Immediate Provisionalization of NanoTite Implants in Support of Single-Tooth and Unilateral Restorations: One-Year Interim Report of a Prospective, Multicenter Study

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ABSTRACT

Background: Clinical studies reporting immediate loading of endosseous implants for edentulous cases and for fixed partial restorations have been well documented with satisfactory survival rates. Implants with a recently developed, nanometer-scale surface topography (NanoTite®, BIOMET *3i*, Palm Beach Gardens, FL, USA), created by discrete crystalline depositions (DCD) of calcium phosphate nano-crystals onto a dual acid-etched (DAE) surface, show enhanced early fixation in preclinical studies when compared with DAE-surfaced implants. These outcomes suggest DCD-surfaced implants may be advantageous for immediate loading approaches.

Objective: The aim of this prospective, multicenter, observational study is to report clinical outcomes for DCD-surfaced implants placed in immediate functional support of single- and multi-unit restorations according to an immediate loading protocol.

Materials and Methods: One hundred eighty-five patients enrolled at 15 international study centers received a total of 335 implants supporting 216 immediate provisionalizations consisting of 128 single-tooth restorations and 88 fixed restorations. Of the 335 implants, 77% are located in posterior and 23% in anterior regions with 55.5% of the total in mandibles and 44.5% in maxillae. Patients were evaluated for implant mobility, gingival health, symptomatology, and radiographic outcomes.

Results: At the time of this 1-year interim report, a total of 17 failures have been observed in 11 patients, yielding a cumulative survival rate of 94.9%.

Conclusion: Relative to other prospective, multicenter studies of immediately loaded implants with various surface enhancements, NanoTite implants perform comparatively well when immediately provisionalized with single-tooth and fixed restorations.

KEY WORDS: dental implants, immediate loading, nanotopography, prospective study, provisionalization, single-tooth restorations

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INTRODUCTION

When procedures for dental implant therapy were first introduced, the timing of initial loading was a major consideration. The original two-stage implant protocol was intended to prevent micromotion during the healing period that could interfere with wound healing and lead to fibrous encapsulation and implant failure. Concern for micromotion led to a convention to allow two-stage implants to heal submerged for at least 4 to 6 months.[1–3] Since then, animal and clinical studies have shown that this unloaded healing time can be shortened.

Initially, it was shown that 2 months of healing may not only be adequate,[4,5] but also that in some cases, implants with a machined or modified implant surface, such as dual acid-etched (DAE), can be placed into function immediately after implant placement, without sacrificing implant integration performance.[6–9]

Encouraged by the ability of implants to successfully integrate with abbreviated healing times, clinicians realized advantages and benefits from reducing the restorative timeline. Immediate provisionalization reduces overall patient chair time and restores the patient to function, avoiding the inconvenience of a removable restorative appliance.

Initially, case selection for the immediate loading approach was restricted based on the notion that loading-induced stress and the risks of micromotion needed to be minimized. Thus, the immediate loading approach was primarily limited to edentulous mandibles and maxillae where splinting and cross-arch stabilization helped to stabilize the implants. The next step was to apply immediate loading procedures to partially edentulous cases having available cross-arch stabilization. Few studies have applied the immediate loading approach to a broad sampling of patients with single-tooth cases and partial edentulism without available lateral or cross-arch stabilization.

In 2007, the NanoTite® surface (BIOMET *3i*, Palm Beach Gardens, FL, USA) was introduced, featuring a nanotopography created by discrete crystalline deposition (DCD) of calcium phosphate (CaP) nanoparticles added to the DAE Osseotite® surface (BIOMET *3i*). This new nanometer-scale surface enhancement shows increases in early fixation outcomes compared with the DAE surface controls in several animal models,[10–12] as well as histomorphometric outcomes in human studies.[13,14]

AIM

The aim of this prospective, multicenter study is to document the clinical outcomes for DCD-surfaced implants when used for immediate, functional loading of fixed partial prostheses and single-tooth restorations (STRs) in patients representative of those seen in a typical implant practice.

MATERIALS AND METHODS

Study Design

This prospective, multicenter clinical study is a longitudinal analysis of the NanoTite implant system under the conditions of immediate loading of fixed bridges and STRs. Within a 6-month enrollment period, study centers were obligated to enroll 15 qualified patients. Fifteen study centers located in Australia, Belgium, Italy, Germany, The Netherlands, Sweden, and the United States participated. Specific treatment plans were based on the need for each patient to incorporate implants for support of prosthetic restorations including single-tooth replacements or fixed partial bridges without cross-arch stabilization. To qualify as an immediate provisionalization, prostheses were required to be inserted within 48 hours of implant placement.

Patient Selection

Patients eligible for enrollment were of either sex, of any race, greater than 18 years of age, and for whom a decision had already been made to incorporate dental implants for the treatment of partial edentulism. Exclusion criteria were limited to patients exhibiting active infection or severe inflammation in the areas intended for implant placement, uncontrolled diabetes or metabolic bone disease, pregnancy at the time of screening, therapeutic radiation to the head, and evidence of severe parafunctional habits. Patients in need of bone grafting at the site of the intended study implant were not candidates for this study. There were, however, no restrictions on bone quality or quantity at the sites intended for implant placement. A healing period of at least 4 months was required after tooth extraction. Between March and December 2006, a total of 185 patients met admission criteria and were consecutively enrolled. The mean patient age was 51.5 years (range of 18 to 83 years) and the gender distribution is 56% females and 44% males. The total number of immediately provisionalized implants was 335, which were placed in support of 216

cases consisting of 128 STRs (59.3%) and 88 multiple-unit fixed prostheses (40.7%)

Study Implants

All implants used in the study are the Certain® Prevail® implant system having a titanium-alloy threaded-body design with an internal connection feature. Implants were supplied in lengths of 8.5, 10, 11.5, and 13 mm and diameters of 4 and 5 mm. At the coronal portion, the implant diameter expands, creating a collar that is 1 mm greater than the body of the implant. The implant seating surface is medialized by 0.35 mm, providing an integrated platform-switch function. The Osseotite DAE surface is present from the apex to the top of the collar. The DAE surface is further treated with application of DCD of nanometer-scale CaP particles in order to achieve the NanoTite surface. These nanocrystals range in length from 20 to 100 nm and are present on all areas that have the acid-etched treatment.

Surgical Procedures

Osteotomy preparations were to be performed with low speed high-torque drill units using irrigation. A countersink drill specific for the expanded collar was to be used to prepare the cortical bone and enhance initial primary stability. A final peak torque at implant placement was to be recorded by setting the drill unit initial torque limit at 15 Ncm and increasing the limit in 10 Ncm increments until either the implant was seated or the drill unit's peak torque was reached. Use of an implant ratchet was to be recorded. The extent of initial implant fixation was recorded as tight, firm or loose, and bone density recorded as soft, normal, or dense. In the event that the implant did not achieve primary fixation or was placed with less than 15 Ncm peak torque, the investigators were given an option to delay loading and exclude the case from efficacy analysis.

Prosthetic Procedures

Investigators agreed to standardize the procedures for constructing and inserting the provisional prostheses. Three basic restorative methods are reported as "pre-," "peri-," and "post-surgical" approach. For the pre-surgical approach, an indirect impression is taken with construction of a prosthesis that is relined and cemented onto the abutments at the time of the implant placement surgery. The peri-surgical approach refers to the complete fabrication and insertion of a prosthesis chairside at the time of the implant placement surgery, and post-surgical refers to the approach where a direct (implant- or abutment-level) impression is taken and sent to a laboratory for preparation of the prosthesis that is inserted after surgery. Abutment selection was also at the discretion of the investigators and restorations could be either screw or cement-retained, and the specific cement product was to be recorded. Prostheses with cantilever units were prohibited and only one internal pontic was allowed for four or greater unit prostheses. Investigators had the option to place restorations in contact with opposing occlusion or to be left out of occlusion. Occlusal contact cases were to be documented as having registered centric contact points when using 20-micron articulating paper (Accu Film II, Parkell, Farmingdale, NY, USA) but with no holding resistance when using 8-micron Shim Stock (Hanel, Germany).

Follow-Up Evaluation Schedule

Evaluations were scheduled at the permanent prosthesis installation appointment 6 months following implant placement and at annual intervals for 5 years. At these intervals, patients return for assessment of both implant and prosthesis function and a standardized evaluation of his/her oral health. Standardized periapical radiographs are taken and examined to identify peri-implant radiolucencies and crestal bone levels.

Evaluation Criteria

Data from implant placement surgery through 12-month observation on all cases are included in this report. Implant survival is based on the absence of persistent signs and symptoms of infection, pain, paresthesia, inflammation, and implant mobility as assessed at the time of impression taking. Outcomes of the permanent prosthesis fabrication and installation, a detailed analysis of crestal bone data, and long-term implant and prosthesis performance will be included in a subsequent report.

RESULTS

Fifteen study centers located in Australia, Belgium, Italy, Germany, The Netherlands, Sweden, and the United States enrolled 185 patients between March and December 2006. Among these patients, 335 implants were placed supporting 216 prosthetic cases, including 128 STRs (59.3%) and 88 multiple-unit partial fixed prostheses (40.7%). Mean patient age at the time of

TABLE 1 Distribution of Implants by Length

Length (mm)	8.5	10	11.5	13	15
Percent	7.9	26.5	25.9	35.3	4.4

enrollment was 51.5 years with a range of 18 to 83 years and a gender distribution of 56% females and 44% males. Fourteen patients (8%) reported smoking with an average daily habit of 12.5 cigarettes which is greater than the exclusion criterion of 10 as patients confessed a higher smoking habit after receiving study implants. Six patients have yet to return for permanent restorations and an additional five patients are overdue for their 12-month follow-up visit. Their implants are censored in the analysis as lost-to-follow-up, but upon their return to clinics they will be included in subsequent life table analyses.

The implant/prosthesis ratio for the 88 multi-unit cases is 2.33. The distribution of multi-unit prostheses is as follows: two-unit 50%, three-unit 39%, four-unit 8%, and >4 units 3%. The distribution of implants by dimension is presented in Table 1 showing a nearly even proportion of implants among the 10, 11.5, and 13 mm lengths. The majority of implants placed were 4 mm in diameter (80.8%), with the remaining having a diameter of 5 mm. Table 2 shows the distribution of implants by region, with a majority placed in the posterior mandible (50.7%). The distribution of all implants by tooth site location in both the maxilla and mandible is illustrated in Figure 1. According to the clinicians' tactile assessment of bone density during osteotomy preparation, 20.5% of the implants were placed in bone identified as soft, 56.5% in bone identified as medium or "normal," and 23.0% in dense bone. During placement, 59.9% of the implants were observed as having a tight fit, 35.5% as a firm fit, and 4.9% as a loose fit. There were six cases involving seven implants where the investigator decided they did not reach a level of initial stability at implant

TABLE 2 Percent of total implants by locations in the four quadrants of the jaws

	Anterior	Posterior	Total
Maxilla	18.7	26.2	44.9
Mandible	4.7	50.4	55.1
Total	23.4	76.6	

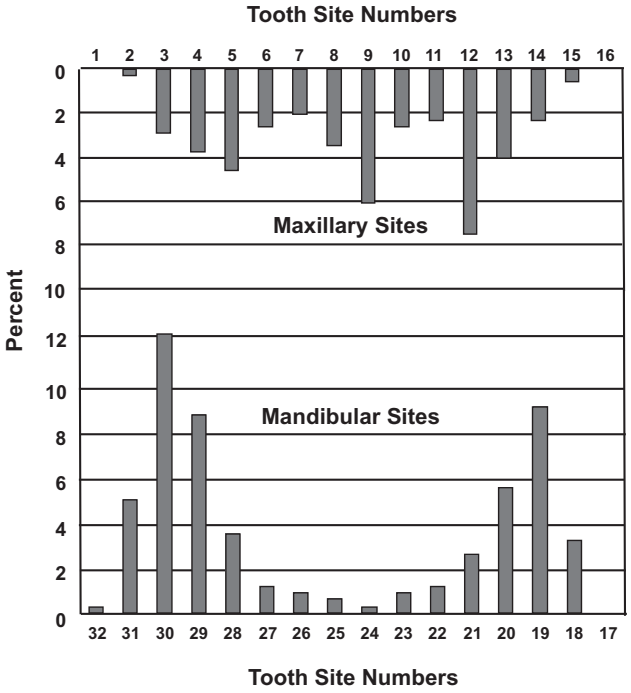

Figure 1 Distribution of implants by percentages according to tooth site numbers in the maxilla and mandible.

placement surgery to allow immediate provisionalization. The investigators elected to exclude these cases and postpone the restorative procedures.

For the immediate restorative approaches, 54% of investigators reported their procedures as being pre-surgical, 30% as peri-surgical, and 16% as post-surgical having a laboratory fabricate the temporary prosthesis for delivery within the 48-hour deadline. The majority of abutments used for prostheses were PreFormance® (BIOMET *3i*) components (Table 3A) which accounts for why most abutment preparations were performed chairside (72%). The next most frequently reported abutments were healing abutments (30%) as these were placed in cases that had prosthesis insertion later in the day. Some investigators placed abutments that were to be used for the permanent restoration (22%).

More than 40% of temporary crowns and prostheses were constructed from acrylic resin and 45% were bis-acryl resin fabricated with either Luxatemp® (DMG, Hamburg, Germany) or Protemp™ (3M ESPE, St. Paul, MN, USA), and prefabricated crown shells. Fifty-five percent of prosthetic cases were referred to outside dental laboratories for fabrication procedures, with the remaining 45% fabricated at "in-office" laboratories. Regarding single-tooth and fixed-prosthesis attachment, 80% of all cases had cement-retention and of these 56%

TABLE 3A Distribution of types of abutments (BIOMET *3i*) used for temporary prostheses

	PreFormance®					
	Post	Cylinder	GingiHue®	Provide®	Ti-Healing Cylinder	Not Specified
Percent	25.9	16.7	17.7	1.4	27.0	11.3

TABLE 3B Distribution of types of cement used for temporary restorations

	Temporary Cements			Permanent Cements			
	Tempbond®[1]	Tempbond-NE®[1]	Not Specified	Ketac™ Cem[2]	RelyX™[2]	Durelon®[2]	Not Specified
Type	With eugenol	Without eugenol		Composite resin	Glass ionomer	Carboxylate	
Percent	45.8	2.3	7.9	18.1	7.0	13.5	5.4
Percent	56			44			

[1]Kerr, Orange, CA, USA.
[2]3M ESPE, St Paul, MN, USA.

used "temporary" cement products with Tempbond® (Kerr, Orange, CA, USA) used most frequently (Table 3B). Those using "permanent" cement included polycarboxylate and glass ionomer cements. All provisionalizations were placed within the specified immediate-loading time limit; 85% were placed on the same (first) day, 8% on the second day (within 24 hours), and 7% on the third day between 24 and 48 hours of implant placement. Of the temporary restorative cases, 14% registered centric contact points on Accu Film II and constitute the immediate occlusal-loading cases in this project.

At the time of this 1-year interim report, 17 implants in 11 patients have been declared failures for an overall implant cumulative survival rate (CSR) of 94.9%. All but two of the failed implants were associated with signs of infection or persistent signs of either paresthesia or radiolucency. Regarding the timing of implant failure, 82% of all implant failures were declared within the first 3 months after implant placement and loading procedures. There was a two-implant case declared a failure 3 months after the permanent prosthesis was attached, 9.2 months after implant placement surgery.

DISCUSSION

Immediate loading protocols were first described for edentulous mandibles using a rigid fixed bar with cross-arch stabilization and a minimum of four implants. Because of concerns for bone loading trauma and failure to integrate, cases were selected with consideration of the following: using a surgical technique based on achieving primary fixation; placing the largest possible number of implants; determining implant dimensions to fit available quantity of bone; selecting implants with proven designs and surface textures; and adjusting the direction of occlusal forces and contact intensity.[15–17] With the growing recognition that immediate loading was a viable treatment option, case selection became less restrictive and included partially edentulous cases. Initially, restorative approaches for fixed bridges emphasized the value of cross-arch stabilization and absence of direct occlusal contacts.[18] Other considerations included the amount of insertion torque, its impact on primary stability,[19] and biomechanical loads, both of which were perceived to contribute to implant failure.[20] In the literature, multiple studies following immediately loaded DAE-surfaced implants for both fully[21–28] and partially[29] edentulous cases have been reported. Yet these and most other studies have protocols with specific criteria for selection of patients and cases unlike the study reported here. This prospective, multicenter study is distinctive because of a study design that intentionally includes unrestrictive admission criteria, single-tooth and unilateral restorations allowing direct occlusal contacts, and an implant featuring a newly developed nanometer-scale surface texture.

The immediate loading requirement for the present study is 48 hours and most (85%) cases were completed on the first day. This large same-day proportion of cases

most likely reflects the restorative approaches selected by the investigators and those who chose PreFormance abutments (40% of implants) and prepared them chairside. It is noteworthy that 53% of NanoTite implants were restored with a pre-surgical approach and that in-house labs were available for nearly half of all procedures. Investigators who selected abutments intended for permanent prostheses avoided the need for removal and reconnection thought to promote increased regressive crestal bone remodeling.[30] These are all advantages and may facilitate procedural success.

Although the occlusion on most of the provisional prostheses lacked direct occlusal contacts, forces generated during mastication, during movements of surrounding soft tissues and the musculature of the tongue, and through vibrations generated during speech serve to deliver functional loads on prostheses.[31,32] In this way, an immediately provisionalized implant is also an immediately loaded implant.

Provisionalized implants might be expected to be more frequently located in the anterior maxilla where patients often have concerns regarding their appearance, especially after loss of a single tooth.[33] Patients also do not want to be inconvenienced wearing a removable restorative "flipper" appliance during a submerged implant healing period.[34] In the present study, 19% of implants were placed in the anterior maxilla, and with only one implant failure, the CSR for the esthetic zone is 98.5%.

The protocol for the current study allows implant-supported STRs as a treatment option. Single-tooth implants may be at an increased risk for failure because they are subjected to a greater range of masticatory forces because of lack of lateral support and/or cross-arch stabilization. The large proportion of STR cases in this study (60%) was unanticipated. With seven failures out of a total of 128 STR implants, the CSR for these cases is 94.5%. A comprehensive MEDLINE search was done to find existing prospective studies in peer-reviewed journals that report integration performance of immediately loaded implants supporting STRs for comparison to the present study. The search resulted in over 380 citations and after reviews of relevant abstracts, and full-text articles, a total of 12 qualified publications were identified.[19,34–44] The authors of the earliest article, published in 1998,[35] report a case series of 10 STRs at 6 months and because no implants failed, they suggest that the immediate loading approach for STRs may be a feasible option. The subsequent 11 studies, of which five are prospective, were published between 2000 and 2006, and are summarized in Table 4. The data show that the number of immediately loaded STRs placed in the present study exceeds the number of STRs placed in each of the 11 clinical studies and that the CSR falls within the range of the studies (78.2–100%).

Groisman and colleagues,[37] with the largest number of cases, 92, conclude that there is a need for more long-term, prospective, multicenter studies to fully address the safety of immediately loading STRs and Ottoni and colleagues[19] suggest that functional forces can lead to STR failures and may have accounted for their 10 failures out of 46 implants placed. A recent

TABLE 4 Selected publications on clinical studies reporting performance of immediately-loaded implants supporting single-tooth restorations (STR)

Publication	Study Type	Number of STRs	Primary Location	Follow-Up (Months)	Failures	CSR (%)
Ericsson et al. 2000[40]	Case Series	14	Anterior maxilla	5	2	85.7
Hui et al. 2001[36]	Prospective	13	Anterior maxilla	1–15	0	100
Andersen et al. 2002[41]	Case Series	8	Maxilla	60	0	100
Lorenzoni et al. 2003[42]	Case Series	12	Anterior maxilla	12	0	100
Groisman et al. 2003[37]	Prospective	92	Anterior maxilla	24	6	93.5
Kan et al. 2003[34]	Prospective	35	Anterior maxilla	12	0	100
Cornelini et al. 2004[38]	Prospective	30	Posterior mandible	12	1	96.7
Abboud et al. 2005[39]	Prospective	20	Posterior mandible and maxilla	12	1	95.0
Ottoni et al. 2005[19]	Retrospective	46	Anterior maxilla and mandible	24	10	78.2
Ferrara et al. 2006[43]	Case Series	33	Anterior maxilla	48	1	97.0
Barone et al. 2006[44]	Case Series	18	Not Specified	12	1	94.4

CSR = cumulative survival rate.

consensus conference recommended that further prospective clinical trials with large patient numbers are "urgently needed to provide definitive data" on the effectiveness of immediate loading of STRs.[45] With relatively few articles found in the MEDLINE search conducted here, we report for comparison this 1-year interim evaluation because of the high proportion of STRs.

Preclinical observations indicating that the NanoTite surface may have a significant effect on primary fixation soon after implant placement laid the foundation for initiating this clinical study. In one biomechanical study, DCD-surfaced implants placed in rabbit tibiae required pull-out forces 189% greater to detach from bone in comparison with DAE-surfaced implants after 2 weeks of healing.[10] Nishimura and colleagues[12] also demonstrate the early fixation properties of the DCD surface in a rat model measuring a 76% increase in mechanical withstanding loads in comparison with the DAE surface. These results suggest that DCD effects occur during the time when de novo bone formation is most susceptible to micromotion and other forces that may impede osseous fixation mechanisms prior to mineralization of the bone matrix. Human histomorphometric outcomes for NanoTite implants placed in posterior maxillae demonstrate significantly greater bone-implant-contact at 4 weeks in comparison with DAE-surfaced implants (>194%).[13]

The first published study reporting clinical outcomes for immediately loaded NanoTite implants is a prospective 1-year evaluation.[46] Thirty-five patients enrolled at one study center received 102 NanoTite Prevail® (BIOMET *3i*) implants placed according to a protocol aimed at achieving high primary fixation requiring an insertion torque of at least 25 Ncm and an implant stability quotient above 55. During the first year of function, one implant failed resulting in a CSR of 99.2% and crestal bone loss was reported to be 0.37 mm (SD 0.39). These preclinical and clinical outcomes suggest that the DCD surface effects occur early and may have had a positive influence on the clinical outcomes for the immediate loading cases presented here.

CONCLUSION

The 1-year interim results from this prospective, multicenter study suggest that immediately loaded implants with the NanoTite surface perform comparatively well to immediately loaded implants with other surface textures in studies using stricter inclusion criteria.

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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.]

REFERENCES

1. Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. Int J Oral Surg 1981; 10:387–416.
2. Zarb GA, Jansson T. Prosthodontic procedures. In: Brånemark PI, ed. Tissue-integrated prostheses. Chicago, IL: Quintessence Publishing Co, 1985: 241–282.
3. Albrektsson T, Brånemark PI, Hansson HA, Lindström J. Osseointegrated titanium implants. Requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. Acta Orthop Scand 1981; 52:155–170.
4. Lazzara RJ, Porter SS, Testori T, Galante J, Zetterqvist L. A prospective multicenter study evaluating loading of Osseotite implants two months after placement: one-year results. J Esthet Dent 1998; 10:280–289.
5. Testori T, Del Fabbro M, Feldman S, et al. A multicenter prospective evaluation of 2-months loaded Osseotite implants placed in the posterior jaws: 3-year follow-up results. Clin Oral Implants Res 2002; 13:154–161.
6. Engstrand P, Gröndahl K, Ohrnell LO, Nilsson P, Nannmark U, Brånemark PI. Prospective follow-up study of 95 patients with edentulous mandibles treated according to the Brånemark Novum concept. Clin Implant Dent Relat Res 2003; 5:3–10.
7. Rocci A, Martignoni M, Gottlow J. Immediate loading of Brånemark System TiUnite and machined-surface implants in the posterior mandible: a randomized open-ended clinical trial. Clin Implant Dent Relat Res 2003; 5(Suppl 1):57–63.
8. Testori T, Del Fabbro M, Szmukler-Moncler S, Francetti L, Weinstein RL. Immediate occlusal loading of Osseotite implants in the completely edentulous mandible. Int J Oral Maxillofac Implants 2003; 18:544–551.
9. Testori T, Meltzer A, Del Fabbro M, Zuffetti F, Troiano M, Weinstein RL. Immediate occlusal loading of Osseotite implants in the lower edentulous jaw. A multicenter prospective study. Clin Oral Implants Res 2004; 15:278–284.
10. Kenealy JN, Stach RM, Berckmans B. Nanometer-scale Ca P enhances early implant-bone fixation in an animal model. Clin Oral Implants Res 2006; 17:cxxi.
11. Mendes VC, Moineddin R, Davies JE. Discrete calcium phosphate nanocrystals render titanium surfaces bone bonding. Biomaterials 2007; 28:4748–4755.

12. Nishimura I, Huang Y, Butz F, Ogawa T, Lin A, Wang CJ. Discrete deposition of hydroxyapatite nanoparticles on a titanium implant with predisposing substrate microtopography accelerated osseointegration. Nanotechnology (Serial online) 2007; 18. Epub 245101.
13. Goené RJ, Testori T, Trisi P. Influence of a nanometer-scale surface enhancement on de novo bone formation on titanium implants: a histomorphometric study in human maxillae. Int J Periodontics Restorative Dent 2007; 3:210–219.
14. Orsini G, Piattelli M, Scarano A, et al. Randomized, controlled histologic and histomorphometric evaluation of implants with nanometer-scale calcium phosphate added to the dual acid-etched surface in the human posterior maxilla. J Periodontol 2007; 78:209–218.
15. Gapski R, Wang HL, Mascarenhas P, Lang NP. Critical review of immediate implant loading. Clin Oral Implants Res 2003; 14:515–527.
16. Misch CE, Wang HL, Misch CM, Sharawy M, Lemons J, Judy KW. Rationale for the application of immediate load in implant dentistry: part I. Implant Dent 2004; 13:207–217.
17. Misch CE, Wang HL, Misch CM, Sharawy M, Lemons J, Judy KW. Rationale for the application of immediate load in implant dentistry: part II. Implant Dent 2004; 13:310–321.
18. Rocci A, Martignoni M, Gottlow J. Immediate loading in the maxilla using flapless surgery, implants placed in predetermined positions, and prefabricated provisional restorations: a retrospective 3-year clinical study. Clin Implant Dent Relat Res 2003; 5(Suppl 1):29–36.
19. Ottoni JM, Oliveira ZF, Mansini R, Cabral AM. Correlation between placement torque and survival of single-tooth implants. Int J Oral Maxillofac Implants 2005; 20:769–776.
20. Degidi M, Piattelli A. 7-year follow-up of 93 immediately loaded titanium dental implants. J Oral Implantol 2005; 31:25–31.
21. Testori T, Szmukler-Moncler S, Francetti L, et al. Immediate loading of Osseotite implants: a case report and histologic analysis after 4 months of occlusal loading. Int J Periodontics Restorative Dent 2001; 21:451–459.
22. Ibanez JC, Jalbout ZN. Immediate loading of Osseotite implants: two-year results. Implant Dent 2002; 11:128–136.
23. Testori T, Szmukler-Moncler S, Francetti L, Del Fabbro M, Trisi P, Weinstein RL. Healing of Osseotite implants under submerged and immediate loading conditions in a single patient: a case report and interface analysis after 2 months. Int J Periodontics Restorative Dent 2002; 22:345–353.
24. Testori T, Del Fabbro M, Szmukler-Moncler S, Francetti L, Weinstein RL. Immediate occlusal loading of Osseotite implants in the completely edentulous mandible. Int J Oral Maxillofac Implants 2003; 18:544–551.
25. Drago CJ, Lazzara RJ. Immediate provisional restoration of Osseotite implants: a clinical report of 18-month results. Int J Oral Maxillofac Implants 2004; 19:534–541.
26. Lazzara RJ, Testori T, Meltzer A, et al. Immediate occlusal loading (IOL) of dental implants: predictable results through DIEM guidelines. Pract Proced Aesthet Dent 2004; 16:3–15.
27. Testori T, Meltzer A, Del Fabbro M, Zuffetti F, Troiano M, Weinstein RL. Immediate occlusal loading of Osseotite implants in the lower edentulous jaw: a multicenter prospective study. Clin Oral Implants Res 2004; 15:278–284.
28. Tsirlis AT. Clinical evaluation of immediate loaded upper anterior single implants. Implant Dent 2005; 14:94–103.
29. Testori T, Bianchi F, Del Fabbro M, Smuckler-Moncler S, Francetti L, Weinstein RL. Immediate non-occlusal loading vs. early loading in partially edentulous patients. Pract Proced Aesthet Dent 2003; 15:787–794.
30. King G, Hermann J, Schoolfield J, Buser D, Cochran DL. Influence of the size of the microgap on crestal bone levels in non-submerged dental implants: a radiographic study in the canine mandible. J Periodontol 2002; 73:1111–1117.
31. Bousdras VA, Sindet-Pedersen S, Cunningham JL, et al. Immediate functional loading of single-tooth TIO2 grit-blasted implant restorations: a controlled prospective study in a porcine model. Part I: clinical outcome. Clin Implant Dent Relat Res 2007; 9:197–206.
32. Laney WR. Prosthodontics. In: Laney WR, ed. Glossary of oral and maxillofacial implants. Berlin: Quintessence Publishing Co. LTD, 2007: 62,73.
33. Kan JY, Rungcharassaeng K. Immediate placement and provisionalization of maxillary anterior single implants: a surgical and prosthodontic rationale. Pract Periodontics Aesthet Dent 2000; 12:817–824.
34. Kan JY, Rungcharassaeng K, Lozada J. Immediate placement and provisionalization of maxillary anterior single implants: 1-year prospective study. Int J Oral Maxillofac Implants 2003; 8:31–39.
35. Kupeyan HK, May KB. Implant and provisional crown placement: a one stage protocol. Implant Dent 1998; 73:213–219.
36. Hui E, Chow J, Li D, Liu Y, Wat P, Law H. Immediate provisional for single-tooth implant replacement with Brånemark system: preliminary report. Clin Implant Dent Relat Res 2001; 3:79–86.
37. Groisman M, Frossard WM, Ferreira HM, de Menezes Filho LM, Touati B. Single-tooth implants in the maxillary incisor region with immediate provisionalization: 2-year prospective study. Pract Proced Aesthet Dent 2003; 15: 115–122.
38. Cornelini R, Cangini F, Covani U, Barone A, Buser D. Immediate restoration of single-tooth implants in mandibular molar sites: a 12-month preliminary report. Int J Oral Maxillofac Implants 2004; 19:855–860.
39. Abboud M, Koeck B, Stark H, Wahl G, Paillon R. Immediate loading of single-tooth implants in the posterior region. Int J Oral Maxillofac Implants 2005; 20:61–68.

40. Ericsson I, Nilson H, Lindh T, Nilner K, Randow K. Immediate functional loading of Brånemark single tooth implants. An 18 months' clinical pilot follow-up study. Clin Oral Implants Res 2000; 11:26–33.
41. Andersen E, Haanaes HR, Knutsen BM. Immediate loading of single-tooth ITI implants in the anterior maxilla: a prospective 5-year pilot study. Clin Oral Implants Res 2002; 13:281–287.
42. Lorenzoni M, Pertl C, Zhang K, Wimmer G, Wegschider WA. Immediate loading of single-tooth implants in the anterior maxilla. Preliminary results after one year. Clin Oral Implants Res 2003; 14:180–187.
43. Ferrara A, Galli C, Mauro G, Macaluso GM. Immediate provisional restoration of postextraction implants for maxillary single-tooth replacement. Int J Periodontics Restorative Dent 2006; 26:371–377.
44. Barone A, Rispoli L, Vozza I, Quaranta A, Covani U. Immediate restoration of single implants placed immediately after tooth extraction. J Periodontol 2006; 77:1914–1920.
45. Wang HL, Ormianer Z, Palti A, Perel ML, Trisi P, Sammartino G. Consensus conference on immediate loading: the single tooth and partial edentulous areas. Implant Dent 2006; 15:324–333.
46. Östman PO, Ann Wennerberg A, Albrektsson T. Immediate occlusal loading of NanoTite™ Prevail® implants: a prospective 1-year clinical and radiographic study. Clin Implant Dent Relat Res 2008; Oct; Epub 121459870 (ahead of print).