10 Loading Strategies

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Abstract

Implantology has offered an alternative to the conventional denture providing much more stability and retention. This alternative is referred to as an implant overdenture. According to *The McGill Consensus Statement on Overdentures* (Romanos, Advanced immediate loading, Quintessence Books, 2012, p. 179), the minimum standard of care for an edentulous mandible is a two-implant overdenture. Therefore, in the case of an edentulous mandible, conventional dentures should be considered an alternative treatment. In fact, there are several advantages of two-implant overdentures as they improve support, retention, and stability. Consequently, they improve the patients' ability to chew food. Patients found implant overdentures more comfortable, and an ease of speech was noted in comparison with a conventional denture (Romanos, Advanced immediate loading, Quintessence Books, 2012, p. 179). Implant overdentures should also be considered for their benefits from a bone-conservation point of view. Implants stimulate the bone and help maintain its level (Davarpanah and Szmukler-Moncler, Manuel d'implantologie clinique: concepts, protocoles et innovations récentes, Paris, 2008).

The timing suggested for implant loading after placement of the implant, which also refers to the delivery of the prostheses, varies. Traditionally, there was a wait period of 3–6 months prior to implant loading in the mandible which is referred to as the conventional loading protocol, introduced initially by Brånemark (Javed and Romanos, J Dent 38:612–20, 2010). In order to reduce this wait period, other protocols have been introduced: immediate loading (under 1 week) and early loading (1 week to 2 months). Additionally, due to improved implant surfaces and techniques, conventional loading is now acceptable as of 2 months (Misch, Contemporary implant dentistry, Elsevier Health Sciences, 2007; Misch et al., J Oral Maxillofac Surg 57:700–6, 1999). There are numerous factors that come into play when determining the appropriate loading protocol.

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10.1 Introduction

In the last decade, immediate loading has been introduced as a viable option to reduce the wait period and accelerate implant treatment.

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However, the success of this concept relies mainly on implant stability and adequate osseointegration. Several factors have been identified as playing a key role in osseointegration: initial implant stability, implant surface characteristics, bone metabolism, interim prosthesis design, and occlusion pattern during the healing phase [1]. Ideally, all these factors should be considered in the selection of an appropriate loading protocol for the edentulous patient.

This chapter will explore the different factors affecting the osseointegration of an implant. It will describe various methods of evaluating the stability of the implant in the bone. Finally, conventional, early and immediate loading protocols will be defined and discussed.

10.2 Osseointegration

10.2.1 Concept of Primary Stability

In order to have a long-term success with dental implants, the surrounding bone has to be mechanically stable, bearing the occlusal loading forces. Initial mechanical stability of the implant with the surrounding lamellar bone is necessary during implant insertion. The gentle osteotomy, without overheating or significant mechanical trauma, is necessary to get good primary contact between the implant and bone. This is clinically determined as primary implant stability [1].

Primary stability is defined as the mechanical anchorage immediately after implant insertion. It is obtained by surface of contact between the implant and bone [2, 3]. It is an important factor in the establishment of osseointegration and contributes to determining the prognosis of the implant and, in consequence, to the choice of the appropriate loading protocol [2].

Primary stability is obtained through the quality and quantity of the contact area between the implant and the bone [2]. The measure of this contact area is given by the bone-implant contact (BIC) measured in percentage [4]. Several factors related to the bone (bone quality and quantity) and implant type (implant length, diameter, surface type, and macrogeometry) influence the BIC.

The quality of bone density has been classified into four categories by Lekholm and Zarb [2, 4]. Quality 1 bone consists of homogenous compact bone, quality 2 consists of a thick layer of cortical bone surrounding a think layer of compact trabecular bone, quality 3 consists of resistant trabecular bone surrounded by a thin layer of cortical bone, and lastly quality 4 consists of low-density trabecular bone surrounded by a thin cortical bone layer [4]. Low-density trabecular bone, being more porous than cortical bone, offers a reduced BIC and leads to uneven and concentrated force distribution from implant to bone. The increased forces on the implant-bone interface can lead to excessive microstrain and in some cases implant mobility and failure [4, 5]. In general, higher bone density has a higher BIC, and consequently, the greater the bone density, the greater the primary stability [4]. However, it is to be noted that this does not automatically translate to a higher implant success rate.

Next, the implant length plays an important role in increasing the bone-implant contact area. A longer implant can increase the bone-implant contact area and further engage the cortical bone [6–8]. Ideally the length should vary between 10 and 15 mm. An implant length above 15 mm is deemed unnecessary. The risk of implant failure increases if the implant length is under 10 mm [8]. In the case of poor bone quality, an increase in implant length has a more significant increase on primary stability [7]. In fact, every 3 mm increase of length of the implant can increase the bone-implant interface (or contact area) by approximately 20–30% [5]. However, placement of short dental implants could be a predictable alternative to longer implants to reduce surgical complications and patient morbidity in situations where vertical augmentation procedures are needed. The 1-year and 5-year cumulative survival rates for short implants were reported to be 98.7% and 93.6%, respectively [9].

It is found that the larger the diameter, the greater the primary stability due to the increased contact area [8]. This is limited by the width of the alveolar ridges. Increased diameter implants allow for a greater distribution of forces by further engaging the cortical bone, thus increasing primary stability and reducing micromotions [4]. This effect is more prominent in the cortical bone already absorbing a greater proportion of forces due to its larger contact area [2]. However, it should be noted that several studies on wide-diameter implants have reported an increased failure rate, which was linked with over-instrumentation and heat generation [10]. More recent studies believe the failure rate is mainly associated with operators' learning curves, poor bone density, implant design, and site preparation [11]. Hultin-Mordenfeld et al. reported a higher implant failure rate with wide-diameter implants but better results in the mandible (94.5%) than the maxilla (78.3%).

Next, macrogeometry and morphology can influence the BIC as well. Primary stability was found to be more positively affected by a slightly tapered implant in comparison to a cylindrical one [12]. With regard to the macrogeometry of the implant, the form of the neck is important as it engages the cortical, and in a lower-density bone, smaller treads promote a better primary stability [5].

Additionally, the surface topography of the implant is an important factor in the process of osseointegration. However, surface topography does not affect primary stability and will be discussed in the next section regarding secondary stability [13].

After taking into consideration and maximizing all these variables, it is important to assess the implant's primary stability. To do so, it is recommended to evaluate the implant's torque. A torque is a measure of the force applied to the implant causing it to rotate and is expressed in newton centimeters (Ncm). There are different ways of assessing it, such as cutting torque resistance analysis and insertion torque value (ITV). For cutting torque resistance analysis, a torque gauge is incorporated into the drill used to cut into the bone. This measures the energy required to cut the bone. This value correlates with bone density types which contribute to the primary stability [3]. Cutting resistance during insertion is commonly used to determine primary stability. In this case, a sudden stop while seating the implant indicates better primary stability [14]. However, one of the preferred techniques of assessing primary stability is the ITV, a measure of the highest insertion torque obtained by the motor during placement of the implant. ITV of 32, 35, and 40 Ncm and higher have been suggested as indicating adequate stability for an immediate loading protocol [3, 15, 16]. Studies demonstrate a high failure rate at 20 Ncm or less with an immediate loading protocol (ILP) [17], and so many studies exclude ILP when the ITV is low. Additionally, it is to be noted that several studies found that there was no statistically significant difference in insertion torque and cutting resistance in failed versus successful implants with a conventional loading protocol [18, 19].

Above, the graph (Fig. 10.1) represents a generalized overview of early wound healing after implant placement: showing the implant stability in function of time. It is suggested that implant stability is at its maximum immediately following the surgery; this is known as primary stability. In the beginning, osteoclastic activity causes the implant stability to decrease, which causes a micromotion of the implant. It was found that micromovements between 50 and 150 μm could jeopardize the osseointegration of the implant [21]. This period marked by a drop in primary stability is shown until week 4, at which time secondary stability gradually takes over, provid-

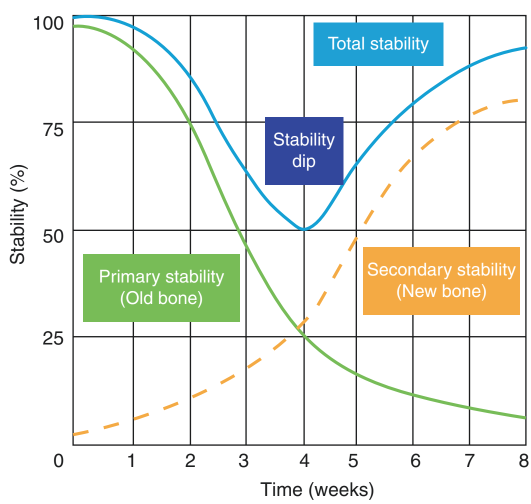

Fig. 10.1 Primary and secondary stability in function of time [20]

ing the main source of stability (Fig. 10.1). Secondary stability refers to the formation of new bone around the implant.

10.2.2 Concept of Secondary Stability

Secondary stability refers to the formation of new bone around the implant. After implant placement, the bone surrounding the newly placed implant is reorganized, and during this process, primary stability is gradually replaced by secondary stability. Secondary stability is given by the level of osseointegration. This refers to the concept of an anatomical and functional junction formed directly between the living bone and implant without the presence of fibrous matter.

Depending on temperature during preparation of the implant bed and placement of the implant, there is a certain amount of necrosis of the adjacent bone, generally up to 1 mm. For osteogenesis to take place, there must be a stable surface; adequate cells, either from the bone marrow or from undifferentiated mesenchymal cells; nutrition for these cells; and an appropriate biomechanical environment. Although some mechanical stimulation is necessary for osteogenesis, too much (50–150 μm) has the undesirable effect of stimulating differentiation through the fibroblast lineage [21]. This leads to the formation of a fibrous mass parallel to the vertical axis of the implant known as fibrointegration, as opposed to osseointegration [2].

In the trabecular bone, secondary stability begins with the formation of a blood clot, filling the gap between the implant and remaining bone. The fibrinogen in the blood attaches to the implant, allowing for preferential adsorption of platelets to the implant surface, and their immediate degranulation, releasing factors attracting undifferentiated cells to the site [2].

A network of fibrin is then formed followed by angiogenesis, which allows the undifferentiated mesenchymal cells to arrive to the site, providing both the adequate cells and cell nutrition necessary for osteogenesis. Ideally, these cells would then differentiate following the osteoblast lineage. As these cells migrate toward the implant surface, they exert a certain amount of tension on the fibers causing a retraction. At this point, the osteogenesis can be divided into two types. Depending on whether or not the fibers manage to resist this force, the osteogenesis will be in contact or in distance [22]. Therefore, it is important to limit micromovements as discussed above [2].

In contact osteogenesis, the cells arrive directly to the implant surface, recognizing it as stable, and begin to differentiate into osteoblasts producing trabecular bone. Bone apposition occurs simultaneously from the implant to the bone and from the bone to the implant, thus creating a trabecula that is perpendicular to the vertical axis of the implant [2]. On the other hand, in osteogenesis at distance cells begin apposition from the most stable surface away from the implant, the walls of the socket, and move toward the implant. This type of osteogenesis is a slower process and creates an osseous shell (corticolization) [2].

The type of osteogenesis can be influenced by the type of surface modification used. The first category is topographic modification. Implants with a rough and/or etched surface offer more retention for the fibers compared to smooth surface implants, allowing for contact osteogenesis rather than osteogenesis at a distance. The second category is surface coating. It has been reported that hydrophilic implant surfaces, such as Straumann's SLActive®, can reduce the risks during the critical early treatment by accelerating implant integration. The bone formation process is initiated at an earlier stage, resulting in improved implant stability in the "critical dip" period (Fig. 10.2). The improved and optimized secondary stability process leads to a higher implant stability between week 2 and 4. While healing showed similar characteristics with bone resorptive and appositional events for both regular and hydrophilic surfaces between 7 and 42 days, the degree of osseointegration after 2 and 4 weeks was superior for the SLActive® compared with the regular implant surface [23].

In cortical bone, the process of osteogenesis is much slower due to the reduced vascularization. The effects of the implant surface are also less apparent than in the trabecular bone. These fac-

Fig. 10.2 Edentulous patient with lower worn dentition (**a**). Extraction of lower teeth, alveoloplasty, and placement of four mandibular dental implants (**b**). Placement of multiunit abutments and closure of the surgical site (**c**). Immediate loading of the four implants with an acrylic fixed provisional prosthesis

tors can explain the lower degree of osseointegration seen in quality 1 bone. In fact, the quickest degree of osteogenesis is usually seen in quality 3 or 4 trabecular bone with rough surface implants. However, overall, qualities 2 and 3 tend to yield better results for implant success [2].

10.2.3 Evaluation of Osseointegration

In order to evaluate implant success, several criteria have been established. The most recognized criteria were established by Albrektsson et al. [24]. Initially, accepted vertical bone loss was set at 1.5 mm during the first year and 0.1 mm for the following years. These criteria were later revised, and the accepted vertical bone loss was changed to 0.2 mm annually after the first year of service [25].

Criteria for implant success [26]:

– An individual unattached implant is immobile when tested clinically.
– The radiograph does not demonstrate any evidence of periimplant radiolucency.
– Vertical bone loss is less than 0.2 mm annually after the first year of service of the implant.
– Individual implant performance is characterized by an absence of persistent or irreversible signs and symptoms such as pain, infections, neuropathies, paresthesia, or violation of the mandibular canal.
– Success rates of 85% at the end of a 5-year observation period and 80% at the end of a 10-year period are minimum criteria for success.

There are also several techniques used to evaluate osseointegration. To begin, it is important to perform a clinical examination of the implant. This exam should determine if the implant is mobile, if there is sensitivity to percussion, and eventually if there is presence of infection, as these can be signs of implant failure. Radiographs are essential to assess bone height as well as any radiotranslucency surrounding the implant. The implant threads are commonly used as a reference of dimension [27, 28]. It is also important to take a periapical X-ray, in particular when implant presents mobility. If a radiotranslucent border appears around the implant in the X-ray, this is a sign that the implant did not osseointegrate [8].

There are also other methods to evaluate osseointegration that are available to clinicians. These include the Periotest® and the Osstell™ method.

10.2.3.1 Periotest®

The Periotest® is an electromechanical instrument consisting of a metallic rod and handpiece. The rod percusses the implant 16 times, while a sensor records the length of time of contact. The greater the time, the more mobile the implant and the greater the Periotest value. The lower the value, the greater the stability and damping effects of the measured implant or tooth. Values of −8 to 0 indicate that the implant may be loaded, and +1 to 9 indicate that further clinical examination is needed prior to loading [28]. Superior values indicate that the osseointegration is insufficient. This test has proven to be a reliable method to evaluate primary stability [28, 29].

10.2.3.2 Osstell™

Osstell™ is an indirect measure of osseointegration. This instrument measures the frequency at which the sensor on the implant vibrates, which is known as the resonance frequency analysis (RFA). This value is converted into an implant stability quotient (ISQ). Values on this scale range from 1 to 100, with greater values indicating greater stability. According to Osstell™, an ISQ of 70 and greater represents high stability, 60–69 represents medium stability, and below 60 is low stability. According to another source, a resonance frequency of at least 60 was required from ILP; however, the evidence base is lacking in this area [30]. Although this test gives information regarding failure to osseointegrate, single readings offer limited clinical value [31].

10.3 Implant Loading Protocols

There are three recognized loading protocols for implants: conventional loading, immediate loading, and early loading. A conventional loading protocol is when the restoration is delivered 2 months after implant placement. Immediate loading refers to a restoration delivered within 1 week following implant placement. Finally, early loading implies that the restoration is delivered between 1 week and 2 months after implant placement [32].

10.3.1 Definitions

Loading protocols	New definitions
Conventional	Restoration delivered after 2 months following implant placement
Immediate	Restoration delivered within 1 week following implant placement
Early	Restoration delivered between 1 week and 2 months following implant placement

10.3.2 Conventional Loading Protocol

During the 1960s, Dr. Brånemark established the first surgical protocol for implants. This was a two-stage conventional loading protocol. For this protocol there is a first surgery to place the implants, followed by a 4–6-month waiting period to allow the implants to become osseointegrated, thereby ensuring a certain secondary stability regardless of primary stability [33]. This is particularly important in low-density bone. Next is a second surgery to uncover the implants and place healing caps, followed by a 4–8-week waiting period to allow soft tissue to heal prior to taking an impression for the two-implant overdenture and loading of the implants [2].

The multiple surgeries suggested by this protocol demand time from both the patient and the dentist, as well as recovery periods during each of which the patient experiences some discomfort. Additionally, during the combined wait periods prior to loading, the completely edentate patient must function with either a conventional denture or no denture. Consequently, the patient must deal with unsatisfactory function and aesthetics for several months before receiving their final treatment (two-implant overdenture) [2].

In order to reduce the inconveniences of waiting for the final restoration, without compromising osseointegration, a one-stage conventional protocol was established. With this protocol, healing caps are placed during the first surgery immediately following implant placement, thus eliminating the specific wait period for soft tissue healing by merging it with the osseointegration wait period [34]. Nonetheless, with this protocol, there is still a wait period [2]. Today implant surfaces have been improved, lessening the time necessary for osseointegration and decreasing the wait period for the conventional loading protocol to 2 months.

To this day, the conventional loading protocol remains the option of choice. However, for those with good primary stability, there are more possibilities that may be of greater interest to the patient.

10.3.3 Immediate Loading Protocol

In fact, an immediate loading protocol was suggested in order to answer to the demand to shorten this wait period. Following the immediate loading protocol, the overdenture is delivered within 1 week of implant placement, meaning prior to osseointegration [35]. Through several studies, it has been proven that the immediate loading protocol is an effective treatment option yielding a success rate comparable with that of the conventional loading protocol and offering greater patient satisfaction than the later [36]. That said, it is necessary to mention that there are some requirements prior to adopting an immediate loading protocol and that it is only indicated in cases involving good primary stability, otherwise the success rate plummets [17]. Indeed, when the overdenture is delivered and put into occlusion, it exerts certain forces on the implants, and without adequate primary stability to immobilize these, they are more susceptible to micromotion. When this micromotion exceeds 50–150 μm, it will prevent osseointegration by causing fibrointegration instead, which will lead to implant failure. Hence, the importance of primary stability when subjecting implants to a load prior to osseointegration, such as in the immediate loading protocol. In order to prevent implant failure, primary stability must be gauged prior to selecting a loading protocol. There are many methods and values suggested to deem whether or not primary stability is sufficient for the use of the immediate loading protocol, but one of the best and most commonly used is the insertion torque value (ITV). ITV takes into account bone density, which should be of quality 1, 2, or 3 for immediate loading, as the lower the bone density, the less torque is necessary to cut through it and place the implant [2]. Again, as ITV is a good indicator of primary stability, it is suggested to have a minimum ITV of 32 Ncm to proceed with an immediate loading [3, 16].

Additionally, with immediate loading, it is particularly important to minimize forces that may cause micromotion. For instance, splinting of the implants allows the occlusal forces to be more evenly distributed on the implants and diminishes the stress placed on each of them, allowing the horizontal forces to be minimized at the bone-implant interface [4]. Moreover, it is recommended to place the implant(s) in nonfunctional occlusion in order to minimize stress and optimize primary stability [8]. In fact, a study has shown that immediate nonfunctional loading increased the implant survival rate when compared with immediate functional loading [37]. The implant surface is also important in the ILP, and a rough surface implant is found to yield the best result [8]. It is also important to mention that the patient adhering to a liquid and soft diet for 6–8 weeks after implant placement decreases the risk of overload failure [8].

10.3.4 Early Loading Protocol

Finally, an early loading protocol, where the restoration is delivered between 1 week and 2 months of implant placement, has also been suggested as an alternative to conventional loading. This protocol, however, is not ideal as it has a higher failure rate [35]. Referring back to Fig. 10.1 (page 4), necrosis of the bone adjacent to the implant occurs gradually in the weeks following placement of the implant bringing primary stability from 100% the day of implant placement to 75% in the first

2 weeks and then to 25% by the fourth week and continuing to diminish. At this time, the process of osseointegration has begun to offer some secondary stability but is still only at 25% by the fourth week and takes another 4 weeks to provide an adequate total stability as primary stability continues to diminish. Consequently, this process of acquiring stability spans the entire window of restoration delivery of the early loading protocol. That said adopting the early loading protocol means subjecting implants to forces when stability is at its lowest and putting osseointegration at risk. This explains the higher failure rate associated with this particular loading protocol [2].

10.4 Patient Perception of Immediate Loading

Another important factor in determining whether a particular treatment or loading protocol could be advised is patient perception and satisfaction with this option. As these are subjective, they vary from person to person and do not rest entirely upon the degree of fulfillment of the patient's functional needs (reestablishment of phonetic and masticatory capacity). In fact, the patient's expectations, preferences, and knowledge, as well as their sociocultural background, level of education, and even personality, can influence their level of satisfaction [38–40]. That being said, it can be noted that patients were generally more satisfied and had an improved oral health quality of life (OHQoL) with two-implant mandibular overdentures in comparison with conventional mandibular dentures [39, 41]. Additionally, it has been suggested that the use of an immediate loading protocol could further increase said patient satisfaction and OHQoL [42]. Although studies on this subject are scarce and can refer to fixed prostheses, bar, or other attachments [41–44], some including one pilot trial referring to immediate loading of two-implant overdentures seem to indicate a high satisfaction rate (94.4% with 100% of patients recommending this treatment option) [41, 45–47]. The high patient satisfaction rate for the ILP is due to the decreased wait period prior to achieving the following: satisfactory aesthetic results, positive impact on social life, decrease in discomfort, improved stability and masticatory ability, no additional surgeries, and reduced number of visits [45, 48]. It is also interesting to note that the pain experienced during the longer appointment associated with ILPs did not negatively impact patients' opinion of this loading protocol. However, more research must be done on immediate loading of mandibular two-implant overdentures to confirm this information.

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