Immediate Load on the Edentulous Mandible: Treatment Planning Considerations

Steven J. Sadowsky, DDS, FACP

Private Practice, Seattle, WA

Keywords
Immediate load; edentulous mandible; implant overdenture; fixed implant complete denture.

Correspondence
Steven J. Sadowsky, 15415 Harvey Rd., Bainbridge Island, WA 98110. E-mail: sadow333@hotmail.com

Previously presented at the Annual Meeting of the Pacific Coast Society for Prosthodontists (Sunriver, OR 2009).

Accepted October 29, 2009

doi: 10.1111/j.1532-849X.2010.00641.x

Abstract

Immediate load protocols for the edentulous mandible offer the patient many advantages in terms of decreased number of visits, improved early function, and reduction of surgical exposure; however, this treatment modality is not universally appropriate for all patients. The available evidence will assist the clinician in developing a customized and comprehensive informed consent. Patient selection and patient-mediated factors will dictate the suitability of not only a fixed or removable prosthesis, but also whether immediate loading would enhance the cost/benefit ratio. The indications, objective and subjective patient considerations, and design strategies are discussed for the immediate load scenario.

The submerged 3- to 6-month healing phase, while considered a conditio sine qua non for successful osseointegration, was eventually described as empirical.[1] The effectiveness of immediately loading the edentulous mandible within 1 week[2] has been established in recent literature.[2-6] This provides several advantages, such as immediate restoration of function, decreased number of patient treatment visits, and reduced morbidity of a second surgical intervention;[7] however, controversy persists regarding whether treatment with immediate loading on the edentulous mandible improves patient satisfaction and cost effectiveness, in comparison with conventional implant treatment protocol.[7,8] In fact, increased complications have been reported when an immediate loading approach was used for both removable and fixed designs, compared to the conventional time-to-loading protocol.[7,9] Moreover, although there is a large body of information on the clinical success of various loading modalities, there are few studies reporting parameters such as quality-of-life (QoL) and overall patient satisfaction.[6-8,10]

It is not uncommon for patient-centered outcomes to be documented without controls, as in a 1-year study on immediately loaded (IL)-fixed prostheses.[11] When a recent longitudinal investigation did include controls, similar outcomes in QoL were demonstrated for bar-retained implant overdentures, loaded immediately or conventionally.[12] Furthermore, differences in prosthetic protocol have added to the heterogeneity of the research. For example, provisional immediate loading has been used by some investigators with both fixed and removable designs. De Bruyn et al[9] delivered a relined denture immediately after implant surgery, 1 month before the definitive fixed restoration was installed. Cooper et al[13] placed high-profile healing abutments on two interforaminal implants and provisionally loaded them with an overdenture relined with tissue conditioner for 3 months, before final ball and socket connection. Ormianer et al[14] provisionally loaded a two-implant overdenture by placing a flexible polyether lining in the metal housings over ball attachments for 3 months, before the plastic retention cap was attached. Castellon et al[15] compared the advantages of delivering an interim or definitive restoration in the immediate load scenario.

Even though the methodological rigor of the evidence has not been strong, and the treatment outcomes have mostly been surrogate and less patient-centered, there has been momentum to apply a universally superior design/loading modality;[16-18] however, patient selection and patient-mediated factors should be considered to determine a customized treatment plan and comprehensive informed consent for the implant restoration of the edentulous mandible.[19] Indications for immediate load on the edentulous mandible include functional, anatomic, and psychologic factors;[20] however, the medical status, loading forces, anatomic/surgical presentation, and level of oral hygiene will dictate the patient's candidacy.[21] Furthermore, fixed and removable implant designs each have their own advantages and disadvantages in terms of retention security, hygiene access, facial and dental esthetics, application in unfavorable occlusal relationships, and initial and long-term costs.[22]

This article discusses factors to consider in selecting an IL-fixed complete denture or overdenture prosthesis for the edentulous mandible.

Indications

Patients requiring extraction of their remaining teeth often struggle with both the challenge of wearing an immediate denture and grief over tooth loss. Those who are transitioning from a dentulous to an edentulous state would benefit functionally and psychologically from the auxiliary retention of an IL restoration, which feels more like their own teeth.[23] Compromised hard and soft tissue anatomy as well as a retruded tongue, high muscle attachments, and/or hyperactivity of the floor of the mouth often predispose patients to denture instability and soreness.[24] An immediate load prosthesis would offer superior patient function and comfort during the healing period of implants. This treatment modality also could, without delay, rectify somatogenic gagging, which may result from mobile mandibular dentures due to xerostomia or other local factors.[25]

Patient selection

Host-related risk factors include those conditions that would compromise either wound healing capability or implant stability. Metabolic diseases that directly affect bone metabolism, such as osteoporosis/osteopenia or hyperparathyroidism, may interfere with the cascade of angiogenesis, osteoprogenitor cell migration, woven bone scaffold formation, and deposition of lamellar bone.[21] Patients with diabetes, heavy smoking habits (>20 cigarettes/day), history of therapeutic radiation to the head or neck, bone augmentation to the implant site, history of drug/alcohol abuse, or current treatment with antiblastic chemotherapy or steroids, are generally excluded from the immediate load protocol.[2,26-28] Heavy parafunctional forces may generate more than 15 times the amount of bite force used during eating and may be sustained for many hours.[29] While there is insufficient evidence to directly link occlusal overload to the failure of IL implants, heavy bruxers and clenchers have been reported to be poor candidates for this treatment.[21,30] Poor oral hygiene has been associated with more bone loss in an IL protocol;[4,31] however, the long-term impact of poor oral hygiene with roughened implants has not been established.[32]

The quality and quantity of native bone will play an important role in determining the predictability of the immediate loading success. Even when a conventional approach is chosen, Jaffin and Berman[33] have shown more than ten times the implant failure rate in type IV bone as opposed to type I-III bone. The anterior mandible, however, presents with predominantly type II bone (850–1250 Hounce field units),[34,35] and therefore the dense bone type will present several advantages for immediate loading. The cortical lamellar bone will heal with minimal interim woven bone formation, and the reduced porosity (<10%) favors good bone strength and better mechanical interlocking, in comparison to soft cancellous bone.[21,36]

A number of authors have recommended that IL implants be at least 10 mm in length;[5,37-39] however, this admonition should be weighed carefully, as these studies were conducted on machined implants. Implant surfaces with roughness ranging between 0.9 and 1.5 μm seem to enhance cell differentiation and bone deposition during the early phase of healing, and enlarge the surface area.[40,41] This appears to be helpful when the bone in contact with the implant surface goes into necrosis and remodels with newly formed bone from the host bone toward the implant, between the first and second week.[42] The roughened surface significantly increases the initial stability and continues to have higher ratings of stabilization for up to 3 months when measured with resonance frequency analysis (RFA);[43] however, the impact of surface modification on critical length and width of implants is yet to be determined.

Surgical protocol

One method for decreasing the risk of immediate occlusal overload is to have more vital bone in contact with the implant surface by decreasing the surgical trauma at implant placement.[44] Causes of surgical trauma include thermal injury. A 2500-rpm drill produces less heat than a 2000-rpm drill.[20] Other factors related to heat generation within the bone while drilling include amount of bone prepared, drill sharpness, depth of osteotomy, variation in cortical thickness, and temperature and solution chemistry of the irrigant.[45]

For the IL implant, primary stability has been underscored as essential for predictable osseointegration.[46,47] The degree of primary stability after implant placement is dependent on factors related to the properties of the bone, the design of the implant, and the surgical technique.[48] Brunski[49] noted that micromovements of more than 100 μm are sufficient to jeopardize healing with direct bone-to-implant contact. Increasing the peak insertion torque values reduces the level of implant micromotion.[50] An optimal range of 45 to 60 Ncm insertion torque value has been proposed;[20,37] however, other immediate load researchers have deemed 20 Ncm sufficient for a minimum insertion torque in their inclusion criteria.[51] An alternative approach is to use a reverse torque test of 20 Ncm[52] or RFA values, a technique used extensively to evaluate initial fixation.[53,54] Nedir et al[55] assessed implant stability using RFA for both delayed-loaded (DL) and IL implants after 1 year. They found that implant stability quotients of 49 and 54 were predictive for achieving and maintaining osseointegration for the DL and IL, respectively.

Modifications in surgical technique have been presented to enhance primary stability; however, due to the heterogeneity of relevant studies, the potential advantages of these protocols have not been clearly established.[6] Furthermore, the healing capacity of the anterior mandible may override the benefits of such methods as underpreparation of the osteotomy site,[56,57] avoiding countersinking and/or tapping,[58-60] using the osteotome technique,[61] and engaging the cortices where available to provide bicortical stabilization;[62] however, in patients with more unfavorable jaw morphology, these modifications may improve the prospect of osseointegration.[31]

Perhaps even more important in terms of surgical technique is the operator skill in implant placement. The implant failure rate of inexperienced surgeons is almost twice that of those who have placed more than 50 implants.[63]

Design considerations

Patient-mediated factors

The decision to restore a patient with a fixed or removable design with implants in the interforaminal region is contingent on a number of objective and subjective factors. In patients with marked resorption of the posterior mandible, a fixed implant complete denture, as opposed to an overdenture design, may not only preserve bone, but also regenerate posterior bone.[64] Jacobs et al[65] demonstrated with orthopantomogram measurements that a bar overdenture design induced two to three times the posterior jaw bone resorption, compared to a fixed complete denture after 2 years of service. Furthermore, Davis et al[66] reported appositional bone growth in the posterior residual ridge, 15-mm distal to the terminal implant, in 29 of 33 edentulous patients restored with a fixed implant complete denture after 6 years. Wolff's law may explain this phenomenon. When a load is focused on the anterior mandible and the closing and opening musculature is at work, a bending moment is created in the functioning mandible, thus producing superior surface tension forces and stimulating osteoblastic activity.[67]

A fixed prosthesis may also be the design of choice on the mandible when there is evidence of considerable resorption in the premaxilla region. Kreisler et al[68] found continuous maxillary ridge resorption, over an 8-year follow-up period, when a resilient bar overdenture was used. On the other hand, Henry et al[69] demonstrated no significant increase in flabby tissue in the premaxilla region over 10 years when patients were restored with a fixed implant complete denture opposing a conventional maxillary denture. Similarly, Gupta et al[70] also found an insignificant mean annual loss of 0.17 mm in the maxillary anterior ridge height in patients similarly restored with a fixed implant restoration.

Patients with temporomandibular joint (TMJ) dysfunction may be best treated with a fixed design. Bergendal and Magnusson[71] found a decrease in moderate-to-severe joint symptoms in a 3-year study, after restoration with a fixed implant prosthesis. Maintaining posterior stops appears to be related to TMJ stability in denture patients.[72] On the other hand, mandibular implant-retained overdentures have been shown to have a hinging effect, contributing to posterior residual ridge atrophy and loss of posterior occlusal contact.[65]

Unfavorable maxillomandibular relations may dictate selecting specifically a removable or fixed implant design in a completely edentulous patient. For example, a removable design would optimize occlusal stability for a Class III malocclusion, while a fixed design would center the occlusal contacts mainly in the anterior region and lead to an unstable maxillary denture and increased resorption in the anterior area.[73] In a retrognathic patient, a resilient overdenture is contraindicated because of rotation around the fulcrum between the two implants during anterior biting. On the other hand, in a patient with jaw size discrepancies, the overdenture design would permit more latitude in idealizing the occlusal interdigitation of the teeth.[73]

A guided, open-ended interview process is effective in eliciting subjective patient concerns regarding treatment outcomes.[74] In a crossover study, Feine et al[75] found that 50% of the patients chose a removable design in favor of a fixed prosthesis because of facial esthetics, comfort, and ease of cleaning. For example, if the patient was formerly wearing a flanged prosthesis, maintaining facial scaffolding and preventing cheek biting may be a high priority. Hygiene access for the geriatric population with dexterity limitations could also be a strong factor in choosing a removable design. On the other hand, when retention security and chewing hard foods is critical to the patient, a fixed design is indicated.

Finally, cost may be an overriding consideration for the patient, not only in the choice of a fixed or removable design, but also in selecting an IL or a conventionally loaded restoration. Both the initial cost and the maintenance burden have been determined to be higher with a fixed as opposed to a removable implant prosthesis, when evaluated with a long-term follow-up period of 15 years.[76] Also, when comparing implant survival and prosthetic stability of the IL-fixed restoration with the two-stage Branemark protocol, the results seem to be inferior.[77] While there is a paucity of studies on the prosthetic complications of IL removable prostheses on the edentulous mandible,[6,8] the bar/clip overdenture design is associated with higher maintenance costs, with resultant higher total costs, in comparison with a standard loading protocol.[7] Clip dislodgement, tooth fractures, and need for acrylic resin addition/reline were most frequently found; however, the short-term data (1-year) on freestanding abutments supporting an IL overdenture did not demonstrate a higher aftercare burden than the conventional approach.[51] The prospect of both reduced costs and surgical exposure with an IL overdenture, using one or two solitary abutments, is encouraging for patients with limited financial means and/or medical reserve.

The overdenture prosthesis

The permutations of IL implant overdenture designs offer the practitioner an array of options to meet patients' needs. Over 20 years ago, Babbush et al[78] published an article describing immediately loading four implants placed in the interforaminal region, rigidly splinted with a metal bar, relined with a soft liner within 2 to 3 days, and finally restored with clips 2 weeks later. The authors reported an 88% implant survival after 8 years. Since then, a number of investigators have used the four-implant design connected with a rigid bar and loaded the definitive clip-retained overdenture within 2 to 3 days, achieving higher implant survival (in the upper 90%), with up to an 8-year follow-up;[18,26,27,79] however, other researchers have tested the premise that the design of four implants splinted with a bar is necessary to support an IL overdenture. Stephan et al[80] conducted a 2-year study that demonstrated comparable results with the delayed approach when immediately loading an overdenture retained by three implants splinted with a bar. Stricker et al[10] reported 100% implant survival with a similar loading protocol and follow-up time, but used only two interforaminal splinted implants.

While Akca et al[81] have demonstrated with strain gauges on human cadavers that splinting of two interforaminal implants significantly reduces bone tissue strains in comparison with unsplinted implants, clinical research has not validated these results. Ormianer et al[14] reported a 96.4% 12- to 30-month implant survival when an unsplinted anchorage system was used. Marzola et al[51] achieved 100% implant survival in a prospective

1-year study on immediately loading two implants supporting a ball attachment-retained overdenture. The investigators emphasized precise adaptation and equilibration of the denture before the surgical procedure, minimal flap reflection with no buccal elevation, no prosthesis removal for 1 week, and a soft diet.

Furthermore, a freestanding symphyseal implant IL was evaluated in a preliminary study, following patients with a mean age of 70 for 1 year.[82] The implant survival rate was 100% for 25 patients, with implants achieving primary stability. The reporting of low maintenance problems lends itself to favorable implications regarding cost effectiveness of this design, albeit for selected patients with reduced functional loads.

The fixed implant complete denture

In 1996, Branemark and colleagues introduced an IL-fixed rehabilitation design for the edentulous mandible, using prefabricated surgical and prosthetic components, for patients with specific jaw morphology and jaw relations. Their first report using the Branemark Novum concept demonstrated a 98% implant survival rate with a follow-up of 6 months to 3 years, when treatment was completed in 7 hours from implant surgery to connection of final prosthesis;[16] however, other investigators, also evaluating this protocol over a similar study period, raised concerns regarding a prosthetic failure rate of 13%.[83]

Schnitman et al[5] developed a protocol to address the problem of losing an IL implant leading to catastrophic loss of the prosthesis. They placed several implants in the mandible, but IL only three implants for support of a fixed prosthesis in a tripod design. A 10-year retrospective study reported a 93.4% survival rate for all implants. The use of a denture conversion technique gained popularity as a transitional prosthesis that could be immediately attached to three to four implants with primary stability, well spaced around the submerged implant(s), on temporary cylinders.[84] An existing complete denture prosthesis is retrofitted, flanges removed, coping height reduced, and the cantilever shortened to the second premolar.[85] The advantages of this IL transitional prosthesis are manifold. It can be fabricated in a few hours chairside; patients can evaluate speech, esthetics, comfort, and the fixed versus removable design; and there is no pressure to fabricate the definitive prosthesis before healing and patients' concerns are resolved.

Malo et al[17] originally followed a similar protocol of placing rescue implants for two-thirds of their patients, and loading four implants in the "All-on-Four" concept, using tilted distal implants. Capelli et al[86] indicated that IL tilted implants may achieve the same outcomes as upright implants. The "All-on Four" prostheses achieved a 98.2% implant survival in the group without rescue implants, but caution should be exercised as this study had only a 6- to 12-month follow-up. The authors recommended reinforcement of the acrylic prosthesis to prevent fracture, although they reported few complications in this group. Other investigators have followed a protocol of placing more than four mandibular implants, which were all IL, and have reported a 98.9% implant survival with a fixed implant prosthesis, monitored up to 48 months.[87] Nonetheless, further prospective studies and longer follow-ups are required to assess the limitations of this protocol.

Finally, the use of computer-assisted virtual treatment planning and flapless surgery to immediately load a fixed prosthesis in the edentulous mandible has been reported in two recent investigations.[88,89] Higher surgical and technical complications have been reported with this procedure on the edentulous mandible, in comparison with other immediate loading protocols mentioned. Technique sensitivity has been underscored. The present studies also suffer from a small sample size, short follow-up time, and lack of standardization in technique and use of components. Future studies on the immediate load protocol for both fixed and removable designs on the edentulous mandible with improved methodological design and patient-centered outcomes will strengthen the evidence available to the clinician and establish more predictable treatment planning algorithms.

Conclusion

An array of implant prosthetic designs is available for restoration of the edentulous mandible. Within the limitations of the present studies, the available evidence will aid the practitioner in assessing the cost/benefit calculus in treatment planning a fixed or removable design modality, with or without immediate loading protocol. Patient selection and patient-mediated factors are essential in developing a comprehensive informed consent and maximizing improvement of QoL outcomes.

References

1. Branemark PI: Introduction to osseointegration. In Branemark PI, Zarb GA, Albreksson T (eds): Tissue Integrated Prostheses: Osseointegration in Clinical Dentistry, Vol 1 (ed 1). Chicago, IL, Quintessence, 1985, pp. 11-77
2. Esposito M, Grusovin MG, Willings M, et al: The effectiveness of immediate, early and conventional loading of dental implants: a Cochrane systematic review of randomized controlled clinical trials. Int J Oral Maxillofac Implants 2007;22:893-904
3. Kawai Y, Taylor JA: Effect of loading time on success of complete mandibular titanium retained overdentures: a systematic review. Clin Oral Implants Res 2007;18:399-408
4. De Smet E, Duyck J, Sloten JV, et al: Timing of loading-immediate, early, or delayed-in the outcome of implants in the edentulous mandible: a prospective clinical trial. Int J Oral Maxillofac Implants 2007;22:580-594
5. Schnitman PA, Wohrle PS, Rubenstein JE, et al: Ten-year results for Branemark implants immediately loaded with fixed prostheses at implant placement. Int J Oral Maxillofac 1997;12:495-503
6. Attard NJ, Zarb GA: Immediate and early implant loading protocols: a literature review of clinical studies. J Prosthet Dent 2005;94:242-258
7. Attard NJ, Laporte A, Locker D, et al: A prospective study on immediate loading of implants with mandibular overdentures: patient-mediated and economic outcomes. Int J Prosthodont 2006;19:67-73
8. Cochran DL, Morton D, Weber HP: Consensus statements and recommended clinical procedures regarding loading protocols for endosseous dental implants. Int J Oral Maxillofac Implants 2004;19(Suppl):109-113
9. De Bruyn H, Kisch J, Collaert B, et al: Fixed mandibular restorations on three early-loaded platform Branemark implants. Clin Implant Dent Relat Res 2001;3:176-184

10. Stricker A, Gutwald R, Schmelzeisen R, et al: Immediate loading of 2 interforaminal dental implants supporting an overdenture: clinical and radiographic results after 24 months. Int J Oral Maxillofac Implants 2004;19:868-872
11. Dierens M, Collaert B, Deschepper E, et al: Patient-centered outcome of immediately loaded implants in the rehabilitation of fully edentulous jaws. Clin Oral Implants Res 2009;20:1070-1077
12. Alfadda SA, Attard NJ, David LA: Five-year clinical results of immediately loaded dental implants using mandibular overdentures. Int J Prosthodont 2009;22:368-373
13. Cooper LF, Scurria MS, Lang LA, et al: Treatment of edentulism using Astra tech implants and ball abutments to retain mandibular overdentures. Int J Oral Maxillofac Implants 1999;14:646-653
14. Ormianer Z, Garg AK, Palti A: Immediate loading of implant overdentures using modified loading protocol. Implant Dent 2006;15:35-40
15. Castellon P, Block MS, Smith MB, et al: Immediate loading of edentulous mandible: delivery of a final restoration or provisional restoration-which to use? J Oral Maxillofac Surg 2004;62(9 Suppl 2):30-40
16. Branemark PI, Engstrand P, Ohrnell LO, et al: Branemark Novum®: a new treatment concept for rehabilitation of the edentulous mandible. Preliminary results from a prospective clinical follow-up study. Clin Implant Dent Relat Res 1999;1:2-16
17. Malo P, Rangert B, Nobre M: "All-on-Four" Immediate-function concept with Branemark system implants for completely edentulous mandibles: a retrospective clinical study. Clin Implant Dent Rel Res 2003;5(Suppl 1):2-9
18. Chiapasco M, Gatti C: Implant-retained mandibular overdentures with immediate loading: a 3- to 8-year prospective study on 328 implants. Clin Implant Dent Relat Res 2003;5:29-35
19. Fitzpatrick B: Standard of care for the edentulous mandible: a systematic review. J Prosthet Dent 2006;95:71-78
20. Misch CE, Wang H-L, Misch CM, et al: Rationale for the application of immediate load in implant dentistry: part I. Implant Dent 2004;13:207-215
21. Gapski R, Wang HL, Mascarenhas P, et al: Critical review of immediate implant loading. Clin Oral Implants Res 2003;14:515-527
22. Sadowsky SJ: The implant-supported prosthesis for the edentulous arch: design considerations. J Prosthet Dent 1997;78:28-33
23. Misch CM: Immediate loading of definitive implants in the edentulous mandible using a fixed provisional prosthesis: the denture conversion technique. J Oral Maxillofac Surg 2004;62(Suppl 2):106-115
24. Yanase RT: Diagnosis and treatment planning for the denture cripple. CDA J 1986;14:61-69
25. Bassi GS, Humphris GM, Longman LP: The etiology and management of gagging: a review of the literature. J Prosthet Dent 2004;91:459-467
26. Chiapasco M, Abati S, Romeo E, et al: Implant-retained mandibular overdentures with Branemark system MKII implants: a prospective comparative study between delayed and immediate loading. Int J Oral Maxillofac Implants 2001;16:537-546
27. Romeo E, Chiapasco M, Lazza A, et al: Implant-retained mandibular overdentures with ITI implants. Clin Oral Implants Res 2002;13:495-501
28. Fenlon MR, Palmer RM, Palmer P, et al: A prospective study of single stage surgery for implant-supported overdentures. Clin Oral Implants Res 2002;13:365-370
29. Misch CE, Wang H-L, Misch CM, et al: Rationale for the application of immediate load in implant dentistry: part II. Implant Dent 2004;13:310-319
30. Jaffin RA, Kumar A, Berman CL: Immediate loading of implants in partially and fully edentulous jaws: a series of 27 case reports. J Periodontol 2000;71:833-838
31. Attard NJ, David LA, Zarb GA: Immediate loading of implants with mandibular overdentures: one year clinical results of a prospective study. Int J Prosthodont 2005;18:463-470
32. Froberg KK, Lindh C, Ericsson I: Immediate loading of Branemark system implants: a comparison between TiUnite and turned implants placed in the anterior mandible. Clin Implant Dent Relat Res 2006;8:187-197
33. Jaffin RA, Berman CL: The excessive loss of Branemark implants in type IV bone: a 5-year analysis. J Periodontol 1991;62:2-4
34. Truhlar RS, Ornstein IH, Morris HF, et al: Distribution of bone quality in patients receiving endosseous dental implants. J Oral Maxillofac Surg 1997;55(Suppl 5):38-45
35. Misch CE: Bone density: a key determinant for clinical success. In Misch CE (ed): Contemporary Implant Dentistry (ed 2). St. Louis, MO, Mosby, 1999, pp. 113-114
36. Roberts WE, Turley PK, Brezniak N, et al: Implants: bone physiology and metabolism. CDA J 1987;15:54-61
37. Horiuchi K, Uchida H, Yamamoto K, et al: Immediate loading of Branemark system implants following placement in edentulous patients: a clinical report. Int J Oral Maxillofac Implants 2000;15:824-830
38. Tarnow DP, Emtiaz S, Classi A: Immediate loading of threaded implants at stage I surgery in edentulous arches: ten consecutive case reports with 1- to 5-year data. Int J Oral Maxillofac Implants 1997;12:319-324
39. Chiapasco M, Gatti C, Rossi E, et al: Implant-retained mandibular overdentures with immediate loading. A retrospective multicenter study on 226 consecutive cases. Clin Oral Implants Res 1997;8:48-57
40. Wennerberg A, Albrektson T, Andersson B, et al: A histomorphic and removal torque study of screw-shaped titanium implants with three different surface topographies. Clin Oral Implants Res 1995;6:24-30
41. Kasemo B, Lausmaa J: Aspects of surface physics on titanium implants. Swed Dent J Suppl 1985;28:19-36
42. Berglundh T, Abrahamsson I, Lang NP, et al: De novo alveolar bone formation adjacent to endosseous implants. Clin Oral Implants Res 2003;14:251-262
43. Buser D, Schemk RK, Steinemann, et al: Influence of surface characteristics on bone integration of titanium implants. A histomorphic study in miniature pigs. J Biomed Mater 1991;25:889-902
44. Roberts WE, Smith RK, Ziberman Y, et al: Osseous adaptation to continuous loading of rigid endosseous implants. Am J Orthod 1984;86:95-111
45. Haider R, Watzek G, Plenk H: Effects of drill cooling and bone structure on IMZ implant fixation. Int J Oral Maxillofac Implants 1993;8:83-91
46. Sennerby L, Roos J: Surgical determinants of clinical success of osseointegrated oral implants: a review of the literature. Int J Prosthodont 1998;11:408-420
47. Chiapasco M: Early and immediate restoration and loading in completely edentulous patients. Int J Oral Maxillofac Implants 2004;19:92-102
48. Ostman P-O, Hellman M, Wendelhag I, et al: Resonance frequency analysis measurements of implants at placement surgery. Int J Prosthodont 2006;19:77-83

49. Brunski JB: Avoid pitfalls of overloading and micromotion of intraosseous implants. Dent Implantol Update 1993;4:77-81
50. Trisi P, Perfetti G, Baldoni E, et al: Implant micromotion is related to peak insertion torque and bone density. Clin Oral Implant Res 2009;20:467-471
51. Marzola R, Scotti R, Fazi G, et al: Immediate loading of two implants supporting a ball attachment-retained mandibular overdenture: a prospective clinical study. Clin Implant Dent Relat Res 2007;9:136-143
52. Sullivan DY, Sherwood RL: The reverse torque test: a clinical report. Int J Oral Maxillofac Implants 1996;11:179-185
53. Meredith N, Sennerby L, Linden B, et al: Stability measurements of one-stage Branemark implants during healing in mandibles. A clinical resonance frequency analysis study. Int J Oral Maxillofac Surg 1999;28:266-272
54. Glauser R, Sennerby L, Meredith L, et al: Resonance frequency analysis of implants subjected to immediate or early functional occlusal loading. Successful vs. failing implants. Clin Oral Implants Res 2004;15:428-434
55. Nedir R, Bischof M, Szuckler-Moncler S, et al: Predicting osseointegration by means of implant primary stability. Clin Oral Implants Res 2004;15:520-528
56. Rocci A, Martignoni M, Gottlow J: Immediate loading of Branemark system TiUnite and machined-surface implants in the posterior mandible: a randomized open-ended clinical trial. Clin Implant Dent Relat Res 2003;5:57-63
57. Nikellis I, Levi A, Nicolopoulos C: Immediate loading of 190 endosseous dental implants: a prospective observational study of 40 patient treatments with up to 2-year data. Int J Oral Maxillofac Implants 2004;19:116-123
58. Payne AG, Tawse-Smith A, Kumara R, et al: One-year prospective evaluation of the early loading of unsplinted conical Branemark fixtures with mandibular overdentures immediately following surgery. Clin Implant Dent Relat Res 2001;3:9-19
59. Glauser R, Lee A, Lundgren A, et al: Immediate occlusal loading of Branemark implants applied in various jawbone regions: a prospective 1-year clinical study. Clin Implant Dent Relat Res 2001;3:204-213
60. Calandriello R, Tomatis M, Rangert B: Immediate functional loading of Branemark system implants with enhanced initial stability: a prospective 1- to 2-year clinical and radiographic study. Clin Implant Dent Relat Res 2003;5(Suppl 1):10-21
61. Grunder U: Immediate functional loading of immediate implants in edentulous arches: two-year results. Int J Periodontics Restorative Dent 2001;21:545-551
62. Malo P, Friberg B, Polizzi G, et al: Immediate and early function of Branemark system implants placed in the esthetic zone: a 1-year prospective clinical multicenter study. Clin Implant Dent Relat Res 2003;5:37-46
63. Lambert PM, Morris HF, Ochi S: Positive effect of surgical experience with implants on second stage implant survival. J Oral Maxillofac Surg 1997;55:12-18
64. Sadowsky SJ: Mandibular implant-retained overdentures: a literature review. J Prosthet Dent 2001;86:463-473
65. Jacobs R, Schotte A, van Steenberghe D, et al: Posterior jaw bone resorption in osseointegrated implant-supported overdentures. Clin Oral Implants Res 1992;3:63-70
66. Davis WH, Lam PS, Marshall MW, et al: Using restorations borne totally by anterior implants to preserve the edentulous mandible. J Am Dent Assoc 1999;130:1183-1189
67. Misch CE: Bone density: a key determinant for clinical success. In Misch CE (ed): Contemporary Implant Dentistry (ed 2). St. Louis, MO, Mosby, 1999, pp. 318
68. Kreisler M, Behneke N, Behneke A, et al: Residual ridge resorption in the edentulous maxilla in patients with implant-supported mandibular overdentures: an 8-year retrospective study. Int J Prosthodont 2003;16:295-300
69. Henry PJ, Bower RC, Wall CD: Rehabilitation of the edentulous mandible with osseointegrated dental implants: 10-year follow-up. Aust Dent J 1995;40:1-9
70. Gupta S, Lechner SK, Duckmanton NA: Maxillary changes under complete dentures opposing mandibular implant-supported fixed prostheses. Int J Prosthodont 1999;12:492-497
71. Bergendal T, Magnusson T: Changes in signs and syptoms of temporomandibular disordersfollowing treatment with implant-supported fixed prostheses. Int J Prosthodont 2000;13:392-398
72. Agerberg G, Viklund L: Functional disturbances in complete denture patients. Int J Prosthodont 1989;2:41-50
73. Naert IE: Prosthetic aspects of implant-supported prostheses. In Naert IE, van Steenberghe D, Worthington P (eds): Osseointegration in Oral Rehabilitation. London, Quintessence, 1993, pp. 107
74. Koper A: The initial interview with complete denture patients. J Prosthet Dent 1970;23:590-597
75. Feine JS, de Grandmont P, Boudrias P: Within subject comparisons of implant-supported mandibular prostheses: choice of prosthesis. J Dent Res 1994;73:1105-1111
76. Attard NJ, Zarb GA, Laporte A: Long-term costs associated with implant-supported mandibular prostheses in edentulous patients. Int J Prosthodont 2005;18:117-123
77. Astrand P, Ahlqvist J, Gunne J, et al: Implant treatment of patients with edentulous jaws: a 20-year follow-up. Clin Implant Relat Res 2008;10:207-217
78. Babbush CA, Kent JN, Misiek DJ: Titanium plasma sprayed (TPS) screw implants for the reconstruction of the edentulous mandible. J Oral Maxillofac Surg 1986;44:274-282
79. Gatti G, Haeflinger W, Chiapasco M: Implant-retained mandibular overdentures with immediate loading: a prospective study of ITI implants. Int J Oral Maxillofac Implants 2000;15:383-388
80. Stephan G, Vidot F, Noharet R: Implant-retained mandibular overdentures: a comparative pilot study of immediate loading versus delayed loading after two years. J Prosthet Dent 2007;97:S138-S145
81. Akca K, Akkocaoglu M, Comert A, et al: Bone strains around immediately loaded implants supporting mandibular overdentures in human cadavers. Int Oral Maxillofac Implants 2007;22:101-109
82. Liddelow GJ, Henry PJ: A prospective study of immediately loaded single implant-retained mandibular overdentures: preliminary one-year results. J Prosthet Dent 2007;97:S126-S137
83. Gualini F, Gualini G, Cominelli R, et al: Outcome of Branemark Novum® implant treatment in edentulous mandibles: a retrospective 5-year follow-up study. Clin Implant Dent Rel Res 2008;11:330-337
84. Misch CM: Immediate loading of definitive implants in the edentulous mandible using a fixed provisional prosthesis: the denture conversion technique. J Oral Maxillofac Surg 2004;62:106-115
85. Chow J, Hui E, Liu J: The Hong Kong Bridge protocol. Immediate loading of mandibular Branemark fixtures using a fixed provisional prosthesis: preliminary results. Clin Implant Dent Relat Res 2001;3:166-174
86. Capelli M, Zuffetti F, Del F, et al: Immediate rehabilitation of completely edentulous jaw with fixed prostheses supported by

either upright or tilted implants: a multicenter clinical study. Int J Oral Maxillofac Implants 2007;22:639-644
87. Testori T, Del Fabbro M, Szmuckler-Moncler S, et al: Immediate occlusal loading of osseotite implants in the completely edentulous mandible. Int J Oral Maxillofac Implants 2003;18:544-551
88. Komiyama A, Klinge B, Hultin M: Treatment outcome of immediately loaded implants installed in edentulous jaws following computer assisted virtual treatment planning and flapless surgery. Cin Oral Implants Res 2008;19:677-685
89. Yong LT, Moy PK: Complications of computer-aided design/computer-aided-machining-guided (NobelGuide) surgical implant placement: an evaluation of early clinical results. Clin Implant Dent Relat Res 2008;10:123-127