Immediate and Early Loading of Hydrothermally Treated, Hydroxyapatite-Coated Dental Implants: 2-Year Results from a Prospective Clinical Study

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This investigation was undertaken to determine if multithreaded implants partially coated with plasma-sprayed hydroxyapatite (HA) could be effectively loaded earlier than 3–6 months after placement. Forty-eight patients (22 men, 26 women) were enrolled in the study and received 48 implants. The population was divided into 2 groups: A implants (n = 23) were loaded immediately on the day of surgery and group B implants (n = 19) were loaded 3 weeks after surgery. Cone beam computerized tomography (CBCT) scans were taken preoperatively to aid in treatment planning. Bone density was evaluated by tactile feedback during surgery. Insertion torque was recorded at time of implant placement. Resonance frequency analysis, performed on the day of surgery, at the time of loading, and at 6, 12, and 24 months, was used to record implant stability according to the unit's implant stability quotient (Osstell ISQ). Standardized radiographs were taken at time of implant placement and at 6, 12, and 24 months to measure crestal bone stability. Bone level changes were measured by software (Image J). Bone quality was judged as either type 1 (n = 1), 2 (n = 31), 3 (n = 15), or 4 (n = 1). There were no failures in the group A (survival = 100%, n = 23/23) and 1 failure in group B (survival = 94.7%, n = 18/19). After 2 years in function, cumulative mean radiographic bone loss was 0.75 ± 0.50mm (maxillae: 0.92 ± 0.49 mm, n = 14; mandibles: 0.67 ± 0.49 mm, n = 28). No differences in bone levels were noted between implants placed in previously augmented and nonaugmented sites, and there were no periodontal or soft tissue complications. After 2 years in function, implants partially coated with plasma-sprayed and hydrothermally treated HA were clinically predictable when restored in occlusion immediately after or within 3 weeks of implant placement.

Key Words: hydroxyapatite, early loading, immediate loading

INTRODUCTION

Numerous studies have reported that achieving adequate primary stability at implant placement, coupled with other factors, such as the design and surface characteristics of the implant, and the volume and density of available bone, may enable successful immediate or early loading of dental implants in selected patients.[1–5] The question of what constitutes *adequate* primary stability and how to accurately measure it is currently being debated.[6] Apart from subjective manual assessments, such as attempted torqueing or movement of the implant after placement, 3 devices designed or adapted for clinical measurements of implant stability have been reported in the dental literature. Two electronic instruments are designed to measure implant vibrations in response to either resonance frequency analysis (RFA) (Osstell, Gothenburg, Sweden) or percussion (Periotest, Medizintechnik Gulden, Modautal, Germany). Both instruments record implant stability according to a proprietary scale developed by their respective manufacturers. The third device is a manual torque wrench, which usually measures the implant's insertion torque (IT) in Newton centimeters (N.cm). All 3 instruments are precalibrated by their manufacturers, but only the torque wrench can be clinically calibrated to verify the consistency of its readings. Nonetheless, research has shown strong correlations among primary implant stability, IT values, and RFA's proprietary Implant Stability Quotient (ISQ) (Osstell).[6] Certain levels of IT and ISQ values have been reported to be suitable indicators for immediate (IT = 35–45 N.cm; ISQ = >70) or early (IT = 30–45 N.cm; ISQ = 40–70) loading of dental implants.[5,7]

Various types of plasma-sprayed hydroxyapatite (HA) coatings have been used since the early 1980s.[8–12] In the human body, HA forms 98% of the enamel, 77% of the dentin, 70% of the cementum, and 60–70% of bone by weight.[13,14] Synthetic HA is a calcium phosphate ceramic that is chemically

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Table 1

Patient selection criteria

Inclusion	Male or female
	At least 18 years old
	Healthy enough to undergo routine implant surgery and subsequent dental treatment
	Partially edentulous requiring single dental implants in either jaw
	Adequate volume of native or grafted bone to accommodate dental implants at least 10 mm long
	No active infections
	Physically, emotionally and financially able to undergo planned implant procedures
	Adequately compliant to meet study requirements and necessary appointments
Exclusion	Medical need for antibiotic premedication for infective endocarditis, artificial joints, or any other medication
	Uncontrolled hypertension
	Uncontrolled diabetes
	Serological human immunodeficiency virus (HIV) positive
	History of significant heart, stomach, liver, kidney, blood, immune system or other organ impairment or systemic disease that would prevent undergoing the proposed treatment
	Smoke cigarettes or other tobacco products
	Use of investigational drugs during the previous month
	Unresolved dental conditions likely to require exiting the study for treatment, such as deep cavities, abscesses, or moderate to severe periodontal disease
	History of radiation therapy to the head and neck
	Unwilling or inability to sign the informed consent form
	Failure to demonstrate willingness to return for a required number of visits
	Need immediate dental implant placement following tooth extraction

similar to the HA and forms naturally in the human body. After implantation, researchers have reported that calcium phosphate from the implant surface is released into the peri-implant region, which increases the saturation of body fluids and results in the precipitation of a biological apatite layer on the implant surface.[12] Other researchers have reported increased adhesion and proliferation of bone-forming cells at the bone-HA interface in both animal[15] and human[16] models,[10,17] which results in accelerated bone formation, maturation, and union between HA-coated implants and the surrounding bone.[12] However, these findings have remained controversial because they often lacked adequate follow-up studies to substantiate the reported clinical findings. Consequently, it remains unclear to what extent simply having a rougher surface may have contributed to the reported differences between HA-coated and uncoated implants in some studies conducted over the past 2 decades. Apart from a recent small, short-term study[18] on immediate loading of HA-coated implants (reporting cumulative results of 100% implant survival with 0.26 $\pm$ 0.59 mm of crestal bone loss after 1 year in function), very little research has been published on immediate and early loading of plasma-sprayed HA-coated implants.

For these reasons, continuing research is needed into the clinical efficacy of plasma-sprayed HA-coated implants with different loading times. The purpose of this prospective study was to evaluate the predictability of immediate and early loading of single-tooth restorations supported by implants with plasma-sprayed, partially HA-coated surfaces. The hypothesis was that there would be no difference in survival rates between HA-coated implants and prostheses subjected to immediate loading as compared to those subjected to early loading.

Methods and Materials

This randomized clinical trial was conducted by the authors under the auspices of the Louisiana State University and the Department of Periodontics with the necessary LSUHSCNO Intentional Review Board approvals. It was done in accordance with international standards for health, safety, and good clinical practices, and adhered to the patient privacy rules of the US Health Insurance Portability and Accountability Act of 1996.

The study was open to all qualifying patients who presented in the university's dental clinic with 1 or more missing nonadjacent teeth, adequate bone volume to accommodate dental implants, and who met the study's inclusion criteria (Table 1). Each candidate's medical and dental histories were carefully reviewed, clinical and radiographic examinations were performed, and assessments were made of the patient's oral hygiene and ability to commit to study procedures and clinical monitoring.

A diagnostic work-up was performed to assess the volume and location of available bone and the esthetic and functional needs of the patient (Figure 1a). The quantity and quality of available bone and the locations of vital anatomic structures were confirmed with cone beam computerized tomography (CBCT). Working casts were fabricated to determine the jaw relationships, available occlusal dimension, proposed implant positions, crown-root ratios, and potential complications. This allowed fabrication of a prosthetic wax-up and surgical template to guide placement of the implants relative to the planned prosthesis. After discussing the treatment plan, alternative options, and answering patient questions, each subject provided signed informed consent prior to implant treatment. Forty-eight subjects were enrolled in the study. Each subject accepted for the study was assigned a number. These numbers were randomized into one of two groups by the study coordinator: group A, implants to be loaded the day of surgical

Table 2

Stability criteria for immediate and early implant loading

Loading Time	Minimum Required Stability		Description
	IT†	ISQ‡	
Immediate	45 N.cm	65	At implant placement
Early	45 N.cm	65	≥3 weeks postplacement but before 3–6 months of healing*

†Implant insertion torque.

‡Implant stability quotient (Osstell).

*Evaluated every 3 weeks after implant placement until ISQ ≥65 was reached.

placement; and group B, implants to be loaded 3 weeks after surgery.

Implant placement

All implants were placed in healed extraction sites with or without prior augmentation by a periodontal resident. The study implants (Tapered Screw-Vent MP-1 HA, Zimmer Dental Inc, Carlsbad, Calif) were a multithreaded, tapered design made of titanium alloy. The external implant surface was microtextured titanium created by grit-blasting the surface with HA particles, followed by washing to remove the blasting media. The midsection of the implant was coated with a band of plasma-sprayed HA coating that was subjected to a postcoating hydrothermal treatment to return the HA to a highly crystalline phase.[16,19] The HA coating was positioned 2.5 mm below the top and 3.3 mm above the bottom of the implant. The implant's internally beveled prosthetic platform was designed with an internal hexagon that accepted friction-fit abutments for single-tooth and fixed partial-denture applications.

At the time of surgery, patients were provided adequate local anesthesia, and implants were placed according to the manufacturer's instructions. Implant placement was performed manually using a gauged insertion calibrated torque wrench. The IT value of each implant was recorded in the patient's chart. Bone density was evaluated by tactile feedback during surgery according to the Lekholm and Zarb[20] scale. RFA (Osstell) assessment was immediately conducted after implant placement as follows. A small magnetic abutment was screwed into the implant. To record ISQ values, an RFA probe was charged with electric power and placed close to the abutment. Two readings were taken with the probe pointing toward the abutment from 2 different directions. An average of the 2 ISQ values was obtained and recorded in the patient's chart.

Provisional prosthesis

Patients were randomly assigned to 1 of 2 study groups (Table 2). Patients in group A received a provisional restoration the day of surgery loading the implant (Figure 1b through d). Patients in group B received a healing abutment the day of surgery and returned in 3 weeks. At this time, a provisional restoration was placed and the implant loaded. The 2 study groups allowed for comparison of implant survival and restorative success relative to immediate and early loading times.

Definitive prosthesis

RFA was conducted at six months and 12 months of provisionalized loading. After one year of provisionalized function, a final impression was made for a computer-aided designed and computer-aided manufactured custom abutment, which was delivered with a definitive, cement-retained crown (Figure 1e). Provisional and final restorations were placed by an implant restorative fellow in training.

Follow-up care

Continuous follow-up with periodic maintenance care was performed every 6 months for 2 years following implant placement. During these periodic follow-up appointments, clinical and radiographic evaluation was performed along with oral hygiene prophylaxis. At every appointment, oral hygiene was reinforced and patients were advised on existing problems, if any. If required, patients were referred for additional treatment and resolution of those problems before implant treatment. Periodontal parameters were assessed by clinical evaluation and standardized digital radiographs (Shick, Sirona Dental Systems, Inc, New York, NY), which were performed using a prefabricated template made for each patient.

Study endpoints

Implant and prosthesis success, the primary endpoints of the study, were derived from a systematic review of success criteria reported in the dental literature[21] and are summarized in Table 3. Secondary study endpoints included peri-implant crestal bone loss (measured from a fixed point on the implant to the area of first bone contact with the implant surface) and implant stability (measured by insertion torque at the time of implant placement and RFA taken at implant placement, 6 months, and at 12 months immediately prior to definitive restoration). Data were collected on the following covariates for each patient: age, sex, bone quality (type 1, 2, 3, or 4)[20] and implant location (ie, mandible or maxilla, anterior or posterior).

Statistical analysis

Success as the primary endpoint measurement was inferred by comparing success rates of the early loading subgroup to the delayed loading subgroup using a two-sided Fisher exact test with an alpha level of 0.05, where sufficient data existed. Outcome variables were summarized using standard descriptive statistics. Summaries were chosen as appropriate for the scale and distribution of the measures being analyzed. For categorical

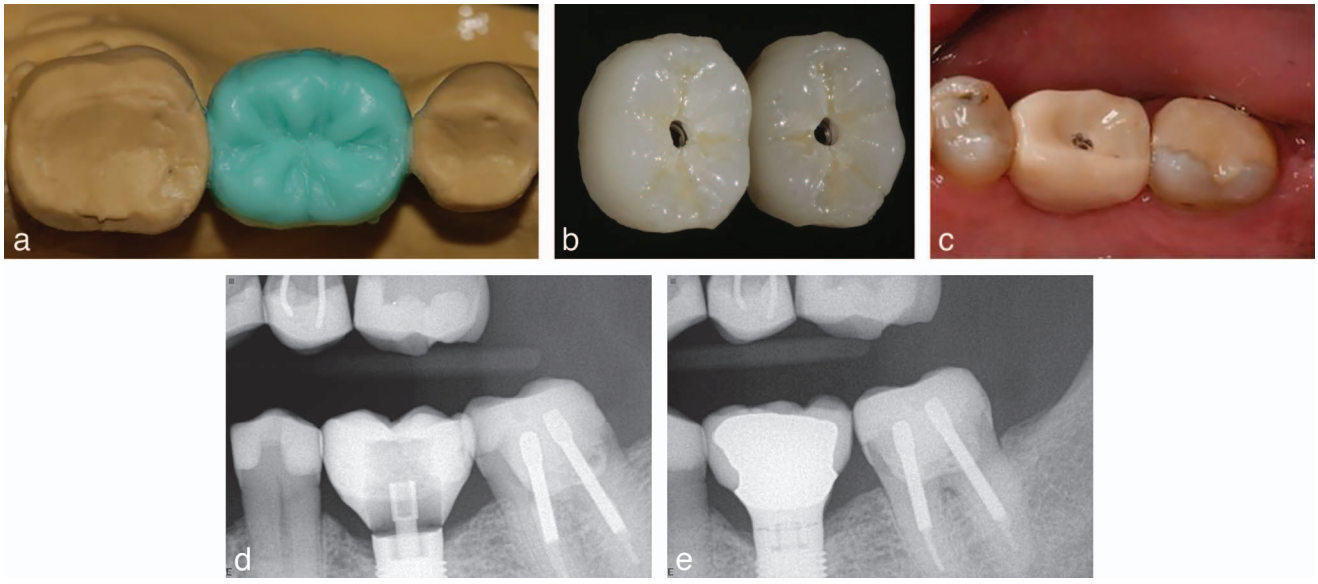


Figure 1. (a) Wax up for provisional crown. (b) Provisional crown. (c) Placement of provisional crown on day of surgery. (d) Radiograph of provisional crown day of surgery. (e) Radiograph of final crown 12 months postsurgery.

variables (sex, bone quality, implant location), summary consists of counts and percentages to describe the distribution of the endpoint. For continuous variables (age, crestal bone loss, ISQ, insertion torque value), descriptive summaries consist of N, Mean, Median, Standard Deviation, Minimum, and Maximum. Ninety-five percent confidence intervals for percentages and means were used to assess differences between meaningful strata. Implant success and other time to event summaries were assessed using a Kaplan-Meier method. Crude rates for success were also be expressed as percentages and reported with the statistical summary. Patient confidentiality was protected at all times, and patient identifiers were not included in any summaries. A confidence interval for the sample size of 50 was generated using the expected rate of implant success of 94%. A 95% interval for this rate with a sample size of 50 was 87.4% to 100.0%.

Multiple regression analysis was conducted to determine which factors were associated with bone loss. Forward selection was used for variable selection to obtain the final regression model to determine which factors are associated with bone loss. Predictors considered in the full regression model were (a) type of bone (clinical), (b) location (mandible or maxilla), (c) implant diameter, (d) implant length, (e) load time (immediate or early), (f) augmented or nonaugmented bone, (g) ISQ values, (h) patient age (years), and (i) patient gender. A separate regression model was fit for each response variable of (a) average distal bone loss and (b) average mesial bone loss. A p-value below 5% was required for a predictor to be added to the regression model.

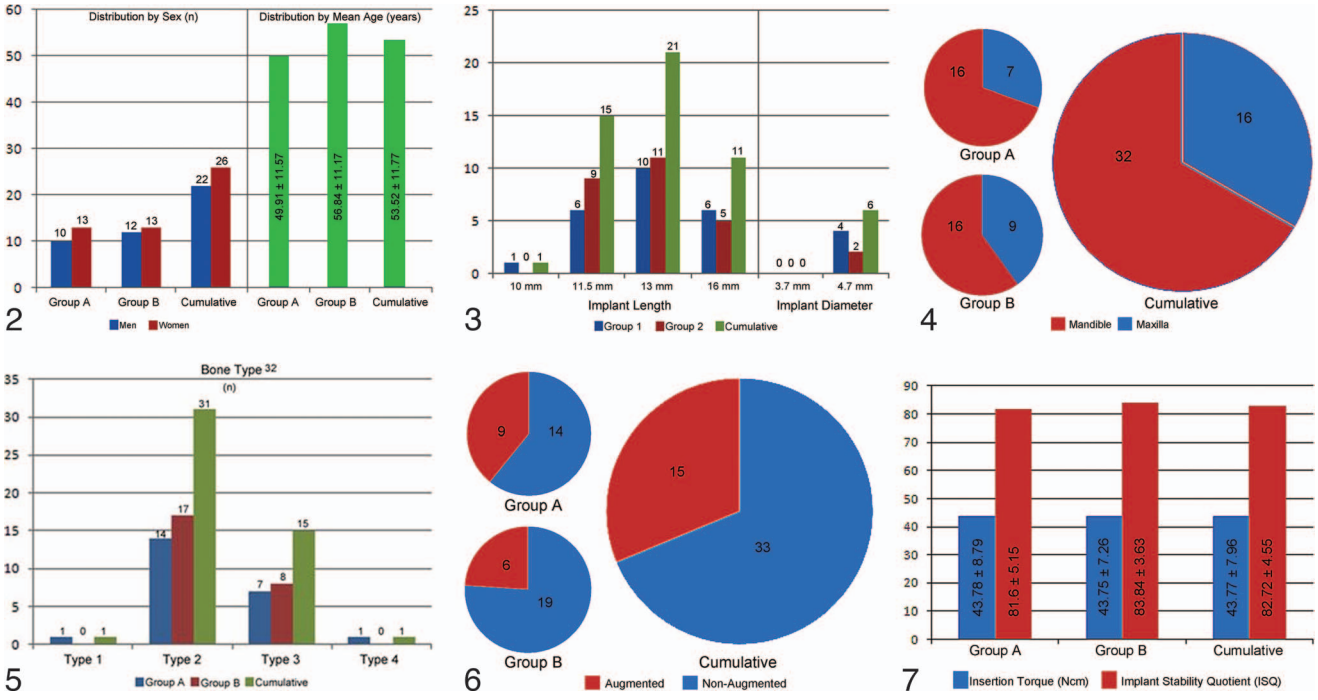
Results

A total of 48 subjects (22 men, 26 women) with a mean age of 53.52 ± 11.77 years were enrolled in the study (Figure 2) and

Table 3

Outcome success criteria[54]

Implant Success	Clinically immobile when tested manually or with RFA (minimum ISQ = 65)
	Absence of peri-implant radiolucency present on an undistorted radiograph
	Absence of unresolved pain, discomfort, infection, or neuropathy, or peri-implant soft tissue complications attributable to the implant
	Implant placement that does not preclude delivery of a prosthetic crown with an appearance that is satisfactory to the patient and the dentist
	Crestal bone loss that is <1.5 mm after the first year of loading followed by not more than 0.2 mm of annual crestal bone loss thereafter
Prosthesis success	Absence of unresolved peri-implant soft tissue complications, such as bleeding, swelling, suppuration, or recession, attributable to the prosthetic restoration
	Absence of unresolved prosthetic complications, such as screw loosening or porcelain fracture
	Absence of esthetic complications, such as implant or abutment visibility, or compromised porcelain translucency or mismatched prosthetic tooth color
	Immediate loading success: A functional provisional crown in occlusion placed on the day of surgery followed by delivery of a definitive crown after 12 months of function
	Early loading success: A functional provisional crown placed ≥3 weeks and <3–6 months after implant placement, followed by delivery of a definitive crown after 12 months of function



Figures 2–7. Figure 2. Sex and age distribution of study subjects. **Figure 3.** Implant length and diameter distribution. **Figure 4.** Mandibular and maxillary distribution of study implants. **Figure 5.** Clinical bone types. **Figure 6.** Distribution of augmented and nonaugmented sites. **Figure 7.** Relationship between insertion torque and implant stability quotient.

treated with 48 implants: 23 in group A, and 25 in group B (Figures 3 through 5). Within this group, 15 implants (group A = 9; group B = 6) were placed in augmented bone and 33 implants (group A = 14, group B = 19) were placed in nonaugmented bone (Figure 6). One maxillary implant in group B failed to maintain stability and was removed after 3 weeks. The implant was listed as a failure, and the patient was removed from the study. After 2 years of functioning, cumulative implant survival was 97.7% (n = 47/48) (group A = 100%, n = 23/23; group B = 96%, n = 24/25) There were no periodontal or soft tissue complications. Mean implant stability values at placement were 82.72 ± 4.55 ISQ (n = 46) (group A = 81.6 ± 5.15 ISQ, n = 23; group B = 83.84 ± 3.63 ISQ, n = 23) with RFA, and 43.77 ± 7.96 N.cm (group A = 43.78 ± 8.79 N.cm, n = 23; group B = 43.75 ± 7.26 N.cm, n = 24) with IT (Figure 7). ISQ values showed a significant positive correlation with implant diameter but not with implant length. There were no correlations between insertion torque and ISQ values or type of bone. Grafted sites showed significantly higher insertion torque (IT) values as compared to nongrafted sites.

Marginal bone loss is summarized in Table 4. After 2 years of follow-up, cumulative mean radiographic bone loss after 2 years in function was 0.75 ± 0.50 mm (group A = 0.81 ± 0.59 mm, n = 19; group B = 0.70 ± 0.41 mm, n = 23). No differences in bone levels were noted between augmented and nonaugmented implant sites. Cumulative mean bone loss was significantly higher for implants placed in the maxilla (0.92 ± 0.49 mm, n = 14) than in the mandible (0.67 ± 0.49 mm, n = 28). There was not a significant correlation between type of bone and average mesial bone loss ($r = 0.071$, $P = 0.630$), nor was there a significant correlation between type of bone and average distal bone loss ($r = -0.045$, $P = 0.759$).

Regression analysis of marginal bone loss (Table 5) indicates that, compared to maxillary implants, mandibular implants exhibited significantly greater mesial ($P = 0.005$) and distal ($P = 0.025$) bone loss. Implant diameter showed a significant *negative* correlation with average distal bone loss ($r = -0.390$, $P = 0.006$) but was not significantly correlated with average mesial bone loss ($r = 0.018$, $P = 0.901$). Implant length showed a significant *positive* correlation with average distal bone loss ($r = 0.373$, $P = 0.008$), but was not significantly correlated with average mesial bone loss ($r = 0.244$, $P = 0.095$). Patient age was not significantly correlated with average mesial ($r = -0.054$, $P = 0.7179$) or average distal ($r = 0.176$, $P = 0.227$) bone loss. There was no significant difference in average mesial ($P = 0.579$) or distal bone loss for males compared to females ($P = 0.366$). There was no significant difference in average mesial ($P = 0.256$) or distal ($P = 0.877$) bone loss for augmented compared to nonaugmented bone, and no significant difference in assessments of bone type in augmented compared to nonaugmented sites ($P = 0.807$). ISQ was not significantly correlated with bone type ($r = -0.228$, $P = 0.127$) but showed a significant *positive* correlation with implant diameter ($r = 0.736$, $P < 0.001$) but was not significantly correlated with implant length ($r = -0.190$, $P = 0.207$).

Discussion

This was the first study comparing the HA coated Zimmer Tapered Screwvent Implant survival when loaded immediately to loading in 3 weeks. There has been a reluctance to

TABLE 4

Marginal bone loss (mm)

Category	n	Mean	Std Dev
Bone loss by jaw			
Maxilla			
Group A	6	0.89	0.67
Group B	8	0.94	0.36
Cumulative	14	0.92	0.49
Mandible			
Group A	13	0.77	0.58
Group B	15	0.58	0.39
Cumulative	28	0.67	0.49
Cumulative			
Group A	19	0.81	0.59
Group B	23	0.70	0.41
Cumulative	42	0.75	0.50
Bone loss by implant dimensions (mm)			
Lengths			
Group A			
8 mm	1	.67	—
10 mm	6	.48	.16
11.5 mm	10	50.1	.10
13 mm	6	.47	.07
16 mm	0	—	—
Group B			
8 mm	0	—	—
10 mm	9	.58	.09
11.5 mm	11	.53	.14
13 mm	5	.61	.03
16 mm			
Cumulative			
8 mm	1	.67	—
10 mm	15	.54	.12
11.5 mm	21	.52	.12
13 mm	11	.54	.09
16 mm	0	—	—
Diameters			
Group A			
3.7 mm	4	.60	.06
4.1 mm	8	.44	.11
4.7 mm	11	.50	.11
6.0 mm	0	—	—
Group B			
3.7 mm	2	.57	.14
4.1 mm	7	.59	.08
4.7 mm	9	.56	.12
6.0 mm	7	.54	.13
Cumulative			
3.7 mm	6	.59	.08
4.1 mm	15	.51	.12
4.7 mm	20	.53	.12
6.0 mm	7	.54	.13
Mesial and distal bone loss			
Mesial			
Study group			
A	18	0.78	0.58
B	23	0.65	0.40
Cumulative	41	0.71	0.48
Jaw			
Maxilla	14	0.85	0.50
Mandible	27	0.63	0.46
Sex			
Males	20	0.73	0.48
Females	21	0.69	0.49
Bone augmentation status			
Augmented*	12	0.83	0.57
Not augmented†	29	0.66	0.44

Table 4

Continued

Category	n	Mean	Std Dev
Distal			
Study group			
A	19	0.87	0.72
B	23	0.76	0.54
Cumulative	42	0.81	0.62
Jaw			
Maxilla	14	0.99	0.63
Mandible	28	0.72	0.61
Sex			
Males	20	0.78	0.58
Females	22	0.84	0.67
Bone Augmentation Status			
Augmented*	13	0.76	0.68
Not Augmented†	29	0.83	0.61
Cumulative			
Study Group			
A	19	0.81	0.59
B	23	0.70	0.41
Cumulative	42	0.75	0.50
Jaw			
Maxilla	14	0.92	0.49
Mandible	28	0.67	0.49
Sex			
Males	20	0.75	0.46
Females	22	0.75	0.54
Bone augmentation status			
Augmented*	13	0.76	0.62
Not Augmented†	29	0.75	0.45

*Implants placed in healed augmented bone sites.
†Implants placed in healed, non-augmented bone sites.

manipulate implants in 3 weeks due to fear of disrupting osseointegration. By using resonance frequency analysis, we were able to dispel this myth. With this implant, we found no significant loss of stability and were able to get a survival success rate of 97.9%. This was equal or better than other immediate loading studies.[2–5]

It has been theorized by some researchers that the layer of apatite that forms of the implant surface during the early stages of osseointegration may (or may not) contain endogenous proteins and serve as a matrix for osteogenic cell attachment and growth on the implant surface.[12] Because the biologic fixation of bone tissue to implant surfaces has been reported by some clinicians to be faster with a calcium phosphate coating than with uncoated titanium surfaces,[15,16] some clinicians have assumed that the bone healing process around the implant may be enhanced by the formation of the biological apatite

Table 5

Multiple regression analysis summary

Category	Variable	Model	Significance
Implants	Mandibular location	Mesial bone loss	Significant, $P = 0.005$
		Distal bone loss	Significant, $P = 0.025$
	Diameter	Mesial bone loss	Not Significant, $P = 0.901$
		Distal bone loss	Significant, $P = 0.006$
	Length	Mesial bone loss	Not Significant, $P = 0.095$
		Distal bone loss	Significant, $P = 0.008$
Patients	Age	Mesial bone loss	Not Significant, $P = 0.7179$
		Distal bone loss	Not Significant, $P = 0.227$
	Gender	Mesial bone loss	Not Significant, $P = 0.579$
		Distal bone loss	Not Significant, $P = 0.366$
Bone	Augmented	Mesial bone loss	Not Significant, $P = 0.256$
		Distal bone loss	Not Significant, $P = 0.877$
		Bone type	Not Significant, $P = 0.807$
Implant stability	Bone type	ISQ values	Not Significant, $P = 0.127$
	Implant diameter	ISQ values	Significant, $P < 0.001$
	Implant length	ISQ values	Not Significant, $P = 0.207$

layer, which may result in better early stability.[12] All of the implants in the study were stable enough to load at the time of placement. In group B, all of the implants were stable enough to load at 3 weeks. Stability of all implants increased over the 12-month period. During the 1990s, the US government conducted a prospective, randomized, multicenter study of HA-coated (n = 1725) and uncoated (n = 1070) implants placed in patients and monitored for 36–71 months of clinical follow-up.[19] More than 85 dentists in 30 study sites participated, and an independent external review committee composed of experts internationally recognized in their respective fields closely monitored the study.[19] The researchers concluded that HA coating might offer some clinical advantages up to 36 months over uncoated surfaces when placed in poor-quality bone,[22] smokers, or when implants were mobile at the time of placement but cautioned that further prospective research was needed to verify these findings. Other researchers in the same study reported that there was no clinically significant difference between in periodontal-type measurements between HA-coated and uncoated dental implants.

Nonetheless, the dissolution behaviors of HA coatings with amorphous calcium phosphate phases resulted in relatively isolated reports of possible coating delamination and particle release from the implant surface, which resulted in the clinical failure of the implants.[12] A meta-analysis of clinical trials of HA-coated implants published in 1990 through 1999 conducted at the time, however, found that HA-coated and uncoated implants exhibited no significant differences in survival and success rates.[23] During the mid-1990s, shifting of the calcium phosphate phase was addressed by subjecting HA-coated implants to a hydrothermal treatment that caused their calcium phosphate phase to revert from amorphous to highly crystalline, which significantly helped to resist dissolution.[24,25] Despite many years of clinical use as a dental implant surface coating, long-term data has remained very limited.[12] A subsequent meta-analysis of clinical trials on HA-coated implants published in 2013 reported that annual failure rates and cumulative survival rates of HA-coated dental implants were comparable to those of noncoated implants.[12]

Implant survival and success rates (97.9%, n = 47/48, respectively) at the interim 2-year follow-up period were consistent with earlier outcomes[18,24] of the same highly crystalline HA-coated surface used on cylindrical rather than threaded implant designs. Crestal bone loss was significantly correlated with implant diameter ($P = 0.003$). For each millimeter increase in implant diameter, there was a predicted decrease in distal bone loss of 0.41 mm.

Conclusions

After 2 years in function, implants partially coated with plasma-sprayed and hydrothermally treated HA were clinically predictable when restored in occlusion immediately after or after 3 weeks of implant placement.

Abbreviations

CBCT: cone beam computerized tomography
HA: hydroxyapatite
ISQ: implant stability quotient
IT: insertion torque
RFA: resonance frequency analysis

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