Academy Report

Position Paper

Dental Implants in Periodontal Therapy*

Over the past 30 years, research has validated the success of osseointegrated implants as a viable alternative to fixed or removable prosthetic restorations. Periodontists are extensively trained in surgical procedures to treat and maintain patients with edentulous and partially edentulous arches. They also have a primary role in treatment planning and maintenance therapy. Thus, periodontists routinely integrate endosseous implants into periodontal therapy. This paper was prepared by the Research, Science and Therapy Committee of the American Academy of Periodontology and is intended to inform the dental profession regarding the utility of endosseous dental implants in the treatment of full and partial edentulism. *J Periodontol 2000;71:1934-1942.*

Oral health surveys of the American population indicate that there are significant numbers of individuals with compromised dentitions for whom endosseous dental implants may be indicated.[1,2] In many circumstances, implants are an alternative to fixed or removable prosthetic appliances and it has been estimated that 300,000 to 428,000 endosseous dental implants are placed annually.[3] The success of implants has been attributed to their firm bone anchorage, referred to as osseointegration,[4] or functional ankylosis.[5]

Osseointegration has been defined as a direct structural connection at the light microscopic level between bone and the surface of a load-carrying implant.[4] No soft connective tissue or periodontal ligament-like interface is detectable between the bone and the implant, and the osseointegrated implant functions without mobility. At the electron microscopic level, bone has been shown to be approximately 20 nm from the implant surface,[6] or in contact with the implant surface.[7] An oxide layer (3 to 5A°), formed by the oxidation of titanium and its alloys, is found on metal implant surfaces.[6] The oxide layer, like ceramic, is hydrophilic, corrosion resistant, and biocompatible.[8]

Initial studies focused on commercially pure titanium implants with a relatively smooth surface created by the machining process.[4] Subsequent investigations have indicated that implants made of titanium alloy and/or with relatively rougher surfaces also become integrated with bone. These include, but are not limited to, the following types of implants: titanium plasma sprayed,[9] acid-etched,[10] grit blasted-acid-etched,[10] and hydroxyapatite coated.[11,12]

The bonding of hydroxyapatite to bone is different from titanium and has been termed biointegration.[11] Biointegration denotes a direct biochemical bond of the bone to the surface of an implant at the electron microscopic level and is independent of any mechanical interlocking mechanism.[11,12]

Placement of endosseous implants has become an option in comprehensive periodontal treatment plans for both fully and partially edentulous patients. Partially edentulous patients with periodontitis often have remaining teeth that have significant amounts of attachment loss or mobility. The decision to extract these teeth and place implants or to maintain compromised teeth is therefore complex. Following restoration with endosseous dental implants, maintenance of the implant-supported prosthesis becomes a necessary and regular part of the periodontal maintenance visit.[13]

IMPLANT SYSTEMS

Several kinds of dental implant systems are available. These are classified according to their shape and relation to the bony housing. They include subperiosteal, transosteal, and endosseous implants. The most frequently used implants are endosseous implants. Endosseous implant systems include a range of sizes, shapes, coatings, and prosthetic components.[14] Implant length and width can be chosen to fit the available bone and prosthetic components can be selected in a size and angle to accommodate the final restoration.

Implant shape is usually a screw-type or cylindrical press-fit design. The selection of implant shape involves the exercise of professional judgement–taking into account such factors as available bone quality and the dimensions of the edentulous ridge. A threaded implant may provide additional immedi-

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ate fixation compared to cylindrical implants. In this regard, a screw-type implant has more surface for bonding than a parallel walled press-fit implant.[15,16] The implant surface further affects the long-term fixation and stabilization of the implant.[17] A porous coating on an implant can achieve more bone contact per implant length than an implant with a machined titanium surface.[18] Other surface modifications of implants include a roughened surface (i.e., grit-blasted,[19,20] or grit-blasted and acid-etched[10]), microgrooved or plasma-sprayed titanium,[21] and plasma-sprayed hydroxyapatite coatings.[22]

IMPLANT SUCCESS

Studies have shown that the placement of endosseous implants is a predictable procedure. Criteria for success include: 1) absence of persistent signs/symptoms such as pain, infection, neuropathies, parathesias, and violation of vital structures; 2) implant immobility; 3) no continuous peri-implant radiolucency; 4) negligible progressive bone loss (less than 0.2 mm annually) after physiologic remodeling during the first year of function; and 5) patient/dentist satisfaction with the implant supported restoration.[23,24] Many implant systems have shown multi-year success rates of greater than 90% for fully edentulous patients.[25-29] Similarly, multi-year studies of implants in partially edentulous patients have generally reported greater than 90% success rates for both maxillary and mandibular implants.[29-35]

A meta-analysis concerning endosseous dental implants in human clinical trials indicated that implants with rough surfaces may offer advantages with respect to implants with relatively smooth machined surfaces.[36] Furthermore, implants placed in the mandible appear to have significantly higher success rates than implants placed in the maxilla.[36] Others have suggested that implant surgical and restorative procedures are more successful than the management of molar furcations vis-à-vis root resection therapy.[37] However, regardless of the reported high implant success rates, there has been a relative lack of well-controlled prospective longitudinal studies to compare commonly used systems.[12,38]

PATIENT SELECTION

It is essential that a candidate for implants be evaluated for potential contraindications to their placement. At present, there are no reports of absolute medical contraindications for placement of implants, but relative contraindications do exist.[12] Adverse effects on implant survival have been attributed to uncontrolled diabetes, alcoholism, heavy smoking, post-irradiated jaws, and poor oral hygiene.[39-42] However, individuals with a strong susceptibility to periodontitis can be treated successfully with implants.[43]

Age is not an important factor that affects implant survival. However, age may be of considerable importance in treatment planning. When implants are placed in an adolescent, it has been recommended that they be monitored closely and restored with a prosthesis designed for adaptation to a developing jaw.[44,45] Furthermore, it has been suggested that implants placed after age 15 in girls and 18 in boys are more likely to have a better prognosis than implants placed in younger children.[46,47] As with other periodontal or prosthetic procedures, prospective patients should be emotionally stable, cooperative, and willing to keep the appointments required for completion of treatment and maintenance.[35] Every candidate for an implant should be made to understand that not all implants are successful; and, that if an implant fails, an alternative treatment without implants may be the only viable option.

PRESURGICAL EVALUATION

Restorative requirements, interarch space and jaw relationships, location of edentulous areas, and the quantity and quality of available bone should be evaluated before implants are selected as a treatment option. Radiographs, including panoramic, lateral, and occlusal views and periapical films, may be necessary to determine the height of available bone and for selection of the dimensions of the implants. They also may be needed to determine the proximity of potentially complicating structures including the maxillary sinuses, foramina, mandibular canal, and adjacent teeth or roots. The use of 3-dimensional computerized tomography (CT) scans might be advocated when more accurate information regarding the topography of osseous structures is required.[48,49]

Bone quality and bone volume influence successful outcomes. Lower success rates are associated with cancellous than with cortical bone.[50,51] The volume density of bone matrix in cortical bone is about 80 to 90% and in cancellous bone about 20% to 25%.[52] Therefore, cortical bone contributes to greater implant-bone contact and implant fixation. Classification schemes have been devised to presurgically evaluate the amount and quality of available bone.[53,54] However, the proposed classification schemes have not been validated in the literature.[12,55]

SITE PREPARATION

If bone quality and quantity are inadequate for the placement of implants, bone augmentation procedures may be indicated. These could include the use of either bioabsorbable or non-resorbable barrier membranes and bone grafts or bone substitutes to enhance bone regeneration.[56,57] A review of the literature indicated that implants in grafted bone are successful.[58] However, it was unclear as to which graft materials are most efficacious.[58] Accordingly, long-term, well-controlled, prospective longitudinal comparative studies are needed in this rapidly advancing area of reconstructive bone surgery.[59,60]

At a consensus conference on sinus grafting and the placement of dental implants, retrospective data from sinus floor augmentation bone grafts were collected and evaluated.[61] Data from 38 surgeons who performed 1,007 sinus grafts and placed 2,997 implants which were monitored for 3 years or more over a 10-year period were evaluated.[61] Members of the conference concluded that the sinus graft should be considered a highly predictable and effective therapeutic modality, but that identification of the ideal graft material and surgical technique requires further study.[61]

IMMEDIATE IMPLANT PLACEMENT

If an implant is to be inserted into an extraction site, the timing of the extraction is important due to the potential for postextraction bone resorption and ridge deformation.[62,63] Insertion of implants at the time of extraction (immediate placement) is viable if mechanical fixation can be achieved.[64-67] In this regard, a single histometric report on human biopsies noted that titanium plasma-sprayed implants can achieve osseointegration when placed immediately into extraction sockets.[68] However, the horizontal component of the peri-implant defect was a critical determinant as to the final amount of bone-implant contact.[68] At present there are short-term data to support immediate placement of implants.[68]

Alternatively, implants can be inserted after complete healing of the extraction socket. To shorten treatment time, a 2- to 3-month post-extraction implant technique has been proposed.[69] This approach waits for soft tissue healing of the site. It features the use of barrier membranes and bone grafts and takes advantage of the highly metabolically active new bone formation at the site.[70] However, research is still needed on the quality of bone regenerated by such procedures and on the long-term survival analysis of the inserted implants.

SURGICAL PROCEDURES

Three important guidelines have traditionally governed both submerged and non-submerged endosseous dental implant systems. These are: 1) surgical procedures that minimize thermal trauma to bone; 2) a primary healing period of variable duration to permit osseointegration to be achieved; and 3) maintenance of no micromotion greater than 100 microns during the healing period.[71] However, the necessity for maintenance of an initial unloaded period of 3 to 6 months to achieve osseointegration is being questioned and several reports suggest that implants can be placed into function at the time of surgery, if they are splinted.[71-75] This concept was reported in 1979 with nonsubmerged, 1-piece titanium, plasma-sprayed screws with an immediate loading of bar-splinted implants.[75]

The importance of controlling heat generated by surgical implant site preparation has been demonstrated in animal and human studies.[76,77] Thermal trauma to bone can be avoided by the use of low-speed, high torque handpieces and a graded series of both externally and internally cooled drills.[78] Surgical procedures may be performed under aseptic conditions, and a retrospective study addressing implants placed under aseptic "clean" conditions as compared with "sterile" or operating room conditions showed no significant differences in success rates using either technique.[79]

IMPLANT COMPLICATIONS AND MAINTENANCE

A failed implant has been described as one that is clinically mobile.[12] In contrast, an implant that shows progressive loss of supporting bone, but that is clinically immobile, is a failing implant.[12] Early implant failures denote a lack of initial integration while late failures and failing implants occur after initial integration, physiological remodeling, and loading.[12] Problems limited to the soft tissues surrounding implants and not involving the supporting bone have been defined as "ailing implants"[80] and, more recently, as biological complications.[81]

Endosseous dental implants rarely fail beyond the first year after restoration.[25,82] However, it has been suggested that conventional periodontal therapy should be instituted if inflammation develops around an implant.[83] With regard to the peri-implant microbiota, the peri-implant sulcus and surface of endosseous dental implants acquire the patient's indigenous periodontal microflora.[84] Furthermore, the microbiological findings related to healthy and failing implants are the same as those for healthy and periodontally compromised teeth.[85,86] Failing dental implants have been attributed to several factors, including bacterial infection, improper surgical procedures, and occlusal overload.[87-89]

Infected sites around failed implants may harbor a complex microbiota with a large proportion of *Porphyromonas gingivalis, Prevotella intermedia,* and *Fusobacterium nucleatum*.[83] In contrast, failing implants with a traumatic etiology may have a microflora that is comprised predominantly of streptococci that is consistent with periodontal health.[86] In one report, the terms infectious and traumatic failure were used to describe different clinical and microbiological features.[86]

These findings support the recommendation that patients with implants be evaluated at regular visits for periodontal maintenance procedures and any clinical signs and symptoms of peri-implant disease be recorded and treated.[35,81] Reports indicate that peri-implant disease has been treated by both surgical and non-surgical techniques.[29,81,83,90-95] However, when a failing implant becomes mobile, it is a failure and most clinicians suggest implant removal.[81] If an implant has to be removed, an alternative restorative treatment plan, including the possibility of a second implant, can be discussed with the patient.

Little information is available on the effect of occlusion on implant survival. Currently, there is no direct evidence that non-axial loading is detrimental to the bone-implant interface, but abnormal occlusal loading will adversely affect the various components of an implant supported prosthesis.[12] Furthermore, there are limited data regarding the effects of splinting implants to natural teeth.[96-105]

In this regard, it has been reported that intrusion of splinted teeth and pronounced vertical bone loss around implant abutments are potential sequelae; however, the majority of patients, 8 out of 10, in one study suffered no adverse effects.[101] Other reports have indicated that connecting implants to teeth in a fixed prosthesis has a good prognosis.[102-104] A 5-year prospective study designed to compare bridges supported only by implants with bridges supported by both implants and natural teeth within the same patient, noted no higher risk of implant or prosthetic failure for tooth-implant fixed bridges as compared with implant-supported bridges.[105]

Data indicate that a lack of keratinized tissue attached to an abutment or machined surface implant will have no adverse effect on implant survival.[106,107] With regard to soft tissue apposition, there is no evidence for the presence of Sharpey's fibers between an implant or implant abutment and bone. However, a minimum width of peri-implant mucosa appears to be required to allow a stable epithelial-connective tissue attachment to form. Such a width is analogous to a biological width (height) around natural teeth.[108-110] The location of the microgap between the abutment and the coronal aspect of the implant will also influence the coronal height of bone contact.[111]

Patients should be on a regular recall schedule to monitor the maintenance, including plaque control, of the implant-supported prostheses.[112,113] Maintenance programs should be designed on an individual basis, because there is a lack of data detailing precise recall intervals, methods of plaque and calculus removal, and appropriate antimicrobial agents for maintenance around implants.[81,112,113] Reports indicate that steel curets should not be used to remove calculus as they may scratch abutments, leading to further plaque accumulation.[112,113] To avoid this, titanium-tipped curets have been developed, but one report indicated that titanium-tipped curets produced rougher surfaces than those treated with steel instruments.[114] However, a literature review determined that roughened implant abutment surfaces caused by different maintenance techniques have not been shown to increase implant complications.[81] At this time, all that can be concluded is that more research is needed on the appropriate instrumentation and non-mechanical methods for maintenance of implants and abutments of different configurations and surfaces.[81,112,113]

SUMMARY AND FUTURE RESEARCH

Endosseous dental implants have revolutionized the fields of implants and periodontics. During the last decade, a great deal of information has been generated concerning the effectiveness and predictability of endosseous implants. Implant placement is a viable option in the treatment of partial and full edentulism and has become an integral facet of periodontal therapy. The available implants are remarkably successful. However, there is no one ideal implant system.

The following areas need further study: edentulous sites with inadequate bone for endosseous implants, splinting of implants to natural teeth, long-term effects of microbial and occlusal stresses, the prevention and treatment of peri-implant infection and disease, effects of implants on alveolar ridge maintenance, and routine maintenance protocols. Research on implant design for narrow ridges and atrophic jaws is ongoing, and the clinical efficacy of localized ridge augmentation and sinus floor grafts is being investigated.[58,59,115] An area of research with future clinical significance is the use of growth factors and osteoinductive substances which may be applied locally or incorporated into the implant's surface.[116-123] These factors may increase bone quality and quantity and enhance the osseointegration of implants at recent extraction sites and in areas of inadequate bone.

Equally important are research efforts to determine the predictive ability of biomechanical markers to identify peri-implant bone loss prior to its clinical detectability.[124] Implant surface characteristics also are being evaluated for their effects on bone to implant contact and their ability to decrease the healing period.[10,15,18-22] The placement of implants into the maxillary anterior sextant, which has unique esthetic requirements, has prompted a critical review of existing surgical procedures and implant prosthetic components for the partially edentulous patients.[14,125-127] Ongoing and future research efforts should provide further advancements in these areas.

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REFERENCES

1. Meskin LH, Brown LHJ. Prevalence and pattern of tooth loss in U.S. employed adult and senior populations, 1985-86. *J Dent Educ* 1988;52:686-691.
2. Harvey C, Kelly JE. Decayed, missing and filled teeth among persons 1-74 years, United States. Vital and health statistics. *National Center for Health Statistics. US Department of Health and Human Services* 1981; Pub No 81-1673, series 11, No 223.
3. Seckinger RJ, Barber HD, Phillips K, Saleh N, Ferrarie J. A clinical study of titanium plasma sprayed (TPS)-coated threaded and TPS-coated cylindrical endosseous dental implants. *Guide Impl Res* 1996;1:5-8.
4. Bränemark PI. Introduction to osseointegration. In: Bränemark PI, Zarb G, Albrektsson T, eds. *Tissue Integrated Prostheses: Osseointegration in Clinical Dentistry*. Chicago: Quintessence; 1995;11-76.
5. Schroeder A, Zypen E, Stich H, Sutter F. The reactions of bone, connective tissue, and epithelium to endosteal implants with titanium-sprayed surfaces. *J Maxillofac Surg* 1981;9:15-25.
6. Albrektsson T. Bone tissue response. In: Bränemark PI, Zarb G, Albrektsson T. eds. *Tissue Integrated Prostheses: Osseointegration in Clinical Dentistry*. Chicago: Quintessence; 1985;129-143.
7. Listgarten MA, Lang NP, Schroeder HE, Schroeder A. Periodontal tissues and their counterparts around endosseous implants. *Clin Oral Impl Res* 1991;2:1-19.
8. Hansson H-A, Albrektsson T, Bränemark PI. Structural aspects of the interface between tissue and titanium implants. *J Prosthet Dent* 1983;50:108-113.
9. Han C-H, Han D-H. A study on shear-bond strength on the interface between bone and titanium plasma-sprayed IMZ implants in rabbits. *Int J Oral Maxillofac Implants* 1994;9:698-709.
10. Buser D, Nydegger T, Hirt HP, Cochran DL, Nolte L-P. Removal torque values of titanium implants in the maxilla of miniature pigs. *Int J Oral Maxillofac Implants* 1998;13:611-619.
11. Meffert RM, Block MS, Kent JN. What is osseointegration. *Int J Periodontics Restorative Dent* 1987;7(4):9-21.
12. Cochran D. Implant therapy I. *Ann Periodontol* 1996;1:707-791.
13. Lang NP, Nyman SR. Supportive maintenance care for patients with implants and advanced restorative therapy. *Periodontol 2000* 1994;4:119-126.
14. Binon PP. Implants and components: Entering the new millennium. *Int J Oral Maxillofac Implants* 2000;15:76-94.
15. Schulte W, Heimke G. The Tübingen immediate implant. *Quintessence* Int 1976;6:17-23.
16. Gomez-Roman G, Schulte W, d'Hoedt B, Axman-Kremar D. The Frialit-2 implant system: five-year clinical experience in single-tooth and immediately postextraction applications. *Int J Oral Maxillofac Implants* 1997;12:299-309.
17. Buser D, Schenk RK, Steinemann S, Fiorellini JP, Fox CH, Stich H. Influence of surface characteristics on bone integration of titanium implants. A histomorphometric study in miniature pigs. *J Biomed Mat Res* 1991;25:889-902.
18. Deporter DA, Watson PA, Pilliar RM, Chipman ML, Valique N. A histological comparison in the dog of porous coated vs. threaded dental implants. *J Dent Res* 1990;69:1138-1145.
19. Block MS, Finger IM, Fontenot MG, Kent JN. Loaded hydroxyapatite coated and grit blasted titanium implants in dogs. *Int J Oral Maxillofac Implants* 1989;4:219-225.
20. Wannerberg A, Albrekttson T. Suggested guidelines for the topographic evaluation of implant surfaces. *Int J Oral Maxillofac Implants* 2000;15:331-344.
21. Leimola-Virtanen R, Peltola J, Oksala E, Helenius H, Happonen RP. ITI titanium plasma-sprayed screw implants in the treatment of edentulous mandibles: a follow-up study of 39 patients. *Int J Oral Maxillofac Implants* 1995;10:373-378.
22. Gross KA, Berndt CC, Iacono VJ. Variability of hydroxyapatite-coated dental implants. *Int J Oral Maxillofac Implants* 1998;13:601-610.
23. Albrektsson T, Zarb G, Worthington P, Eriksson RA.

The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *Int J Oral Maxillofac Implants* 1986;1:11-25.
24. Smith DE, Zarb GA. Criteria for success of osseointegrated endosseous implants. *J Prosthet Dent* 1989; 62:567-572.
25. Albrektsson T, Dahle E, Enborm L, et al. Osseointegrated oral implants: A Swedish multi-center study of 8,139 consecutively inserted Nobelpharma implants. *J Periodontol* 1988;59:287-296.
26. Arvidson K, Bystedt H, Frykholm A, von Konow L, Lothigius E. A 3-year clinical study of Astra dental implants in the treatment of edentulous mandibles. *Int J Oral Maxillofac Implants* 1992;7:321-329.
27. Spiekermann H, Jansen VK, Richter EJ. A 10-year follow-up study of IMZ and TPS implants in the edentulous mandible using bar-retained overdentures. *Int J Oral Maxillofac Implants* 1995;10:231-243.
28. Mericski-Stern R, Schaffner TS, Marti P, Geering AH. Peri-implant mucosal aspects of ITI implants supporting overdentures: A five-year longitudinal study. *Clin Oral Impl Res* 1994;5:9-18.
29. Fritz ME. Implant therapy. II. *Ann Periodontol* 1996; 1:796-815.
30. Lekholm U, van Steenberghe D, Herrimann I, et al. Osseointegrated implants in the treatment of partially edentulous jaws: A prospective 5-year multicenter study. *Int J Oral Maxillofac Implants* 1994;9:627-635.
31. Buser D, Weber HP, Bragger U, Balsiger C. Tissue integration of one-stage ITI implants: 3-year results of a longitudinal study with hollow-cylinder and hollow-screw implants. *Int J Oral Maxillofac Implants* 1991;6: 405-412.
32. Fugazzotto PA, Gulbransen HJ, Wheeler SL, Lindsay J. The use of IMZ osseointegrated implants in partially and completely edentulous patients: success and failure rates of 2,023 implant cylinders up to 60+ months in function. *Int J Oral Maxillofac Implants* 1993;8:617-621.
33. Patrick D, Zosky J, Lubar R, Buchs A. The longitudinal clinical efficacy of Core-Vent dental implants: a five-year report. *J Oral Implants* 1989;15:95-103.
34. Saadoun AP, LeGall ML. Clinical results and guidelines on Steri-Oss endosseous implants. *Int J Periodontics Restorative Dent* 1992;12:486-495.
35. Sbordone L, Barone A, Ciaglia RN, Ramaglia L, Iacono VJ. Longitudinal study of dental implants in a periodontally compromised population. *J Periodontol* 1999;70:1322-1329.
36. Cochran DL. Endosseous dental implant surfaces in human clinical trials. A comparison using meta-analysis. *J Periodontol* 1999;70:1523-1539.
37. Kinsel RP, Lamb RE, Ho D. The treatment dilemma of the furcated molar: Root resection versus single-tooth implant restoration. A literature review. *Int J Oral Maxillofac Implants* 1998;13:322-332.
38. Fiorellini JP, Martuscelli G, Weber H-P. Longitudinal studies of implant systems. *Periodontol 2000* 1998;17: 125-131.
39. Bain CA, Moy PK. The association between the failure of dental implants and cigarette smoking. *Int J Oral Maxillofac Surg* 1993;8:609-615.
40. Weyant RJ. Characteristics associated with the loss and peri-implant tissue health of endosseous dental implants. *Int J Oral Maxillofac Implants* 1994;9:95-102.
41. Weyant R, Burt BA. An assessment of survival rates and within-patient clustering of failures for endosseous oral implants. *J Dent Res* 1993;72:2-8.
42. De Bruyn H, Callaert B. The effect of smoking on early implant failure. *Clin Oral Impl Res* 1994;5:260-264.
43. Nevins M, Langer B. The successful use of osseointegrated implants for the treatment of the recalcitrant periodontal patient. *J Periodontol* 1995;66:150-157.
44. Ranly DM. Implants in the circumpubertal patient: Growth considerations. *Am J Dent* 1998;11:86-92.
45. Wagenberg BD, Spitzer DA. Therapy for a patient with ogliodontia: Case report. *J Periodontol* 2000;71:510-516.
46. Oesterle LJ, Cronin RJ, Ranly DM. Maxillary implants and the growing patient. *Int J Oral Maxillofac Implants* 1993;8:377-387.
47. Oesterle LJ, Cronin RJ, Ranly DM. Mandibular implants and the growing patient. *Int J Oral Maxillofac Implants* 1994;9:55-62.
48. Iacono VJ, Livers HN. Special radiographic technique for implant dentistry. In: Wilson TG, Kornman KS, Newman MG, eds. *Advances in Periodontics*. Chicago: Quintessence; 1992;341-345.
49. McGivney GP, Haughton V, Strandt JA, Eicholz JE, Lubar DM. A comparison of computer-assisted tomography and data-gathering modalities in prosthodontics. *Int J Oral Maxillofac Implants* 1986;1:55-58.
50. van Steenberghe D, Lekholm U, Bolender C, et al. The applicability of osseointegrated oral implants in the rehabilitation of partial edentulism: a prospective multicenter study on 558 fixtures. *Int J Oral Maxillofac Implants* 1990;5:272-281.
51. Jaffin RA, Berman CL. The excessive loss of Bränemark fixtures in type IV bone: a 5-year analysis. *J Periodontol* 1991;62:2-4.
52. Schenk RK, Buser D. Osseointegration: a reality. *Periodontol 2000* 1998;17:22-35.
53. Lekholm U, Zarb, GA. Patient selection and preparation. In: Bränemark PI, Zarb G, Albrektsson T, eds. *Tissue Integrated Prostheses: Osseointegration in Clinical Dentistry*. Chicago: Quintessence; 1985;199-209.
54. Misch CE. Divisions of available bone in implant dentistry. *Oral Implantol* 1990;7:9-17
55. Trisi P, Rao W. Bone classification: clinical-histomorphometric comparison. *Clin Oral Impl Res* 1999;10: 1-7.
56. Hermann JS, Buser D. Guided bone regeneration for dental implants. *Current Opinion Periodontol* 1996;3: 168-177.
57. Hämmerle CH, Karring T. Guided bone regeneration at oral implant sites. *Periodontol 2000* 1998;17:151-175.
58. Tolman DE. Reconstructive procedures with endosseous implants in grafted bone: a review of the literature. *Int J Oral Maxillofac Implants* 1995;10:275-294.
59. Lorenzoni M, Pertl C, Polasky RA, Wegscheider WA.

Guided bone regeneration with barrier membranes—a clinical and radiographic follow-up study after 24 months. *Clin Oral Impl Res* 1999;10:16-23.
60. Buser D, Dula K, Hirt HP, Schenk RK. Lateral ridge augmentation using autografts and barrier membranes. a clinical study with 40 partially edentulous patients. *J Oral Maxillofac Surg* 1996;54:420-432.
61. Jensen OT, Shulman LB, Block MS, Iacono VJ. Report of the sinus consensus conference of 1996. *Int J Oral Maxillofac Implants* 1998;13(Suppl.):11-45.
62. Atwood DA. Some clinical factors related to rate of resorption of residual ridges. *J Prosthet Dent* 1962;12: 441-450.
63. Ostler MS, Kokich VG. Alveolar ridge changes in patients congenitally missing mandibular second premolars. *J Prosthet Dent* 1994;71:144-149.
64. Gher ME, Quintero G, Assad D, Monaco E, Richardson AC. Bone grafting and guided bone regeneration for immediate dental implants in humans. *J Periodontol* 1994;65:881-891.
65. Gelb DA. Immediate implant surgery: three-year retrospective evaluation of 50 consecutive cases. *Int J Oral Maxillofac Implants* 1993;8:388-399.
66. Schwartz-Arad D, Ghaush G. Full-arch restoration of the jaw with fixed ceramometal prostheses. *Int J Oral Maxillofac Implants* 1998;13:819-825.
67. Rosenquist B, Grenthe B. Immediate placement of implants into extraction sockets: implant survival. *Int J Oral Maxillofac Implants* 1996;11:205-209.
68. Wilson TG Jr, Schenk R, Buser D, Cochran D. Implants placed in immediate extraction sites: a report of histologic and histometric analyses of human biopsies. *Int J Oral Maxillofac Implants* 1998;13:333-341.
69. Tarnow DP, Fletcher P. The two-to-three month post-extraction placement of root form implants: a useful compromise. *Implants: Clin Rev Dent* 1993;2:1-6.
70. Evian CI, Rosenberg ES, Coslet JG, et al. The osteogenic activity of bone removed from healing extraction sockets in humans. *J Periodontol* 1982;53: 81-85.
71. Brunski JB, Puleo DA, Nanci A. Biomaterials and biomechanics of oral and maxillofacial implants: current status and future developments. *Int J Oral Maxillofac Implants* 2000;15:15-46.
72. Henry P, Rosenberg J. Single-stage surgery for rehabilitation of the edentulous mandible. preliminary results. *Practical Periodontics Aesthetic Dent* 1994;6: 15-22.
73. Randow K, Ericsson I, Nilner K, Petersson A, Glantz P-O. Immediate functional loading of Bränemark dental implants. An 18-month clinical follow-up study. *Clin Oral Impl Res* 1999;10:8-15.
74. Tarnow DP, Emitiaz 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.
75. Ledermann P. Stegprothetische versorgung des zahnlosen unterkiefers mit hilfe von plasmabeschichteten titanschraubenimplantaten (in German). *D Zahnärztl Z* 1979;34:907-911.
76. Eriksson A, Albrektsson T. Temperature threshold levels for heat-induced bone tissue injury: a vital microscopic study in the rabbit. *J Prosthet Dent* 1983;50: 101-107.
77. Eriksson A, Albrektsson T, Grane B, McQueen D. Thermal injury to bone. A vital-microscopic description of heat effects. *Int J Oral Surg* 1982;11:115-121.
78. Erikson A, Adell R. Temperatures during drilling for the placement of implants using the osseointegration technique. *J Oral Maxillofac Surg* 1986;44:4-7.
79. Scharf D, Tarnow D. Success rates of osseointegration for implants placed under sterile versus clean conditions. *J Periodontol* 1993;74:954-956.
80. Krauser JT. Hydroxylapatite-coated dental implants. Biologic rationale and surgical technique. *Dent Clin N Am* 1989;33:879-903.
81. Esposito M, Hirsch J, Lekholm U, Thomsen P. Differential diagnosis and treatment of strategies for biologic complications and failing oral implants: A review of the literature. *Int J Oral Maxillofac Implants* 1999;14:473-490.
82. Buser D, Mericske-Stern R, Bernard JP, et al. Long-term evaluation of non-submerged ITI implants. I. An 8-year life table analysis of a prospective multicenter study with 2359 implants. *Clin Oral Implants Res* 1997;8:161-172.
83. Sbordone L, Barone A, Ramaglia L, Ciaglia RN, Iacono VJ. Antimicrobial susceptibility of periodontopathic bacteria associated with failing implants. *J Periodontol* 1995;66:69-74.
84. Iacono VJ, Sbordone L, Spagnuolo G, Ciaglia RN, Gomes BC, Baer PN. Clinical and microbiological evaluation of dental implants: A retrospective analysis of success and failure. *Recent Adv Periodontol* 1991;2:85-91.
85. Mombelli A, van Oosten MAC, Schurch E, Lang NP. The microbiota associated with successful or failing osseointegrated titanium implants. *Oral Microbiol Immunol* 1987;2:145-151.
86. Rosenberg ES, Torosian JP, Slots J. Microbial differences in two clinically distinct types of failures of osseointegrated implants. *Clin Oral Impl Res* 1991;2: 135-144.
87. Becker W, Becker B, Newman M, Numan S. Clinical and microbiologic findings that may contribute to dental implant failure. *Int J Oral Maxillofac Surg* 1990;5: 31-38.
88. Reiser G, Nevins M. The implant periapical lesion: Etiology, prevention, and treatment. *Compendium Cont Educ Dent* 1995;16:768-777.
89. Tonetti MS. Risk factors for osseodisintegration. *Periodontol 2000* 1998;17:55-62.
90. Mombelli A, Lang NP. Antimicrobial treatment of peri-implant infections. *Clin Oral Implants Res* 1992;3:162-168.
91. Parham PL, Cobb CM, French AA, et al. Effects of an air powder abrasive system on plasma sprayed titanium implant surfaces: an in vitro evaluation. *J Oral Implantol* 1989;15:78-86.
92. Zablotsky MH, Diedrich D, Meffert R. Detoxification of endotoxin contaminated titanium and hydroxylapatite coated surfaces utilizing various chemotherapeutic and mechanical modalities. *Implant Dent* 1992;1:154-158.

93. Zablotsky MH, Wittrig EE, Diedrich DL, Layman DL, Meffert RM. Fibroblastic growth and attachment on hydroxylapatite-coated titanium surfaces following the use of various detoxification modalities. Part II: Contaminated hydroxylapatite. *Implant Dent* 1992;1:195-202.
94. Jovanovic SA, Kenney EB, Carranza FA, Donath K. The regenerative potential of plaque-induced peri-implant bone defects treated by a submerged membrane technique. An experimental study. *Int J Oral Maxillofac Implants* 1993;8:13-18.
95. Mombelli A, Lang NP. The diagnosis and treatment of peri-implantitis. *Periodontol 2000* 1998;17:63-76.
96. van Steenberghe D. A retrospective multicenter evaluation of the survival rate of osseointegrated fixtures supporting fixed partial bridges in the treatment of partial edentulism. *J Prosthet Dent* 1989;61:217-223.
97. Krämer A. Clinical and roentgenological findings and occlusal measurements at implants in the free end situation. *Oral Surg Oral Diagnosis* 1990;1:11-16.
98. O'Leary TJ, Dykema RW, Kafrawy AH. Splinting osseointegrated fixtures to teeth with normal periodontium. In: Laney WR, Tolman DE, eds. *Tissue Integration in Oral, Orthopedic and Maxillofacial Reconstruction.* Chicago: Quintessence; 1990;48-57.
99. Rangert B, Gunne J, Sullivan DY. Mechanical aspects of a Bränemark implant connected to a natural tooth: an in vitro study. *Int J Oral Maxillofac Implants* 1991;6:177-186.
100. Richter E-J, Spiekermann H, Jovanovic SA. Tooth-to-implant fixed bridges: biomechanics based on in vitro and in vivo measurements. In: Laney WR, Tolman DE, eds. *Tissue Integration in Oral, Orthopedic, and Maxillofacial Reconstruction.* Chicago: Quintessence; 1990;133-139.
101. Ericsson I, Lekholm U, Bränemark P-I, Lindhe J, Glantz PO, Nyman S. A clinical evaluation of fixed-bridge restorations supported by the combination of teeth and osseointegrated titanium implants. *J Clin Periodontol* 1986;13:307-312.
102. Åstrand P, Borg K, Gunne J, Olsson M. Combination of natural teeth and osseointegrated implants as bridge abutments: a 2-year longitudinal study. *Int J Oral Maxillofac Implants* 1991;6:305-312.
103. Gunne J, Åstrand P, Ahlén K, Borg K, Olsson M. Implants in partially edentulous patients. A longitudinal study of bridges supported by both implants and natural teeth. *Clin Oral Implants Res* 1992;3:49-56.
104. Kay HB. Free-standing versus implant-tooth-interconnected restorations: understanding the prosthodontic perspective. *Int J Periodontics Restorative Dent* 1993;13:47-69.
105. Olsson M, Gunne J, Åstrand P, Borg K. Bridges supported by free-standing implants versus bridges supported by tooth and implant. A five-year prospective study. *Clin Oral Implants Res* 1995;6:114-121.
106. Wennström JL, Bengazi F, Lekholm U. The influence of the masticatory mucosa on the peri-implant soft tissue condition. *Clin Oral Implants Res* 1994;5:1-8.
107. Mericske-Stern R, Steinlin-Schaffner T, Marti P, Geering AH. Peri-implant mucosal aspects of ITI implants supporting overdenture. A 5-year longitudinal study. *Clin Oral Implants Res* 1994;5:9-18.
108. Berglundh T, Lindhe J, Ericsson I, Marinello CP, Liljenberg B, Thomsen P. The soft tissue barrier at implants and teeth. *Clin Oral Implants Res* 1991;2:81-90.
109. Berglundh T, Lindhe J. Dimension of the peri-implant mucosa. Biological width revisited. *J Clin Periodontol* 1996;23:971-973.
110. Cochran DL, Hermann JS, Schenk RK, Higginbottom FL, Buser D. Biologic width around titanium implants. A histometric analysis of the implanto-gingival junction around unloaded and loaded nonsubmerged implants in the canine mandible. *J Periodontol* 1997;68:186-198.
111. Hermann JS, Cochran DL, Nummikoski PV, Buser D. Crestal bone changes around titanium implants. A radiographic evaluation of unloaded nonsubmerged and submerged implants in the canine mandible. *J Periodontol* 1997;68:1117-1130.
112. The American Academy of Periodontology. Guidelines for Periodontal Therapy (position paper). *J Periodontol* 1998;69:405-408.
113. The American Academy of Periodontology. Supportive Periodontal Therapy (SPT) (position paper). *J Periodontol* 1998;69:502-506.
114. Fox SC, Moriarity JD, Kusy RP. The effects of scaling a titanium implant surface with metal and plastic instruments. An in vitro study. *J Periodontol* 1990;61:485-490.
115. Ten Bruggenkate CM, van den Bergh JPA. Maxillary sinus floor elevation: a valuable pre-prosthetic procedure. *Periodontol 2000* 1998;17:176-182.
116. Cochran DL, Schenk R, Buser D, Wozney JM, Jones AA. Recombinant human bone morphogenetic protein-2 stimulation of bone formation around endosseous dental implants. *J Periodontol* 1999;70:139-150.
117. Yan J, Xiang W, Baolin L, White F. Early histologic response to titanium implants complexed with bovine bone morphogenetic protein. *J Prosthet Dent* 1994;71:289-294.
118. Lynch S, Buser D, Hernandez R, et al. Effects of the platelet-derived growth factor/insulin-like growth factor-I combination on bone regeneration around titanium dental implants. Results of a pilot study on beagle dogs. *J Periodontol* 1991;62:710-716.
120. Nevins M, Kirker-Head C, Nevins M, et al. Induction of bone formation in the goat maxillary sinus by absorbable collagen sponge implanted impregnated with recombinant human bone morphogenetic protein-α. *Int J Periodontics Restorative Dent* 1996;16:9-19.
121. Boyne PJ, Marx RE, Nevins M, et al. A feasibility study evaluating rhBMP-2/absorbable collagen sponge for maxillary sinus floor augmentation. *Int J Periodontics Restorative Dent* 1997;17:11-25.
122. Howell TH, Fiorellini J, Jones A, et al. A feasibility study evaluating rh BMP-2/absorbable collagen sponge device for local alveolar ridge preservation or augmentation. *Int J Periodontics Restorative Dent* 1997;17:125-139.

122. Nevins M, Mellonig JT, Clem DS III, Reiser GM, Buser DA. Implants in regenerated bone: Long-term survival. *Int J Periodontics Restorative Dent* 1998;18:35-45.
123. Cochran DL, Jones AA, Lilly LC, Fiorellini JP, Howell H. Evaluation of recombinant human bone morphogenetic protein-2 in oral applications including the use of endosseous implants: 3-year results of a pilot study in humans. *J Periodontol* 2000;71:1243-1259.
124. Oringer RJ, Palys MD, Iranmanesh A, et al. C-telopeptide pyridinoline cross-links (ICTP) and periodontal pathogens associated with endosseous oral implants. *Clin Oral Implants Res* 1998;6:365-373.
125. Belser UC, Buser D, Hess D, Schmid B, Bernard J-P, Lang NP. Aesthetic implant restorations in partially edentulous patients–a critical appraisal. *Periodontol 2000* 1998;17:132-150.
126. Klokkevold PR, Newman MG. Current status if dental implants: a periodontal perspective. *Int J Oral Maxillofac Implants* 2000;15:56-65.
127. Taylor TD, Agar JR, Vogiatzi T. Implant prosthodontics: current perspective and future directions. *Int J Oral Maxillofac Implants* 2000;15:66-75.