has been excluded in this analysis). Three of these patients had a midline fracture of the prostheses while others reported for minor denture adjustments due to denture sores. The fractured prostheses were laboratory processed, relined and redelivered to the patients. The distribution of extra prosthetic maintenance visits required by patients, in each group is presented in Table 4. There was no statistical difference in the number of visits made by patients in the two groups ($p=0.488$, *Chi Square Test*).

ALL PATIENTS							
NO. OF EXTRA VISITS	0	1	2	3	4	5	6
NO. OF PATIENTS	5	2	1	1	1	1	1

CONTROL GROUP - DELAYED LOADING							
NO. OF EXTRA VISITS	0	1	2	3	4	5	6
NO. OF PATIENTS	1	1	1	1	1	0	0

TEST GROUP - IMMEDIATE LOADING							
NO. OF EXTRA VISITS	0	1	2	3	4	5	6
NO. OF PATIENTS	4	1	0	0	0	1	1

Table 4: Extra visits required by patients in each group for prosthetic maintenance

5.5 Radiographic Bone Level Changes (RBL)

DISTRIBUTION OF RBL AT PATIENT LEVEL IN DELAYED AND IMMEDIATE LOADING GROUPS						
RBL CHANGES (mm)	< 0.5	0.5 - 1	>1 - 1.5	> 1.5 - 2	> 2 - 2.5	> 2.5
NO. OF PATIENTS IN DELAYED LOADING	3	2	0	0	0	0
NO. OF PATIENTS IN IMMEDIATE LOADING	5	1	0	1	0	0
DISTRIBUTION OF RBL AT IMPLANT LEVEL IN DELAYED AND IMMEDIATE LOADING GROUPS						
RBL CHANGES (mm)	< 0.5	0.5 - 1	>1 - 1.5	> 1.5 - 2	> 2 - 2.5	> 2.5
NO. OF IMPLANTS IN DELAYED LOADING	5	3	0	2	0	0
NO. OF IMPLANTS IN IMMEDIATE LOADING	9	3	1	0	0	1

Table 5: Distribution of RBL in test and control groups at patient level and at implant level

Radiographic bone level changes for each group is shown in Table 5. The patient with implant failure is not included in this data analysis.

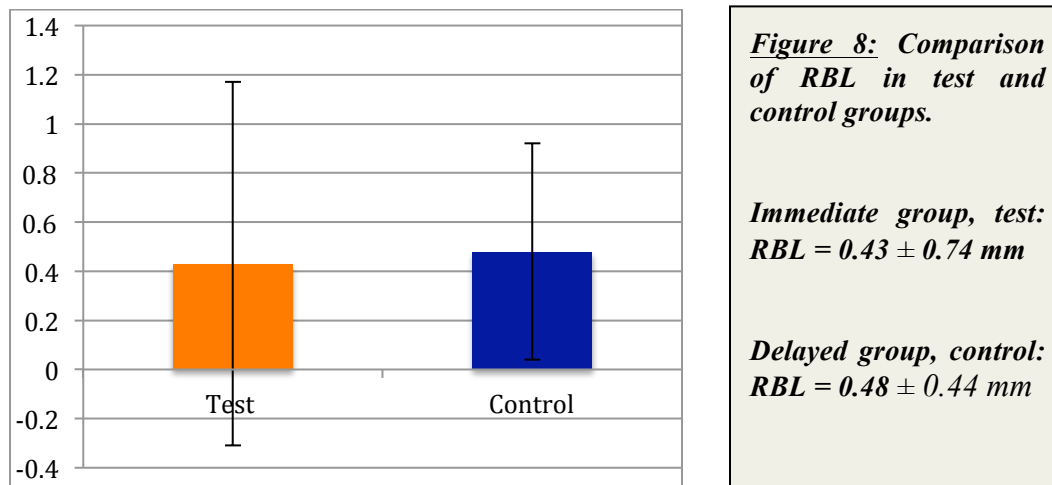
Within Group Analysis

When radiographic bone levels at baseline were compared to the levels after 6 months, at the patient level, significant differences were seen in the immediate loading group but not in the delayed loading group (Immediate loading, $p < 0.032$; Delayed loading, $p < 0.062$; *Wilcoxon signed rank test*)

However, when bone levels at baseline were compared to those at 6 months, at the implant level, significant differences were seen in both immediate and delayed loading group (Immediate loading, $p < 0.020$; Delayed loading, $p < 0.020$; *Wilcoxon signed rank test*)

Between Group Analysis

The average RBL after 6 months were 0.43 ± 0.74 mm and 0.48 ± 0.44 mm in the immediate and delayed loading groups respectively. No significant differences were seen when the RBL in the two groups were compared at the patient and at the implant level. Comparison of RBL in the two groups is shown in Table 6 and Figure 8.



COMPARISON OF RBL AFTER 6 MONTHS, IMPLANT AND PATIENT LEVEL ANALYSIS		
ANALYSIS	TYPE OF STATISTICAL TEST USED	LEVEL OF SIGNIFICANCE
IMPLANT LEVEL COMPARISON OF IMMEDIATE AND DELAYED LOADING RBL	MANN WHITNEY RANK SUM TEST	$p = 0.228$
PATIENT LEVEL COMPARISON OF IMMEDIATE AND DELAYED LOADING RBL	MANN WHITNEY RANK SUM TEST	$p > 0.06$

Table 6: Comparison of RBL in test and control groups at implant level and at patient level

Correlation Analysis

ANOVA was carried out to evaluate RBL in relation to implant length. No statistically significant difference was observed between the groups ($F = 1.31$, $p = 0.292$).

A similar correlation analysis with one-way ANOVA was done to evaluate RBL in relation to IT. No statistically significant difference was seen between the groups ($F = 1.18$, $p = 0.352$).

The maximum IT recommended by *Astra Tech* for OsseoSpeed™ implants is 35 Ncm. With this consideration, implants were categorized depending on their IT. Category I included implants inserted with IT ≤ 35 Ncm (recommended) and category II were the ones inserted with an IT of >35 Ncm (higher than recommended). A statistical analysis was done to evaluate if there was an effect of higher than recommended IT on the RBL. No significant correlation was seen ($p=0.725$, *Mann Whitney Rank Sum Test*).

6. Discussion

The aim of this study was to evaluate, clinically and radiographically, immediate versus delayed loading of OsseoSpeed™ implants supporting a locator retained mandibular overdenture, six months post-surgery. Our results show that there is no statistically significant difference in RBL around implants loaded with a delayed or an immediate protocol. However, a lower success rate of 87.5% was

reported in the immediate loading group versus 100% in the delayed loading group.

Two implants failed in one patient in the immediate loading group. The survival rate of immediate loaded implants supporting overdentures varies according to authors as reported in the literature. *Kronstrom et al* (2010) reported implant survival of 81.8%, when two implants supporting a mandibular overdenture were immediately loaded [104]. Conversely, a higher survival rate was reported by *Alfadda et al* (2009) in a longitudinal study comparing immediate loading of implant supporting overdenture to historical delayed loaded controls. They found 98% success in both the groups [106]. Similarly, *Chiapasco et al* (2001), in a randomized controlled comparison showed a cumulative success rate of 97.5% with either one of the loading protocols using four splinted implants supporting overdentures [107]. *Esposito et al* (2007), in his meta-analysis, stated that immediate loading can be successful only in selected patients and the trend suggests that immediate loaded implants may fail more often than those loaded with a delayed protocol [109-111]. In the present investigation, no conclusions can be drawn regarding survival rates since this is an interim report and the sample size is too small.

Radiographic bone level change was the main response variable that was evaluated in this trial. *Esposito et al* (1998) stated that biologically related implant failures are relatively rare. Hence, RBL has been used as a surrogate for implant

failure. There is substantial agreement and scientific evidence that intraoral radiographic bone level measurement is the most reliable method to monitor implant condition [112]. The mean RBL seen around immediately loaded implants, in our study, is consistent with the literature. *Gatti et al* (2002) studied the radiographic and clinical outcomes of immediately loaded implants supporting a mandibular overdenture in a prospective cohort and concluded that the mean bone loss was 0.5 – 0.9 mm at 2-year follow up [105]. Likewise, *Marzola et al* (2007) saw 0.7 mm of bone loss at 1 year, using an immediate loading protocol [113]. We reported RBL of 0.4 mm at 6 months post surgery. These limited peri-implant bone changes compared to others could be attributable to OsseoSpeed™ implants which possess distinct surface properties such as nano – roughened microstructure and micro - threaded coronal macro architecture. Animal studies show early peri-implant bone healing around nano-roughened implants and the micro-threaded coronal design seems to better maintain marginal bone levels [43, 44, 54, 114, 115]. Preclinical reports using these implants have shown increased bone to implant contact, enhanced removal torque, greater pull out forces and shorter healing time [36, 114, 116-118]. With the presented evidence combined with the results of our study, it can be suggested that OsseoSpeed™ implants are suitable for immediate loading.

Other clinical investigations using OsseoSpeed™ have shown bone gain around immediately loaded implants instead of bone loss. *Roe et al* (2011, 2010) reported bone gain of 0.58 mm using unsplinted immediately loaded implants. This

difference in outcome between our study and the *Roe et al* study could be due to differences in the sample size and method of evaluating marginal bone levels. Moreover, the *Roe et al* study was a case series, wherein only selected patients were included [119, 120]. Ours is a randomized controlled trial with a blinded allocation criteria and no selection bias.

When we compared RBL around immediately loaded implants and delayed loaded implants, we found no statistically significant difference. *Chiapasco et al* (2001) and *Romeo et al* (2002) made similar observations [107, 121]. Conversely, *Attard et al* (2005) compared immediate loading to historical conventionally loaded implants supporting overdentures and reported less bone loss around immediately loaded implants. This disparity in results could be attributable to heterogeneity in study design, follow up time and the type of prosthesis used.

Many studies evaluating immediate loading of overdentures have exclusively used long implants. *Roe et al* (2010, 2011) in their case series of immediate loading of overdentures used only 13 mm long implants [119, 120]. *Turkyilmaz et al* (2006), when evaluating early loading of implant overdentures, used 15 mm implants [122]. In the present investigation implants ranging from 8 – 13 mm were used. When the correlation between implant length and peri-implant bone loss was tested, no significant correlation was observed. Similar results were reported by our group in another trial, when evaluating immediate loading of implants supporting fixed partial dentures in a split mouth trial [123].

The IT values used in our study varied from 20 to >50 Ncm. *Esposito et al* (2009) in their Cochrane review stated that a high value of insertion torque seems to be a prerequisite for successful immediate loading [109]. Also, *Roccuzzo et al* (2009) in a systematic review concluded that immediate loading is a technique sensitive protocol and high insertion torque plays an important role in its success [124]. There is, however, a general lack of consensus with respect to the minimal IT required for immediate loading. We immediately loaded implants with IT as low as 20 Ncm and observed negligible RBL around those implants (raw data not shown). Conversely, we also used high IT of >50 Ncm in 34.6% of implants. Some authors have raised concerns about using high IT due to its detrimental effect on implant supporting bone [27]. *Bashutski et al* (2009) speculated in their case report that excessive insertion torque can cause compression necrosis and failure of implants [125]. When we correlated IT to RBL, no relationship could be established. Similarly, *Schincaglia et al* (2008) and *Khayat et al* (2011) showed that marginal bone levels in implants inserted with high insertion torques (up to 176 Ncm) are comparable to those inserted with lower torques even after 1 year of loading [123, 126]. Also, other studies have illustrated that insertion torque values have no implication on the bone to implant contact and higher values do not seem to alter the process of osseointegration [127, 128]. In addition, the manufacturers of this implant system have recommended a maximum IT of 35 Ncm. When implants with IT >35Ncm were compared to those placed with lower IT, no difference in RBL was seen.

The number of prosthetic maintenance visits made by patients in the two loading groups was similar. Most patients reported for minor denture adjustments while 3 of them presented with midline fracture of the denture. *Mackie et al* in 2011 carried out a longitudinal trial to determine the long-term prosthetic maintenance requirements of mandibular two implant overdentures using different loading protocols. This 8-year prospective study found no difference between the number of prosthetic maintenance events for patients loaded with either immediate, early or delayed protocols [129].

A key limitation of the data presented in this interim report, is the lack of adequate sample size and limited follow up period. We do realize that our small subject population may have led to a high possibility of falsely accepting the null hypothesis (Type II or β error). Once the projected sample size is reached and the subjects are followed up for at least 1 year, more substantial conclusions can be made.

7. Conclusion

In conclusion, within the limits of this interim report, immediate loading of two implants supporting a locator retained mandibular overdenture seems to be a suitable treatment option. The marginal bone level changes around immediately loaded implants are comparable to those seen around implants loaded with a delayed protocol, at 6 months post surgery. Implant length and peak insertion

torque do not effect peri-implant bone loss. Implant survival of immediately loaded implants maybe lower than those loaded with a delayed protocol, but this needs to be confirmed in future investigations with a larger sample size.

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