# Parameters for Successful Implant Integration Revisited
# Part I: Immediate Loading Considered in Light of the Original Prerequisites for Osseointegration

Oded Bahat, BDS, MSD, FACD;* Richard M. Sullivan, DDS†

ABSTRACT

*Purpose:* With the increasing popularity and publication of loading implants at the time of placement, including at time of dental extraction and simultaneous with reconstructive procedures, the objective was to evaluate known variables identified for a traditional unloaded healing period and determine the applicability of these variables to immediate loading.

*Materials:* A total of 124 published reports available as of January 2008 that contained information about loading from the time of surgery up to 3 months postsurgically were examined in light of published variables affecting osseointegration based on a 2 stage surgical approach.

*Methods:* The articles were examined to differentiate between immediate loading (within the initial 48 hours) and early/delayed loading of implants. Success or survival criteria were noted, and where reasons for failure were available, categorized according to six variables considered as determinants for maintaining a long-term bone-to-implant contact.

*Results:* Approximately 60 of the 124 reports described immediately loading implants within 48 with single-tooth, partial, and full-arch restorations, as well as implant overdentures. The implant success or survival rates ranged from 70.8% to 100%. Most studies considered implant survival to be the only criterion for success.

*Conclusions:* Of six parameters identified in 1981 as influencing osseointegration, two parameters (the status of the bone/implant site and implant loading conditions) appear to have diagnostic implications, whereas three (implant design, surgical technique, and implant finish) may affect immediate loading positively or adversely.

KEY WORDS: dental implants, immediate loading, implant seating dynamics, implant stability, occlusal loading, osseointegration

## INTRODUCTION

Early restorations supported by dental implants were applied to the fully edentulous arch.[1] Initially, implants were kept unloaded for 3 months (mandible) or 6 months (maxilla), but methods of avoiding the edentulous period were tested later, including immediate (within 48 hours[2]) or early (48 hours–9 days[3–7] or 3 weeks–3 months[8–16]) loading of implants placed in all areas of the mouth and in both healed and fresh extraction sites. Only one series showed an implant survival rate below 93% at 1 to 5 years.[17–32] All failures in another series[26] followed delayed loading, and one immediately loaded implant that demonstrated mobility and pain at 6 weeks integrated when it was unloaded temporarily.[25]

Several papers have described the outcomes of immediately loaded implants placed at various sites.[33–41] Some specifically examined single implants in an otherwise dentate arch,[12,42–49] implants placed in soft or atrophic bone,[50–59] or those placed in the edentulous mandible[60–69] or maxilla,[70–74] those in the aesthetic zone,[42,63,75–80] and those in fresh extraction sockets.[79,81,82] Still other studies focused on implants having particular designs or surface characteristics,[16,55,79,80,83–100] the factors

*Private practice, Beverly Hills, CA, USA; †clinical director, Nobel Biocare North America, Yorba Linda, CA, USA

Reprint requests: Dr. Oded Bahat, 414 North Camden Drive, Suite 1260, Beverly Hills, CA 90210, USA; e-mail: odedbahat@aol.com

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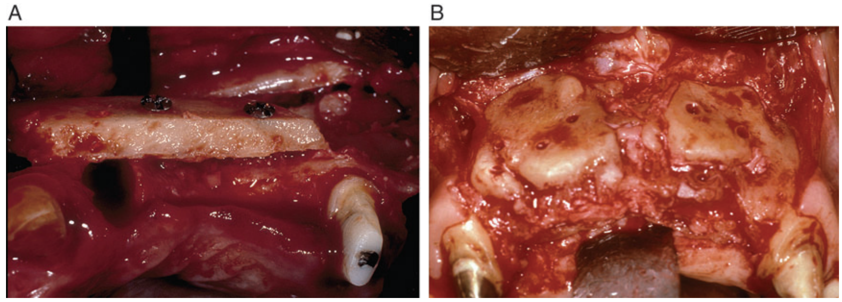

**Figure 1** Importance of status of implant site. (A) Inadequate osseous ridge volume is less favorable for immediate loading. In this case, a cranial veneer bone graft has been placed to augment deficient maxillary left anterior ridge. Density of the graft will impede rapid healing to form a union, making it unfavorable for simultaneous implant placement and immediate loading. (B) Six-month postoperative view of cranial veneer bone graft in another patient. Although graft has substantially increased the ridge width, reduced vitality of grafted bone is evident. This situation is unfavorable for immediate implant loading.

contributing to stability,[16,101–108] and the effects of immediate loading on the bone,[109,110] and soft tissue.[111] Several protocols[112–117] and three reviews[118–120] are available, consistently showing long-term success or survival rates averaging at least 97% (range 72.2–100%) for immediately loaded implants.

Contradictory findings have been published on the factors that may influence the outcome of immediate loading: bruxism and occlusal forces,[3,22,37,51,62,92,108] smoking,[3,92] extraction socket versus healed site,[35,37,47,75] bone quality,[37,72] and anatomic location.[37,54,121] Other than a few papers providing measurements of the aesthetic and soft tissue response,[47,78] implant survival has been the only measure of success and implant loss the only negative outcome.[93,118] In our view, this practice does not represent the full scope of desired results.[93] A fuller picture of success also considers maintenance of physiologic health and aesthetic appearance by all implants and their surrounding hard and soft tissues, continued stability and function of the restoration, and no greater soft tissue or bone loss than would occur with delayed loading.

Immediate loading shortens treatment time, gives patients immediate functional benefits, reduces the number and length of office visits, necessitates fewer provisional restorations, and potentially lowers costs. However, these advantages must be weighed against the risks of multiple simultaneous surgical and restorative procedures. Discussion of the effects and costs of possible complications with the prospective patient is necessary. Compared with staged procedures, the combination of extensive augmentation with simultaneous implant placement and restoration can increase benefits but also exacerbate the consequences of failure for the patient. These adverse consequences include not only additional expense but also unplanned changes in adjacent implants, teeth, and orofacial support. Partly as a result of these complexities, no strict guidelines have been formulated to select patients for immediate loading.[114,119] This article and its companion review the timing of implant loading and present an algorithm for factors to consider in determining when the risks of immediate loading outweigh the benefits.

## DETERMINANTS OF IMMEDIATE LOADING SUCCESS

In 1981, Albrektsson and colleagues[101] identified six factors as influences on osseointegration: (1) status of the bone (or, better, the implant site); (2) loading conditions; (3) surgical technique; (4) implant design (or macrostructure); (5) implant finish (surface); and (6) implant material.

### Status of the Implant Site

Immediate loading poses an earlier challenge to the implant/bone/soft tissue interface, so it is more important to respect the limitations of the healing response. Healthy bone and an adequate blood supply are both essential (Figure 1). The genotype, architecture, and volume of soft tissue are critical to a good esthetic result. Moreover, the implant bed is affected by the patient's health, smoking practices, and current and previous medications.[51] Sites can be categorized as shown in Figure 2.

For successful immediate loading, the bed must allow the surface of the implant to remain close to the bone and soft tissue even as loads challenge its stability. Variations in the quantity and quality of bone between

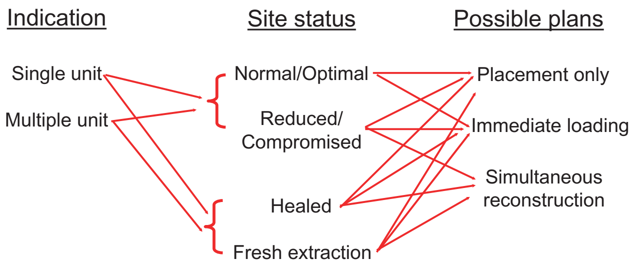


**Figure 2** Categorization of sites for implant placement with immediate loading showing potential complexity of plans.

patients and sites complicate the decision regarding immediate loading (Figure 3). Although placement in a site with reduced bone may shorten the overall treatment time in comparison with a staged augmentation that reconstructs missing tissue, the resulting prosthetic restoration will be larger than optimal, and the esthetic and functional deformities in the ridge will remain unimproved (Figure 4). If the site is reconstructed in stages before implant placement, the decision to load implants immediately should be based on the potentially shorter time required for graft healing. In comparison, unloaded implants at the same site require an additional 4 to 6 months of healing time. A computed tomography scan is useful to evaluate bone density and configuration both longitudinally and continuously. The bone topography of a fresh extraction socket must be assessed (Figure 5). There is, by definition, a large void, and site preparation often must begin on the sloping walls of the socket. There also is a potential for missing labial or buccal supporting walls of bone.[122] The socket must be reviewed intraoperatively, both visually and tactilely, and implant stability must be verified with torque or other stability measurements.

## Implant Loading Conditions

Previous research and observation of their own results led Albrektsson and colleagues to conclude that loading before the end of 3 or 4 months would jeopardize the fusion of the implant with bone. It has since been established that immediately and early-loaded implants can osseointegrate well,[118] but when active or passive occlusal function is introduced at the time of implant placement, the loading conditions assume paramount importance. Even implants placed under suboptimal conditions and loaded immediately can function normally long-term if they are able to survive the initial loading phase.[19]

Research led to the recognition of two types of implant stability: primary and secondary. Primary stability is achieved mechanically by balancing the implant site-preparation diameters with the self-tapping capacities of the implant and the perceived bone quality. Secondary stability is achieved by union between the implant surface and the bone. Implants can survive immediate loading predictably if suitable primary mechanical stability is achieved,[33,61,121] assuming the loading forces do not exceed a threshold that is specific for the patient and site. In contrast, implants that lack sufficient primary stability must be allowed to osseointegrate before they are loaded.[103]

## Surgical Technique

All surgery requires sharp dissection, gentle manipulation, tension-free closure, and obliteration of dead space. It is necessary to maintain asepsis, cool the drill to avoid thermal necrosis, exert minimal pressure on bone and soft tissue, and protect the blood supply.[104,105,123] Adequate initial implant stability requires close evaluation of the bone quality as each osteotomy is prepared.

## Implant Design (Macrostructure)

Virtually all threaded implant designs fall into one of two broad categories: tapered and parallel walled (Figure 6). A *tapered implant* is considered here to be

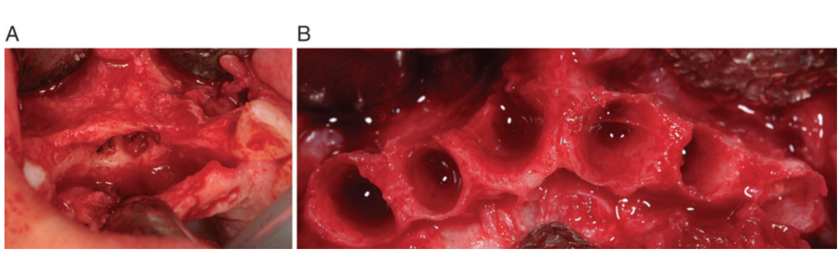


**Figure 3** Problems caused by variations in quality and quantity of bone. (A) Resorbed anterior maxilla with large subnasal concavity and prominent incisive foramen. These conditions are less favorable for immediate loading because of extensive hard and soft tissue deficiencies. (B) Example of missing, undermined, and diminished anterior maxillary facial bone immediately postextraction. Placement of implants in this situation poses increased aesthetic risks because of unpredictability of bone contours after healing. Immediate loading of immediately placed implants would increase the risk of aesthetic compromise even further.

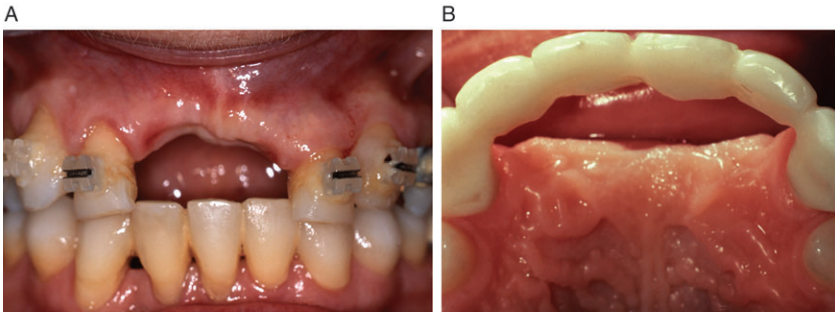

**Figure 4** Sites unfavorable for immediate loading. (A) Asymmetrical and irregular soft tissue contour, combined with resorbed maxillary anterior ridge, make this a less favorable site for immediate loading. Either a staged augmentation approach before implant placement or simultaneous implant placement and augmentation would be a better option. (B) Site unfavorable for immediate loading because of large anterior maxillary horizontal and vertical ridge defect, necessitating surgical reconstruction of both hard and soft tissue. Staged approach to allow graft healing before implant placement and loading is recommended.

one for which the taper extends throughout at least 50% of the length (Figure 7). A consistent benefit is the ease of achieving primary stability.[80,106,107] Each subsequent thread pushes laterally into the bone at a slightly wider diameter than the preceding thread, turning the implant into a wedge and generating more stability as the more coronal threads push laterally into unprepared bone. The resistance of the bone increases along the implant body as the threads are introduced. A tapered design can also condense softer bone, offering a commensurate increase in stability. The effect is analogous to that provided by an osteotome. The trade off is that tapered implants can be more difficult to seat in cortical bone, often necessitating a screw tap for full seating.

When loading implants immediately, it is essential to place the implant collar precisely relative to the available or planned soft tissue depth to achieve an aesthetically pleasing result while assuring adequate stability. This is more difficult to achieve with tapered implants that utilize site preparation with tapered rather than straight drills because tapered drills are length and width specific: a silhouette of the implant shape. Stability will be jeopardized if too deep an osteotomy is created and the implant is placed to less than full depth to enable optimal positioning of the collar. On the other hand, too shallow an osteotomy can result in the collar being too high. Implants placed using a straight drill allow slight overextension in drilled depth, permitting adjustment of implant seating depth for aesthetic reasons without compromise of stability.

*Parallel-walled implants* are defined as having parallel side walls for at least 50% of the threaded surface. Such implants still have an apical taper to allow them to be introduced into an osteotomy with a diameter less than the threaded diameter before the threads begin to engage bone. After twist-drill preparation, parallel-walled implants with a *self-tapping* design can be seated in cortical bone without the use of a screw tap. All implants are to some degree self-tapping if the bone is soft enough or a wide enough osteotomy is prepared. Self-tapping refers to the capacity of an implant to seat when large amounts of cortical bone are present.[89]

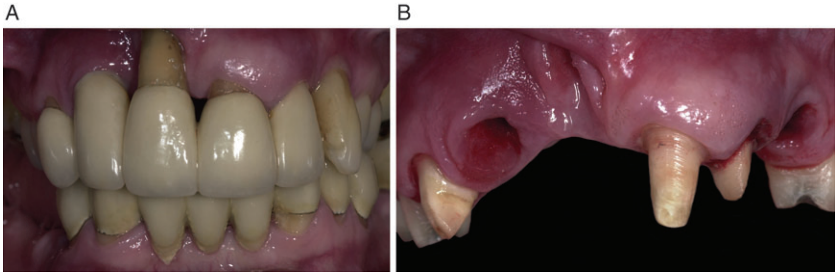

**Figure 5** Considerations for placement in fresh extraction socket. (A) This patient's periodontal disease has resulted in asymmetrical soft tissue architecture and severe bone loss. Removal of right central and lateral incisor will be required. (B) After extraction, extent of the hard and soft tissue loss is even more evident. Staged approach to surgical reconstruction prior to implant placement and loading of implants is recommended because of unpredictable contours that may result after reconstruction.

**Tapered**

*Advantages*

Ease of achieving initial stability in softer bone

*Limitations*

Often requires pretapping and use of wider drills when dense bone encountered

Seating depth correlated to tapered drills; over- or under-insertion affects stability

**Parallel Walled, including self-tapping**

*Advantages*

Seating in moderate to dense bone without pretapping

Flexibility in seating depth with parallel drills

*Limitations*

More difficult to achieve initial stability in softer bone

**Figure 6** Comparison of implant design.

There are cut-out areas at the apex of a self-tapping implant (Figure 8); it is not the threads that cut the bone, but rather the sharp vertical leading edges of the cut-out portions. A channel is created as the edge of the cutout rotates and the implant apex penetrates the site. The shallowest threads begin to cut tracks more laterally with deeper penetration. The body of the implant becomes parallel walled when the inner thread diameter of the implant is reached. The more coronal parallel threads simply follow in the tracks already cut into the bone. Parallel-walled implants placed with a sequence of parallel drills allow flexibility in vertical seating depth because stability is not correlated with various diameters at a preestablished depth, as when using tapered or stepped drills.

## Implant Finish (Surface)

In the 1981 paper by Albrektsson and colleagues,[101] the implant finish (ie, the surface characteristics) was

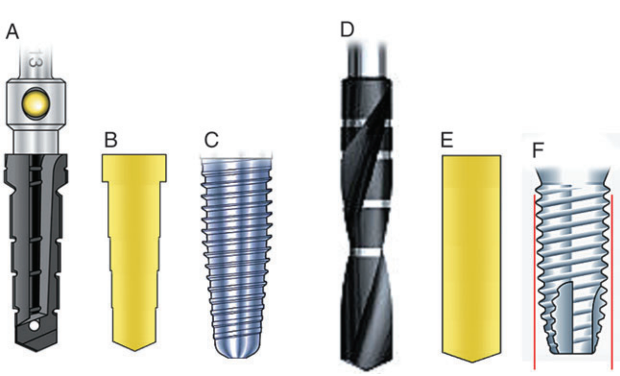


**Figure 7** Two examples of tapered implants. (A–C) Pronounced taper of this implant necessitates use of stepped drills. Seating depth established by final drill influences implant's initial stability. (D–F) Straight drills can be used to place this implant, which has only a slight taper. Stability is not influenced by overextension of osteotomy.

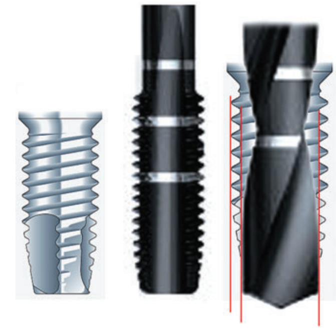

**Figure 8** Note how self-tapping implant (*left*) has cut-out areas like those seen in screw tap (*center*). Sharp edges of cut-out areas cut progressively wider channels into bone until diameter becomes parallel. Remaining threads then follow the channels cut by apical section. As illustrated on the right, implants have both an outer and an inner thread diameter. When self-tapping implants are used in soft bone, a twist drill is selected that is narrower than inner thread diameter. Inner core of the implant pushing laterally contributes to initial stability in soft bone.

recognized as potentially important for achieving and maintaining osseointegration. Today, manufacturers and clinicians cite the potential of various surface treatments to increase the speed at which bone adapts to the implant.

Successful immediate loading depends on maintaining mechanical fixation while osseointegration occurs even as active and passive loads are transmitted by the implant to the bone interface. For an immediately loaded implant to survive long-term, the bone-to-implant interface must allow generational turnovers of bone while continuously supporting the loads. The faster the bone adapts to the surface, the briefer the period of risk from normal functional loads during healing.[83,84] Glauser and colleagues[124] found better maintenance of stability with an anodized surface than with a machined surface and also a quicker return to baseline stability. However, at 1 year, this advantage had disappeared. Although machined-surface implants have demonstrated success with immediate loading,[19,24] surfaces developed for faster bone deposition present a theoretical advantage as long as they do not compromise soft tissue stability and long-term bone health.

## Implant Material

The titanium oxide surface inherent in titanium has excellent bone compatibility, and titanium continues to be the material of choice when implants are being loaded immediately. However, attention also must be paid to which materials can best ensure the long-term health of the soft tissue. Immediate loading protocols utilize transgingival components on the day of implant placement. Abutments and individual restorative components are available in titanium, zirconia, and even plastic (for provisional restorations), as well as the more traditional acrylic, gold, and porcelain. Superior biocompatibility in soft tissue healing in immediate loading applications has not yet been established for any of these materials. Until such superiority has been determined, material selection should be based on such factors as the planned depth of placement, the intended duration of component use, and biocompatibility.

## CONCLUSIONS

The six parameters for implant success identified by Albrektsson and colleagues[101] are a worthwhile starting point for analyzing the variables affecting both osseointegration and the other criteria for the long-term success of immediately loaded applications. Two of the six parameters – status of the bone/implant site and implant loading conditions – have preoperative diagnostic implications. These parameters and their clinical significance are discussed in detail in Part 2 of this paper.

## CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare. [Correction added after online publication 24 May 2010: Conflict of Interest Statement added.]

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