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CHANGING TRENDS IN IMMEDIATE LOADING OF IMPLANTS

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Abstract:

The surgical and prosthetic protocols for the successful placement of root form implants were first developed and reported by Branemark et al. Current loading protocol calls for a judicious modification of the conventional protocol by Branemark. Based on bone density, specific protocols have to be followed to ensure implant success. Many authors suggested that submerged healing period is not necessary, if micromovement of implant is within the tolerable limits of bone. Subsequently, several authors reported that root form implants osseointegrate predictably, even if they were exposed to the oral cavity through soft tissue. Immediate loading has the advantage of having less number of surgical steps, reduced pain and chair time. In addition, immediate loading stimulates the Wnt signaling pathways and the biomolecular mechanisms promoting osteoblast differentiation, which in turn leads to bone formation and remodeling.

Key words:- Dental implants, immediate loading, piezoelectricity, osseointegration.

Introduction

The surgical and prosthetic protocols for the successful placement of root form implants were first developed and reported by Branemark et al[1]. The conventional two-stage protocol consisted of pre requisites like countersinking of implant below the bone crest and achieving a soft tissue covering over the implant without any application of load for 3 to 6 months[2]. The treatment period very often extended upto one year which was a major cause of concern and distress not only to the patient but also to the treating dentist. Hence some of the researchers explored the feasibility of challenging the conventional delayed loading protocol. Dr Leonard Linkow[3] in the 1960's introduced the blade implants that followed the immediate loading protocol. He suggested insertion of definitive prosthesis 3-6 weeks following placement of implants. In 1970's Scroeder et al[4] showed that submerging implants with a long healing period was not mandatory for osseointegration.

Among the different surgical paradigms in Branemark era, the only one still followed is the atraumatic drilling procedure in order to eliminate elevation of temperature in the surrounding bone[5]. Current loading protocol calls for a judicious modification of clinical protocol by Branemark. Misch established a protocol in 1988, which adapts the treatment plan involving implant selection, surgical approach, healing regimen and initial prosthetic loading which would establish implant success irrespective of different bone densities and arch positions[6,7,8,9]. Each bone density had a specific protocol that needs to be followed to ensure implant success.

Subsequently, several authors reported that root form implants osseointegrate predictably, even if they were exposed to the oral cavity through soft tissue[10-12]. This surgical approach was called one stage or non-submerged implant protocol. Gradually, immediate loading of implants came into light with certain modifications in surgical and prosthetic phases. Many authors suggested that submerged healing period is not necessary if micromovement of implant is within the tolerable limits of bone. Since then numerous reviews and consensus statements supported the immediate loading protocol[13]. Branemark himself overturned his recommendations and published his first article on immediately loaded implants in 1999[14].

Considering the Cochrane Report and the 4th ITI Consensus Conference[15], group 3 on loading protocols for the edentulous patient recommends the following ITI definitions for dental implant loading:

Conventional loading (CLI): a healing period of more than 2 months after implant placement.

Early loading (ELI): between 1 week and 2 months subsequent to implant placement.

Immediate loading (ILI): within 1 week subsequent to implant placement.

Immediate loading has the advantage of having less number of surgical steps, reduced pain and chair time. Ledermann, in 1984 reported a 91.2%survival rate for 476 Titanium-plasma sprayed implants which were splinted and immediately loaded in 138 patients[16]. With the advent of newer techniques and newer implant surface modifications, several authors now report 95-100% success rate[17,18]. The purpose of this review article is to give an overview of the immediate loading protocol from a clinician's point of view.

Discussion

Principle of immediate loading

During the Branemark era, it was believed that all micromovements led to fibrous encapsulation of the implants. Subsequently, Cameron et al in 1973[19], put forward the concept of threshold micromovement for implant osseointegration based on his findings that all micromovements does not lead to unwanted fibrous tissue repair. During the healing period, when the implant is subjected to occlusal loading, osseointegration can be obtained by keeping the micromovement within the threshold limit of 50-150 microns[13].

However Maniatopoulos et al,[20] in their study conducted in 1986, suggested that threshold micromovement does exist which is design/ surface dependent. A recent study by Engelke W et al has also documented that quality of the bone also determines the amount of micromovement[21].

How much micromovement is permissible..?

Over the years, different studies have proposed different thresholds of micromovement. 100μm was proposed by Brunski as a rule of thumb[22]. Depending on the nature of the implant surface and the quality of bone, the tolerance threshold for micromovement varies. Machined sufaces have the lowest tolerance i.e., less than 30μm[23]. The tolerance of roughened surfaces like that of Ti plasma sprayed is considered much higher than that of machined. Although, the threshold is not yet been precisely determined, it is known to be between 50-150μm[13]. The tolerance is the highest for bioactive surfaces, which still is not exactly established, but, considered between 250-500μm[23,24,25].

The association between the amount of biomechanical loading, and the extent of micromovement at the interface has been poorly investigated. An axial force of 13-16N produced 100μm movement in the axial direction, which again varies with implant design and bone quality[13].

The quality of the bone at the implant site also dictated the amount of lateral movement around the implant.(Engelke W et al)[26]

- In type 1 bone, a force of 30 N does not cause any detectable movement.
- In type 2 bone, 5-20N of force produced micromovement of 20-50μm, and when 30N of force is exerted, the critical threshold of 100μm is reached.
- In type 3 bone, 5-20N force caused micromovement of 50μm and With 30 N lateral force applied, micromovement exceeded the critical limit of 100μm i.e.,150-170μm.
- In type 4 bone, 5-20N force did not produce micromovement more than 100μm, but 200μm of movement was induced by 30N force.

The same force produced different ranges of micromovement around the implant depending on the bone quality. So, the type of bone in which the implant is placed also affected the micromovement.

Primary stability

An essential requisite for the successful immediate loading of dental implants is primary stability (Espositi 2009, Hartog et al 2008)[27,28], which depends on quality of surrounding bone, implant sink depth, surgical technique, implant design and placement technique. This also decreases the amount of micromovement around the implant. Functional loading on an immobile implant is an essential ingredient to achieve osseointegration (Roberts et al. 1984)[29]. Periotest (-8 to 0), Resonance Frequency Analysis (more than 60) and Insertion Torque (20-50N) are used to assess the primary stability of the implant.

If the axial positioning of the implant is not satisfactory insertion torque has to be increased. High insertion torque values that exceed the elastic limit of the bone is however not recommended. This may lead to compression necrosis which will ultimately proceed to marginal bone resorption30. So, although primary stability of the implant is an undisputed requirement for immediate loading, the ability of the diagnostic tests to measure this is still disputed. It always takes a skillful surgeon to identify the bone conditions under which the patient can be treated conventionally.

If optimum primary stability can't be achieved due to the quality of the bone, several surgical techniques have been described to achieve this

- Undersized drilling technique:

Implants inserted in the undersized beds compress the bone to increase its density, and there by increasing the primary stability. (Alghamdi et al 2011)[31]

- Osteotomes:

They result in apico-lateral condensation of the peri-implant bone, and thereby changing their micromorphology which increases the primary stability of the inserted implant[32,33].

- Bicortical anchorage:

Cortical bone has higher density than cancellous bone. Implants could be anchored in the alveolar cortical bone, but by engaging them in sinus floor, pterygomaxillary bone or even in the nasal floor, double anchorage could be obtained, which further increases the implant stability by increasing the bone implant contact[34].

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- Osseodensification (OD):

With the introduction of osteotomes by Summer[35,36], for increasing the primary stability of the implants by bone compaction, the idea to improve the available bone density rather than to utilize the existing density became popular. In 2013, Huwais et al[37] introduced osseodensification using specially deviced drills. This technique brings about bone preservation as well as condensation through compaction autografting during osteotomy preparation.

Secondary stability

The secondary stability of a dental implant largely depends on the degree of new bone formation at the bone-implant interface[38]. According to Wolff's Law, the subsequent phase of load oriented bone remodeling leads to a replacement of primary woven bone to realigned lamellar bone. This enables optimal transmission of mechanical stimuli to the adjacent bone. At the end of the remodeling phase, about 60–70% of the implant surface is covered by bone[39]. This phenomenon has been termed bone-to-implant contact and is widely used in research to measure the degree of osseointegration. According to the concept of mechanotransduction, bone remodeling continues lifelong[40]. Research efforts have been focused on designing novel topographies of implant surfaces to optimize osteoblastic migration, adhesion, proliferation, and differentiation.

Molecular level changes in implant-bone interface

An understanding of the Wnt signaling pathway, which is involved in bone remodelling is essential before we proceed onto the molecular changes. The Wnt signaling pathway is a ubiquitous system for intercellular communication, with multiple functions in the development and homeostasis of humans and many other species. The name Wnt was derived from a Drosophila gene known as Wingless (Wg) and a mouse proto-oncogene named int1 (integration 1). The Wnt signaling pathwayis known to be important for the regulation of bone formation, influencing osteoblast differentiation, osteoblastogenesis, and osteoclast formation. Two different Wnt pathways have been described, distinguished by the extent to which each promotes β-catenin stabilization within the cytoplasm. The canonical (β-catenin-dependent) pathway regulates multiple aspects of skeletal development, controlling differentiation and function of mesenchymal stem cells (MSCs), chondrocytes, osteoblasts, and osteoclasts. It plays an important role in steady-state conditions. The noncanonical (β-catenin independent) pathway plays a significant role in cell polarity and cell motility. The noncanonical pathway may be Frizzled (Fz)-dependent (also known as the "Planar Cell Polarity (PCP) pathway") or calcium dependent (known as the Wnt/Ca++ pathway)[41].

When occlusal and masticatory forces are applied to jawbone, new bone formation takes place due to the stimulation of the lacuno-canalicular network of the osteocytes. This phenomenon also occurs around teeth under orthodontic movement and around implants under loading[42]. The mineral content of bone within the threads of implants for which slight occlusal contacts were present immediately after implantsurgery was significantly higher than that found when the implants were loaded only after they osseointegrated[43-45]. Two areas seem to play a significant role in the healing of immediately loaded implants. Compressive and tensile forces on the bone in contact with the implant surface may activate the Wnt canonical pathway, fostering the new bone formation. Secondly, in the areas within the implant threads, angiogenesisand collagen matrix formation occur initially due to the activation of the noncanonical PCP pathway, causing cells to migrate to the wound site, while activation of the Wnt/Ca++ pathway in the bone marrow controls cell fate and supports further cell migration[41].

Stimulation of the Wnt signaling pathways, the biomolecular mechanisms promoting osteoblast differentiation, has been proven to control bone formation and remodeling. Fundamental knowledge of these mechanisms and control of the inhibitory pathways in areas of poor bone quality after placement of implants with rough microstructures may provide new therapeutic approaches to enhancing osteogenesis, especially around implants that are immediately loaded[41].

Piezoelectricity and Osseointegration

The piezoelectricity of bone is known to play a crucial role in bone adaptation and remodeling[46]. The application of an external stimulus such as mechanical strain or electric field has the potential to enhance bone formation and implant osseointegration. It is evident from experimental studies[47] that the mechanical loading induces changes in thebone electric potentials in a way that regions exposed to compressive loads generated negative potentials, whereas those exposed to tensile loads generated positive potentials. For electromechanical simulations, negative potentials are associated with osteoblast-induced bone formation, whereas positive potentials are associated with osteoclast-induced bone resorption[48]. These electrical potentials play a vital role in the process of bone healing and remodeling[47]. Placement of electrodes in bone leads to bone deposition around the charged cathode and reportedly to bone loss around the anode49. It was not emphasized that bone formed around the electrodes when placed into bone even when there was no potential difference across the electrodes. In addition, bone formed when no electrical circuit existed thus excluding galvanic action. The technique of osseointegrated implants is a further demonstration that the insertion of a metallic structure within bone is sufficient per se to stimulate bone deposition. The piezoelectric bone remodeling algorithm can also be employed for applications investigating the effect of electrically active implants in the adjacent bone tissue with respect to peri-implant bone remodeling[50,51].

General considerations in immediate loading of implants

1. Patient considerations
2. Bone quality considerations
3. Implant considerations
4. Prosthetic considerations

1. Patient considerations in immediate loading

The greater the occlusal force applied to the prosthesis, the greater the stress at the implant-bone interface and the greater the strain to the bone. Therefore force conditions that increase the occlusal load increase the risks of immediate loading. Parafunction such as bruxism and clenching represents significant force factors because magnitude of the force is increased, the duration of the force is increased and the direction of force is more horizontal than axial to the implants with a greater shear component[2]. Balshi and Wolfinger reported that 75% of all failures in immediate occlusal loading occured in patients with bruxism[52]. Parafunctional loads also increase the risk of abutment screw loosening, unretained prosthesis, or fracture of the transitional restoration used for immediate loading. If any of these complications occur, then the remaining implants that are loaded are more likely to fail.

2. Bone quality considerations in immediate loading

Type IV and V quality bones are generally not suitable for immediate loading of implants, except for the case of single implant without any functional loading. Generally, bone types II and III have been advocated for an immediate loading protocol by several authors (Szmukler-Moncler et al. 1998; Balshi et al. 2005)[13], due to their innate stability and regenerative capacity. Even though most of the authors confirm a greater primary stability of implants in type I bone, a few of them reported a considerable decrease in stability in such cases, particularly during the first month of assessment.

3. Implant considerations in immediate loading

The prime goal for an immediately loaded implant-prosthesis system is to decrease the risk of occlusal overload & its resultant increase in the remodeling rate of bone. Methods to decrease microstrain & remodeling rate in bone is to provide conditions that increase functional surface area to the implant-bone interface. The surface area of load may be increased in a number of ways: implant number, implant size, implant design, and implant body surface conditions[2].

Implant number

In general, two different protocols have emerged: The first approach involves placing more number of implants than required for the conventional loading protocol. Selected implants around the arch (three or more) are loaded immediately with a transitional prosthesis. Enough implants were kept submerged to load them in the conventional manner if immediately loaded implants fail. This was first proposed by Schintmann (1990)[53], by placing 5-6 implants in the anterior mandible and 2 implants distal to mental foramina, and finally loading only 2 distal implants and 1 anterior implant. He suggested this technique only be used for edentulous mandible, where moderate to abundant bone was present both anterior and posterior to mental foramen. In 1999 Tarnow et al[54] who reported on immediate loading did not immediately load all the implants in the transitional prosthesis.

The other protocol is to immediately load all the inserted implants[55-58]. Implants are splinted together, which -

a. Decreases stresses on all developing interfaces &

b. Increases stability, retention & strength of transitional prosthesis during initial healing phase.

Misch proposed placing 8 splinted implants or more for maxillary edentulous conditions. 6 splinted implants or more in mandible, depending on the density of the bone or if force factors are on the higher side[2].

Implant size:

Implant diameter: larger diameter implants were recommended by Misch for posterior regions[2].

Implant length: Lederman in 1979 recommended the use of 11mm implants for immediate loading. Later theimplants were made longer, stating that longer implants provided more primary stability[59,60]. However it was later established that increasing the length more than 15mm added little benefit[61,62]. Each 3-mm increase in length can improve surface area support by more than 20%. Benefit of increased length is not found at crestal bone interface but rather in initial stability of bone-implant interface. Crest of the ridge is where the occlusal stresses are greatest. As a result, width is more important than length of implant[2].

Implant design: more threads and deeper threads were recommended for immediate loading[2]. A screw shaped design was considered as more successful in a recent review[63].

Surface condition: Implant surface conditions may affect

a. Rate of bone contact,

b. Lamellar bone formation,

c. Percentage of bone contact.

Surface condition that allows bone formation in greatest percentage, higher BIC with higher mineralization rate, and fastest lamellar bone formation would be of benefit in immediate loading. HA coated surfaces were recommended in poor bone conditions.

Higher removal torque value (RTV) of dental implants might lead to a more predictable use of short implants and to support prosthesis with a smaller number of implants and allows shorter healing periods.

4. Prosthetic considerations in immediate loading

Splinting : In case of full arch restorations cross arch stabilization with passive fit of the restorations, is essential for minimizing the micromovements. In case of single implants, good interproximal contacts provide the necessary stability to prevent micromotion and promote osseointegration. The presence of rigid splinting also helped to decrease the amount of lateral movement during the early loading phase, thereby reducing the micromovement. Splinting also help to distribute the load over a greater surface area and thereby reduce overloading.

Interim prosthesis : metallic reinforcement of the interim prosthesis is a necessity in maxillary complete dentures. In case of maxilla the forces are applied in a centrifugal direction, unlike the mandibular complete dentures. In addition the bone density of maxilla is less compared to mandible. The presence of embrasure spaces in maxilla further weakens the prosthesis. In case of mandible, however the resin bulk can provide the necessary stability. And metallic reinforcements are rarely used in case of mandible.

Screw or cement retained: A comprehensive review on the prosthetic aspects of immediate loading concluded that screw retained restorations provided a better result, as they were easier to follow up during the healing period.

Occlusal contacts : there are a lot of disagreements regarding when and how to provide occlusal contacts. In the earlier days, full occlusal contact was adviced by Aparicio et al[64], and Nkenke et al[65]. However, the recent concepts stress on keeping the prosthesis out of occlusion in the healing period, recommending a provisional with flat occlusal surfaces. And all authors recommend only keeping centric contacts in case of fully edentulous cases, with a narrowed occlusal surface. A 30% reduction in the surface area decreases the force by 48%.

Conclusion

Just a skillful surgeon will be able to identify the optimal bone conditions under which the patients can be treated conventionally. In summary, when primary stability is achieved and a proper prosthetic treatment plan is followed, immediate functional implant loading is a feasible concept. However, if the primary fixture stability cannot be achieved or is questionable, it is strongly recommended to follow a conventional treatment protocol including an adequate healing time before loading.

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