

Parameters for Successful Implant Integration Revisited

Part II: Algorithm for Immediate Loading

Diagnostic Factors

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ABSTRACT

Immediate loading of dental implants has become a widely reported practice with success rates ranging from 70.8% to 100%. Although most studies have considered implant survival to be the only measure of success, a better definition includes the long-term stability of the hard and soft tissues around the implant(s) and other adjacent structures, as well as the long-term stability of all the restorative components. The parameters identified in 1981 by Albrektsson and colleagues as influencing the establishment and maintenance of osseointegration have been reconsidered in relation to immediate loading to improve the chances of achieving such success. Two of the six parameters (status of the bone/implant site and implant loading conditions) have preoperative diagnostic implications, whereas three (implant design, surgical technique, and implant finish) may compensate for less-than-ideal site and loading conditions. Factors affecting the outcome of immediate loading are reviewed to assist clinicians attempting to assess its risks and benefits.

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

INTRODUCTION

Reevaluating the six parameters for implant success identified by Albrektsson and colleagues¹ is a worthwhile start for analyzing the variables affecting both osseointegration and other features of the long-term success of immediately loaded implants. As discussed in our earlier article,² the status of the bone/implant site and implant loading conditions synergistically enhance or reduce the risk factors. To emphasize the details of each parameter, pertinent subheadings have been formulated into an algorithm helpful in analyzing diagnostic and treatment plans (Table 1).³ Three of the parameters – implant macrostructure, surgical technique, and implant finish –

can compensate for less-than-optimal implant site status; the first two also can be deleterious to immediate loading. The remaining parameter – implant material – is not discussed.

STATUS OF THE IMPLANT SITE

Healed or Immediately Postextraction?

Preparation of implant sites immediately after tooth removal presents a challenge for immediate loading because the drill tends to follow the socket, and there can be deviation of planned alignment if the implant is redirected by denser bone toward the void of the socket. Another factor is the inevitable bone resorption and remodeling at the extraction site. Its unpredictability makes outcomes less certain than when implants are placed in fully healed sites. Bone and soft tissue loss occurs with simultaneous extraction and provisional restoration, but it may be less than expected during a staged approach using a removable appliance.⁴ Furthermore, a well-executed immediate restorative strategy can minimize disruption of the bone/soft tissue complex (Figure 1).⁵

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TABLE 1 Diagnostic Factors for Treatment Planning for Immediate Loading According to Site

	More Favorable for Immediate Loading	Less Favorable for Immediate Loading
Both anterior and posterior		
Site status	Healed without history of significant pathology	Simultaneous dental extraction; large voids, previous chronic infection associated with surgery
Osseous ridge volume	Height = 10 mm <i>and</i> width = implant + 2 mm	Height < 10 mm <i>or</i> width < implant + 2 mm
Vitality	Spontaneous bleeding	No spontaneous bleeding
Risk of collateral damage	Adequate safety margin	Close to vital or limiting anatomic structures, teeth
Anterior		
Adjacent bone level (tooth or implant)	High proximal	Pocketing, unstable
Soft tissue profile	Thick attached gingiva; symmetrical contours	Thin mucosa; irregular or deficient contours
Large reconstruction required for predominant implant support	Staged approach before implant placement	Reconstruction simultaneous with implant placement
Posterior occlusal support	Stable	Unstable
Posterior		
Bone density	Sufficient for implant stability under load	Insufficient for implant stability under load
Splinting effect	Present	Absent
Mobile/compromised teeth adjacent to site	Absent	Present
Opposing arch	Unopposed or opposed by denture	Opposed by teeth or fixed implant restoration
Powerful facial musculature or parafunction	Absent	Present

Adjacent Bone Levels

A goal of all implant placement, especially in the aesthetic zone, is to maintain or even improve the soft tissue and bone contours. Placement of a provisional restoration at the time of implant insertion has some utility in achieving that goal.^{4,6} However, for anterior single-tooth implants, maintenance of aesthetic gingival contours depends on the proximal bone, as well as on the patient's genetically determined tissue biotype and labial bone thickness.⁷⁻¹⁰ An implant placed too close to an adjacent tooth may compromise both the papilla and the tooth and bone.

Both the abutment and the provisional restoration ideally should avoid impinging on at least 1.5 to 2 mm of the bone circumferentially between the implant and the adjacent tooth to protect the soft tissue contours with immediate provisional restoration. Furthermore, the long-term maintenance of the soft tissue contours of the adjoining tooth will be increasingly unpredictable as

the vertical distance between the bone and the clinical crown contact increases even if they appear normal preoperatively (Figure 2).¹⁰

Lack of adequate soft tissue quality and dimensions often accompanies partial or complete edentulism in either jaw. Immediately loading implants placed in such sites without correcting the deficiency may compromise the aesthetics and possibly phonetics. Also, any future correction of the soft tissue deficiencies or deformities may be complicated by the presence of an implant, in the worst case necessitating its removal. A preferred approach is to reconstruct the soft tissue volume and contours as well as the bony support prior to implant placement and loading.

Discrepancies always exist in extraction sockets between the diameters of the cervical root and the implant yet tension-free closure is paramount. The quantity and relative location of the gingiva and mucosa should be evaluated preoperatively. Repositioning the

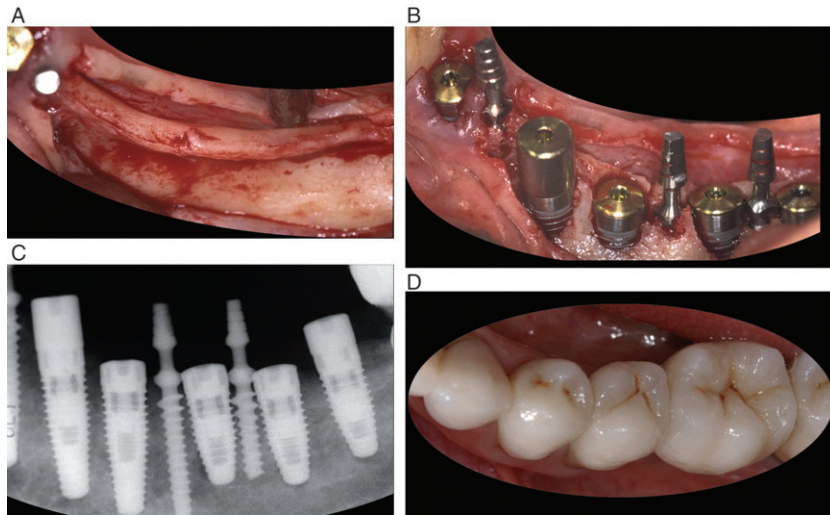


Figure 1 Restoration of left quadrant of resorbed mandible. (A) Preoperative view. (B) Complex strategy includes mixture of provisional implants, implants with abutments for immediate provisional restoration, and implants with healing abutments for unloaded healing. This plan provides immediate function while protecting some implants during osseointegration phase, depending on site-specific requirements and conditions. Provisional implants will be removed at second-stage surgery for protected implants. (C) Radiograph of implants. (D) Final restoration 4 years postoperatively.

thicker gingival contours to the aesthetic zone is beneficial for immediate restoration. Appropriate connective tissue grafts can be placed when indicated. Aesthetic results are achieved and maintained more easily with adequate supporting bone and thick gingival biotypes.¹¹

Bone Density

The dynamic relation for the first hours, days, and weeks differs significantly in a two-stage or protected one-stage approach from that of immediate loading.

For immediate loading, the bone quality must be dense enough to stabilize the implant sufficiently for formation of vital bone at the implant surface so osseointegration can occur and be maintained.¹ Not all trabecular bone contributes to primary implant stabil-

ity. The vascular marrow spaces may include large fatty compartments. Any movement of an immediately loaded implant, therefore, must be slight enough to allow osseointegration and thus supplement the early mechanical stability with long-term union of the bone with the implant.^{12,13} To some degree, both surgical technique and implant macrostructure can increase the initial mechanical stability of the implant within bone of the same density.^{14–20}

Tissue Vitality

Healing and repair should ensue once the implant is stabilized. Animal and human histologic studies demonstrate intimate bone-to-implant contact for unloaded implants and implants loaded at the time of placement.

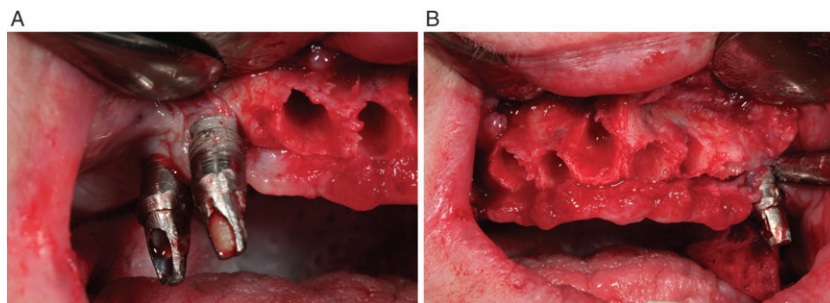


Figure 2 Bone resorption around previous implants and sockets severely involved with periodontal disease. (A) Note irregular bone loss around rough surface implants and partial/complete loss around remaining sockets. (B) Immediate loading creates higher aesthetic risk in view of low crestal bone height and unpredictable future profile.

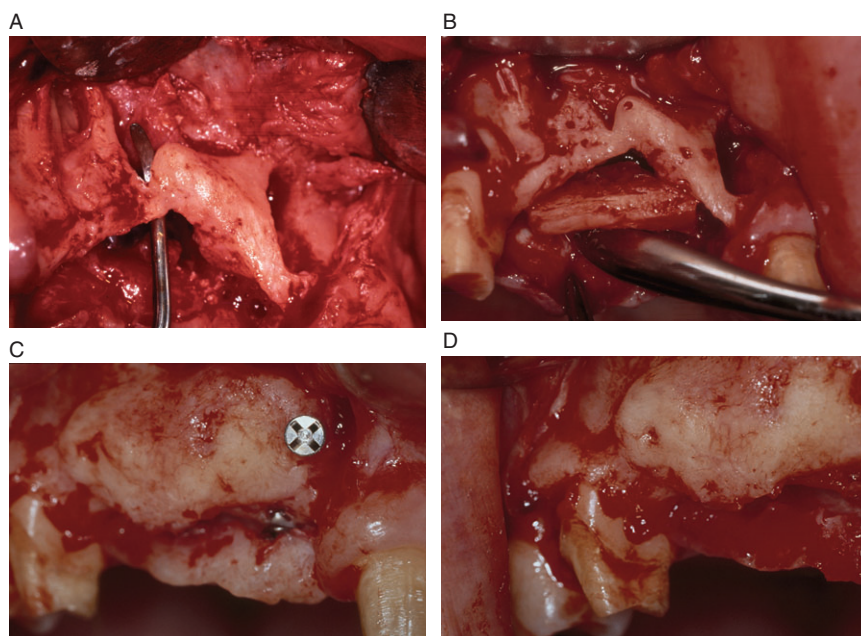


Figure 3 Grafting in area of dense bone with poor blood supply. (A) Severe resorption and irregular profile and architecture of this right maxillary ridge necessitate three-dimensional reconstruction. (B) Palatal bone graft is indicated to support future implant placement and loading. Note density of grafted cortical bone from torus at time of fixation. (C) Graft secured with fixation screws has integrated at 6 months. Note unpredictable healed bony profile of ridge, as well as adjacent to natural dentition. Density of bone has been maintained. (D) Implant placement and immediate loading can be performed safely after removal of fixation screws.

The site must have sufficient vascularity and healing potential during the period from blood clot to the formation of dynamic bone. In addition, vitality must be maintained or enhanced; gentle surgical techniques can preserve bone and soft tissue vitality and the subsequent healing of any tissue reconstruction associated with the implant procedure. The bone should bleed spontaneously on creation of the osteotomy and have sufficient density to enable the implant to withstand a challenge beyond a threshold of 35 to 40 Ncm.^{21,22}

As noted in Part 1 of this article, the healing potential of the site is the preoperative capacity minus the loss of potential caused by trauma, tissue removal, and current or previous use of drugs. The challenge is to maintain the reparative process unaffected, or even to influence it favorably by the introduction of a restoration at time of implant placement.^{15,23–28}

Some marrow spaces are so large that no strategy will yield sufficient mechanical stability to achieve a minimum threshold. Other bone is dense, and the blood supply is minimal (Figure 3).

Bone quality and the degree of implant stability can be determined only intraoperatively.^{29,30} The patient should provide advance consent to an alternative treatment plan that does not include immediate loading.

Osseous Ridge Volume

Ridge augmentation may be performed when the volume is insufficient for ideal implant placement. Soft tissue may be expanded. Hard and soft tissue deficiencies can be restored prosthetically to eliminate the need for or to supplement ridge augmentation. Until additional clinical data are available, a staged approach to the restoration is recommended when the vertical bone height is less than 10 mm and the horizontal dimension cannot assure at least 1 mm of bone on the facial and palatal/lingual aspects of the implant(s). Implants in sites that do not meet this criterion can be highly predictable if a delayed protocol is used (Figure 4).^{31,32}

Large Reconstruction Required

Additional vascularization is required when reconstructive procedures are performed to correct large deformities.^{33–37} Immediately loaded implants may be exposed to forces beyond their thresholds, with loss of the grafted tissue as well as severe additional damage (Figures 5 and 6).

Reconstruction with autogenous bone grafts carries greater significance when the graft becomes the predominant anchorage for the implant. Movement of a fixed graft is as detrimental to healing and ultimate

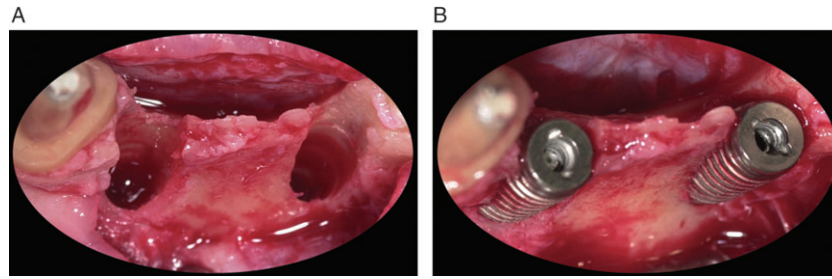


Figure 4 Implant placement in inadequate ridge. (A) Narrow facial/lingual dimensions and facial concavity in anterior mandible. Immediate loading is not recommended although two implants can be placed and site can be reconstructed simultaneously. (B) Implants have been placed and are mechanically stable. Deficient ridge will be grafted, but loading of implants will be delayed until graft site has healed fully.

biologic union as it is to implant integration. Early forces transmitted through implants to large grafts create a risk. Equally important is the blockage of host site blood flow by the implants.

Risk of Collateral Damage

Published studies on immediate loading carried out by experienced investigators report minimal complications

associated with implant placement or loss.^{38–41} With the usual study success criteria, implant or restoration survival has been the emphasis, with objective evaluation of aesthetics being addressed only occasionally. However, it has been our observation that the risk of collateral damage to adjacent teeth, soft tissue, implants, and bone adjacent to the immediately loaded implants can be great. This damage may be attributable to continued



Figure 5 Three-dimensional surgical reconstruction of posterior maxilla with simultaneous implant placement; immediate loading is not performed because of higher risk of excessive forces on implants placed primarily in “free” bone graft. (A) Deficient posterior left maxilla with descended sinus prior to reconstruction. (B) Placement of implants through J graft. (C) Degree of bone healing at junction of maxilla and J graft is optimal but not predictable 6 months postoperatively. Staged approach to bone graft and implant placement before loading allows fixed graft and implants to heal with less chance that micromotion will compromise stability.

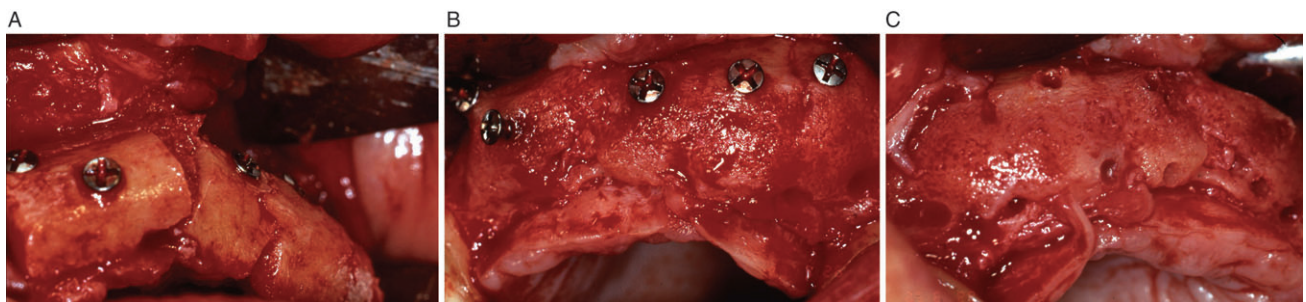


Figure 6 Three-dimensional reconstruction of anterior maxilla; note unpredictable nature of bone profile, affecting aesthetic and functional results. Immediate implant placement and loading at initial reconstruction is contraindicated. (A) Placement of J graft. (B) There is minimal but unpredictable resorption around fixation screw 6 months after bone grafting. (C) Implant placement and immediate loading can be attempted after removal of fixation screws.

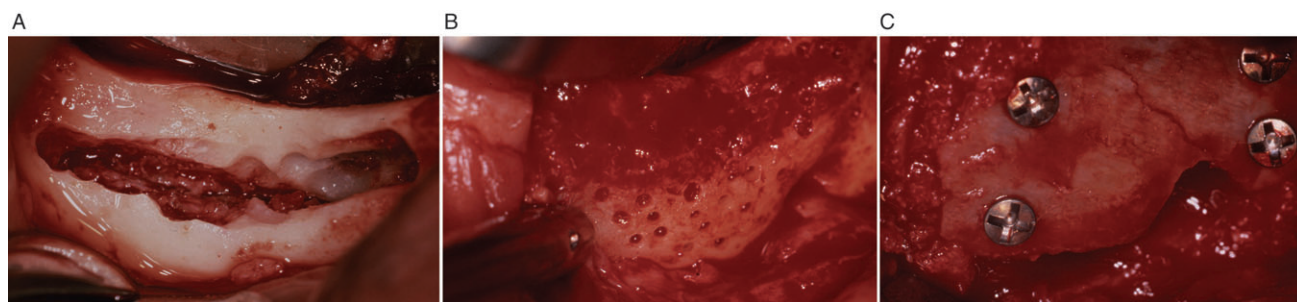


Figure 7 Mandibular sextant unfavorable for immediate loading. (A) Previously placed implants have been removed, exposing mandibular and mental nerve. Immediate function of such implants could compromise their primary stability and pose risk of damage to nerve bundle because of volume of bone to be reconstructed, as well as exposed vital structure. (B and C) Another example of site unfavorable for immediate loading because of volume of defect and scope of necessary surgical reconstruction. In this case, J graft has been secured with bone screws to reconstruct deficient posterior mandibular ridge, which is close to mental nerve.

movement of the implant under occlusal function. These losses can affect the surrounding soft tissue and bone adversely by undermining adjacent structures (Figures 7–9).

IMPLANT LOADING CONDITIONS

Lack of Posterior Occlusal Support

Patients with unstable posterior occlusal support secondary to tooth loss who elect functional and aesthetic replacement of anterior teeth with immediately loaded implants are at higher risk for implant loss unless posterior occlusal support has been restored. This loss is attributable to inability to control shearing and non-axial forces.

Presence of Periodontally Mobile Teeth

Periodontally compromised teeth exhibit abnormal mobility, and osseointegration may be inhibited by unfavorable loading forces if immediately loaded implants are attached to a restoration supported by such dentition.^{15,42,43} Such teeth may shift under function and

intrude on the restorations if they are adjoining rather than directly attached to an implant, subjecting them to unanticipated additional forces and threatening healing.

Powerful Facial Musculature or Parafunction

Patients with powerful facial musculature or parafunctional habits subject their implants to greater and more frequent loading that can cause immediately loaded implants to fail.^{12,44,45}

STRATEGIES FOR UNFAVORABLE IMPLANT-LOADING CONDITIONS

Certain biomechanical strategies may mitigate conditions considered relative contraindications to immediate loading. One is ensuring that the force applied to the implants is distributed evenly. A number of implants adequate to support the intended restoration should be planned, and the implants should be aligned to optimize force distribution. Cantilever forces should be minimized, and the implants should be splinted around a curvo-linear line during healing if possible.⁴⁶

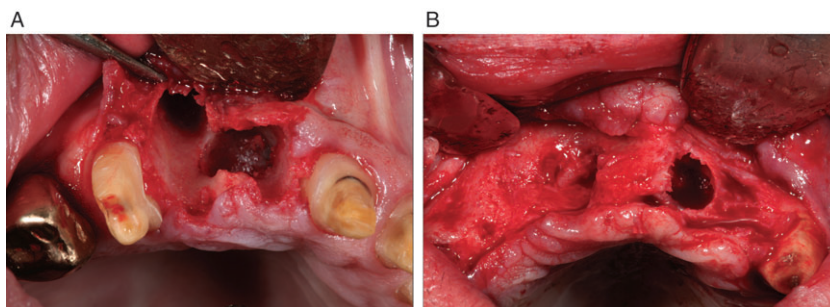


Figure 8 (A and B) Large bone defects associated with immediately loaded implants resulting in severe ridge defects.

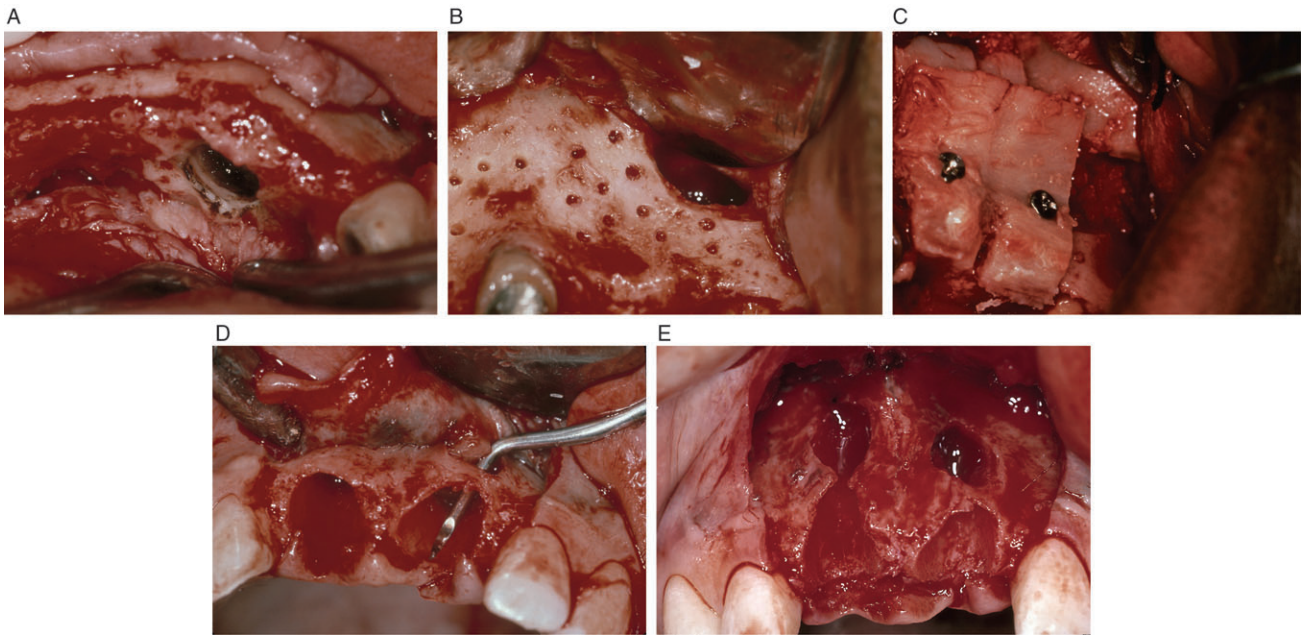


Figure 9 Restoration in presence of significant tissue loss. (A) Veneer graft has been placed to reconstruct anterior maxilla. Note prominent incisive canal. This situation is less than favorable for immediate loading because of unpredictable nature of possible graft resorption. (B) Graft site unfavorable for immediately loaded implants. Vertically and horizontally deficient posterior maxillary ridge has been perforated in preparation for placement of J graft. Note proximity of prominent left sinus. (C) Same patient with J graft in position. (D and E) Large defects subsequent to failed endodontic procedures, resulting in loss of facial bone. Reconstructive procedures should precede implant placement and loading.

An additional strategy is to reduce occlusal contact. Although all restorations at the time of implant placement can be categorized as immediately loaded, short-term provisional restorations can have full occlusal contact, centric stops free of excursive contacts, or no planned occlusion. Provisional restorations on anterior implants provide patients with benefits independent of occlusal function. If patients receiving such restorations have stable posterior occlusion, it may be possible to minimize occlusal contact and thus reduce forces. For patients receiving implants in the fully edentulous arch, occlusal contact is unavoidable. However, it is possible to minimize cantilever function. Lack of occlusal support from a provisional restoration may impose deleterious forces on the remaining anterior dentition when larger posterior segments are being replaced with an immediately loaded implant restoration. In such situations, use of an occlusal splint during the provisional phase and even temporary extracoronary splinting to reduce movement on the anterior teeth may be indicated.

SURGICAL TECHNIQUE AND IMPLANT DESIGN

Clearly, no single implant design is optimal for both dense and soft bone. Some surgeons prefer to use a

self-tapping design in denser bone and a non-self-tapping design for compromised, softer bone. Implant systems that use the same drill system and instrumentation for placing both implant types simplify decision-making and minimize confusion.

The ability to modify surgical techniques is more important in achieving initial stability than the hardware one uses,³⁶ and technique may compensate for site inadequacies. A self-tapping implant can be used in soft bone, because underpreparation of the site can compensate for the sharpness of the implant and create sufficient initial stability. As an alternative, tapered implants compress softer bone and help establish adequate stability in both healed sites and extraction sockets.^{17,47–49} However, seating tapered implants in sites containing significant cortical bone requires pretapping and relatively wider preparation. Using a stepped or tapered drill when preparing the osteotomy for a tapered implant also necessitates precise depth control to achieve adequate primary stability while placing the collar in the desired vertical position.

An implant with reduced self-tapping capacity and a more tapered design is a safer choice and is more likely to achieve primary stability when the quality of the bone

at a given site cannot be identified clearly. Delayed loading is suggested if mechanical stability cannot be achieved.¹²

IMPLANT FINISH

The implant finish has no particular implications during the first days after placement and immediate loading. However, some surface preparations may accelerate bone deposition. The potential for shortening the period of implant vulnerability to overload by selecting a particular surface treatment merits consideration if the selection induces no long-term deleterious consequences.^{50–52}

CONTRAINDICATIONS TO IMMEDIATE LOADING

Lack of primary stability, that is, inability of the implant to withstand an applied torque of 35 to 40 Ncm without rotation, is a relative contraindication to immediate loading.^{29,53} This deficiency may be overcome with multiple-unit splinting. In general, primary stability depends on the creation of an osteotomy with the ideal diameter and angulation. The surgeon's skill and planning typically determine whether this will be accomplished.

Other contraindications to immediate loading may appear intraoperatively. Examples are when the planned seating depth changes in an attempt to gain more stability; there are deviations from the planned implant alignment; or an implant site must be abandoned because of lack of stability. All such situations require accurate intraoperative assessment and the resolve to adjust the treatment plan. Supplemental implants or changes in the provisional restoration design may be required, or immediate loading may need to be abandoned. Delayed loading should be the choice whenever it would be expected to deliver a superior result.

CONCLUSIONS

1. The high degree of variability within patients' jaws and sites as well in surgical and prosthetic abilities complicates the site-determined, multi-factorial decision making required in deciding whether implants should be loaded immediately.
2. Primary stability remains a requirement for immediate functional loading and depends to the greatest extent on skill in preoperative assessment and intraoperative decision making. Surgical technique can

compensate to some extent for less-than-optimal bone quality and quantity, and adverse three-dimensional configuration. Primary stability is least dependent on engineering specifications. However, implant macrostructure considerations are of greater importance for immediately loaded implants and implants placed in softer bone than they are when using delayed loading protocols.

3. Patients should always be informed of the options of multiple procedures such as extractions, placement, augmentation, and immediate loading. They also should know the consequences and limitations of not performing needed reconstructive surgery. The patient's understanding of the commitment required for immediate loading if complications occur should be confirmed.
4. The thresholds of force that can be tolerated during physiologic function on immediately loaded implants without compromising primary stability and treatment outcome differ from patient to patient and site to site. Further studies should be undertaken to better understand the range of tolerances and ultimately to determine the particular threshold at any given site.
5. More studies to evaluate the possibility of modifying compromised areas and enhancing immediate loading of implants in such areas are encouraged. This will provide valuable information regarding short-term and long-term integration as well as optimal tissue health.

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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