An examination of immediately loaded dental implant stability in the diabetic patient using resonance frequency analysis (RFA)

Stephen F. Balshi, MBE[1]/Glenn J. Wolfinger, DMD[2]/
Thomas J. Balshi, DDS[3]

Objectives: To evaluate the stability of 18 immediately loaded Brånemark System dental implants in an insulin-controlled, diabetic, 71-year-old patient over the first 30 months after surgery, and to correlate this data with implant stability in healthy patients. **Method and Materials:** Stability measurements were taken using resonance frequency analysis on all implants at surgery placement and at 5 postsurgical examinations (1, 2, 3, 6, and 30 months). **Results:** All 18 implants remained in function after 2.5 years of follow-up. The mean stability of the implants decreased 12.7% during the first 30 days, a value twice as much as seen in the general population. After the first 30 days, the stability of the implants increased slightly over the next 60 days. After 30 months of follow-up, the mean implant stability continued to increase, however, not to a value equal to that of the initial measurement taken at the time of implant placement. **Conclusion:** Despite the metabolic differences seen in diabetic patients, an immediate loading protocol can be successful and result in osseointegration. *(Quintessence Int 2007;38:271–279)*

Key words: bone-implant interface, diabetes, immediate loading, implant stability, resonance frequency analysis, Teeth in a Day

Diabetes mellitus is one of the world's major chronic health problems, affecting an estimated 6% of the population.[1] This complex syndrome is responsible for numerous complications affecting the body, including an increased incidence of caries,[2] periodontitis,[3] and infection.[4] Another suspected consequence of diabetes is a slower healing period after surgery,[5] which is why diabetes has sometimes been considered a contraindication for the use of dental implants.[6,7]

Osseointegration has been studied extensively in the general population and, to a lesser extent, the medically compromised patient.[8] A small number of implant studies specifically address the diabetic patient population.[9–14] These 2-stage results indicate that diabetes mellitus is no longer considered to be a contraindication for implant-supported prostheses, provided that the patient's blood sugar level is monitored.

Even fewer data have been published about an immediate loading protocol in the diabetic population. In a study by Balshi and Wolfinger,[9] 4 implants were immediately loaded in 1 patient; 3 of the 4 implants failed to achieve osseointegration. Since the time of that patient treatment, the implant physical characteristics have changed and the immediate loading protocol has evolved.[15,16]

[1]Director of Biomedical Engineering, Prosthodontics Intermedica, Institute for Facial Esthetics, Fort Washington, Pennsylvania; Chief Operating Officer, CM-Ceramics USA, Mahwah, New Jersey.

[2]Prosthodontist, Prosthodontics Intermedica, Institute for Facial Esthetics, Fort Washington, Pennsylvania; Staff Prosthodontist, Veterans Affairs Medical Center, Philadelphia, Pennsylvania.

[3]Founder and Prosthodontist, Prosthodontics Intermedica, Institute for Facial Esthetics, Fort Washington, Pennsylvania.

Reprint requests: Dr Stephen F. Balshi, Prosthodontics Intermedica, 467 Pennsylvania Avenue, Suite 201, Fort Washington, PA 19034. Fax: 215-643-1149. E-mail: balshi2@aol.com

Resonance frequency analysis (RFA) is a steady-state, nondestructive technique in which mechanical vibration is utilized to measure implant stability.[17] It is hypothesized that changes in resonance frequency are largely the result of differences of the bone-implant interface and density of the adjacent bone.[18]

The purpose of this study was to gain insight into the dynamic pattern of implant stability under immediate loading conditions in a diabetic patient. Furthermore, it was a goal of this study to correlate the stability pattern of implants in this diabetic patient to similar recorded resonance frequency data of a general population with healthy systemic conditions.[19]

METHOD AND MATERIALS

Patient history, clinical evaluation, and diagnosis

Pretreatment patient communication revealed that this 71-year-old male patient is in good general health, exercises frequently, and has a daily regimen of vitamins, including calcium. He has type 2 diabetes that has been self-monitored for more than 10 years. The patient self-treats with a nightly dosage of 30 units insulin aspart (rDNA origin) injection (NovoLog, Novo Nordisk). The patient also administers, when necessary, insulin glargine (rDNA origin) injection (Lantus, Aventis Pharmaceuticals) usually around mealtime, about 12 to 15 units each injection, averaging 40 units per day.

The patient monitors his blood-sugar levels using the One Touch Ultra kit (LifeScan) several times a day, but not at specific times. He did not record his blood-sugar levels during the follow-up time after his maxillary and mandibular reconstruction. The patient leads a normal business and social life. The patient enjoys long bicycle riding and stated that he believes he could control the blood-sugar levels by exercise if he had the time to dedicate to it. His blood-sugar levels have been known to drop as much as 100 points from a long bicycle ride. The patient stated that he has not had any complications from the diabetic condition other than the inconvenience of having to self-treat his condition.

The patient arrived at the private practice without discomfort. His chief complaint was continuous loosening of his maxillary fixed partial denture and poor functionality of his mandibular partial denture (Figs 1a and 1b). Clinical and radiographic evaluation revealed failing fixed and removable prosthodontic restorations because of recurrent caries, periodontal disease, and bone loss, along with failing endodontic treatment and malocclusion. The patient's dental condition was diagnosed as periodontally and restoratively untreatable.

The patient was presented with a comprehensive treatment plan that recommended extraction of the remaining unrestorable teeth and placement of Brånemark System implants (Nobel Biocare USA) in both the mandible and maxilla. The patient understood that it was not in his best interest to have crowns redone on his existing natural teeth because of their poor prognosis and thus accepted the proposed treatment plan.

Clinical treatment

On-premises dental laboratory technicians fabricated custom-designed acrylic resin immediate complete dentures for both the maxilla and mandible from the initial impressions and jaw records obtained at the patient's first appointment. The patient decided to go forward with full maxillary reconstruction first, followed by full mandibular reconstruction 1 month later, after swelling and soreness had subsided from the maxillary surgery. Before treatment began, the patient reviewed and approved all informed consent forms for both extractions and implant placement.

Local anesthesia was administered with a combination of bupivacaine hydrochloride (Marcaine 0.5%, Cook Waite/Abbott Laboratories) and lidocaine hydrochloride (Lignospan Forte, Septodont), which provided hemostasis at the surgical site. The remaining maxillary teeth were removed and granulation tissue was thoroughly debrided from the alveolus. A crestal incision with dissection and soft tissue elevation was made in the area of the right to left third molars. Before any preparations were made in the bone, all maxillary landmarks were identified. Minor alveoloplasty was performed to remove sharp bony projections and provide an acceptable ridge for

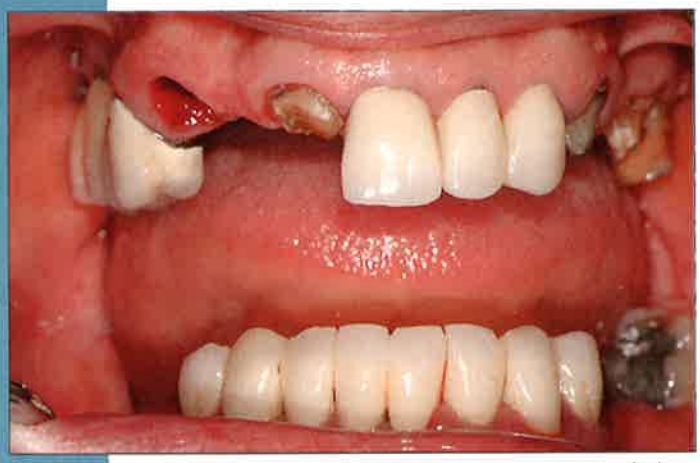


Fig 1a Preoperative facial view illustrating tooth loss resulting from recurrent decay.

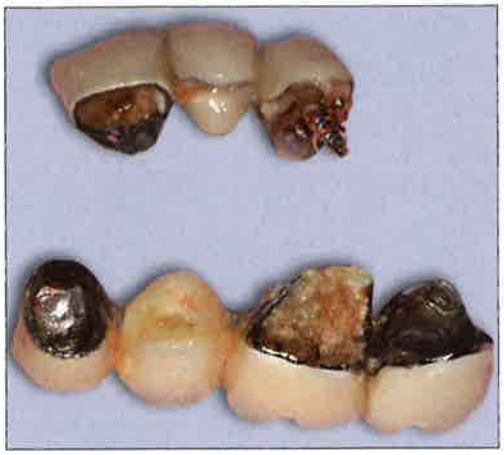


Fig 1b Porcelain-fused-to-gold partial dentures that failed due to recurrent decay.

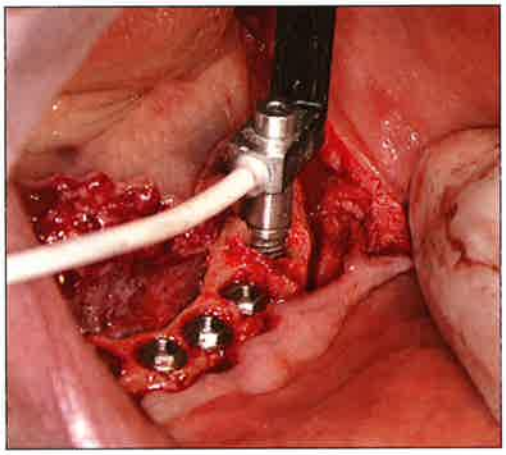


Fig 2a Resonance frequency analysis transducer connected to an implant head for stability measurement.

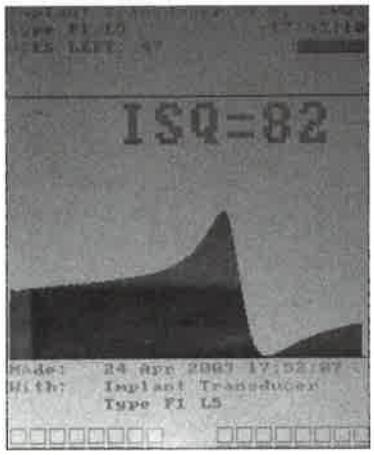


Fig 2b Resonance frequency analysis measurement value for the implant in the area of the mandibular left canine at surgical placement.

placement of an implant-supported screw-retained prosthesis.

Saline irrigation (Baxter Healthcare) was used throughout the drilling procedure and placement of the implants. Eleven regular-platform Brånemark System implants (TiUnite Mk III and Mk IV, Nobel Biocare USA) were placed, 7 anterior to the maxillary sinuses and 4 in the pterygomaxillary region. A combination of Brånemark System abutments (standard, Estheticone, and 17-degree angulated, Nobel Biocare USA) were connected to the implants, and the implants were immediately loaded with a Teeth in a Day (TIAD) prosthesis made as previously described in the literature.[20,21] The bone quality was determined clinically by the surgeon[22] according to the anatomic and bone density criteria established by Lekholm and Zarb.[23] Before the TIAD prosthesis was delivered, RFA measurements (Osstell, Integration Diagnostics), stored as implant stability quotients (ISQs), were made at the abutment level as described earlier[19] (Figs 2a and 2b). Mucosal tissues were sutured (Vicryl, Ethicon/Johnson & Johnson) to achieve primary closure. Ten days later, the sutures were removed.

One month after the maxillary reconstruction, the patient returned for a TIAD prosthesis[15,24] in the mandible using 7 Brånemark System implants. RFA measurements were recorded on the abutment level before the

Table 1 Implant, abutment, and bone qualities for implant sites

Location (tooth no.)	Implant (mm)	Abutment (mm)	Bone quality
1(18)	4.0 × 15 TiUnite Mk IV RP	4.0 Standard	4
2(17)	4.0 × 10 TiUnite Mk IV RP	4.0 Standard	4
4(15)	4.0 × 13 TiUnite Mk IV RP	2.0 Estheticone	3
6(13)	4.0 × 15 TiUnite Mk IV RP	3.0 Angulated 17-degree	3
7(12)	4.0 × 13 TiUnite Mk III RP	2.0 Estheticone	3
8(11)	4.0 × 13 TiUnite Mk III RP	2.0 Angulated 17-degree	3
9(21)	4.0 × 13 TiUnite Mk III RP	2.0 Angulated 17-degree	3
11(23)	4.0 × 13 TiUnite Mk III RP	3.0 Angulated 17-degree	3
13(25)	4.0 × 13 TiUnite Mk III RP	2.0 Estheticone	3
15(27)	4.0 × 15 TiUnite Mk III RP	3.0 Standard	4
16(28)	4.0 × 15 TiUnite Mk IV RP	3.0 Standard	4
20(35)	3.75 × 18 TiUnite Mk III RP	3.0 Standard	2
22(33)	3.75 × 15 TiUnite Mk III RP	3.0 Estheticone	2
23(32)	3.75 × 15 TiUnite Mk III RP	3.0 Standard	2
25(41)	3.75 × 15 TiUnite Mk III RP	3.0 Standard	2
26(42)	3.75 × 15 TiUnite Mk III RP	3.0 Standard	2
28(44)	3.75 × 15 TiUnite Mk III RP	3.0 Estheticone	2
30(46)	3.75 × 8.5 TiUnite Mk III RP	3.0 Standard	1

TIAD prosthesis was delivered. The implants, abutments, and bone qualities associated with each implant site are illustrated in Table 1.

The patient was asked to return for follow-up stability measurements 1, 2, 3, and 6 months postsurgery. The fifth and last stability measurements were recorded 30 months after implant placement.

Prosthetic procedure

After abutment connection of the immediately loaded implants, a screw-retained all–acrylic resin fixed prosthesis was placed (Figs 3a to 3c). The patient was instructed to maintain a soft diet for the first 12 weeks. The screw-retained all–acrylic resin TIAD fixed prosthesis was not removed during the initial healing period—with the exception of testing for RF values[19]—until master impressions were made for the construction of the definitive prosthesis. Before master impressions were made, all implants were manually and visually evaluated for stability (Figs 4a and 4b).

The maxillary definitive prosthesis, a porcelain-fused-to-gold prosthesis, was delivered 8 months after implant placement. The mandibular definitive prosthesis, a gold framework with resin denture teeth, was delivered 4 months after implant surgery (Figs 5a to 5d).

RESULTS

All 18 implants successfully integrated and have remained in function for 2.5 years of follow-up. The dynamic pattern of stability was recorded for each implant. Figures 6 and 7 show the changes in mean stability of the implants in the maxilla and mandible, respectively. Table 2 details the ISQ values during the testing period for all the implants.

In the maxilla, the mean stability of the implants was 70.73 ± 0.74 ISQ at implant placement. For the 1- and 2-month postoperative measurements, the mean implant stability decreased to 63.82 ± 0.53 ISQ and 62.55 ± 0.73 ISQ, respectively. In the third month after implant placement, the mean stability of implants in the maxilla increased to 65.27 ± 0.78 ISQ. RFA measurements at 6 months postsurgery yielded an identical level of mean stability as the 3-month postoperative testing. The 30-month postsurgical RFA measurements remained stable with a mean of 65.55 ± 0.56 ISQ.

At implant placement, the mean implant stability in the mandible was 83.29 ± 0.36 ISQ, which is significantly higher than that of the implants in the maxilla. At the 1-month postoperative checkpoint, the mean implant stability decreased to 69.43 ± 0.86 ISQ. Unlike the

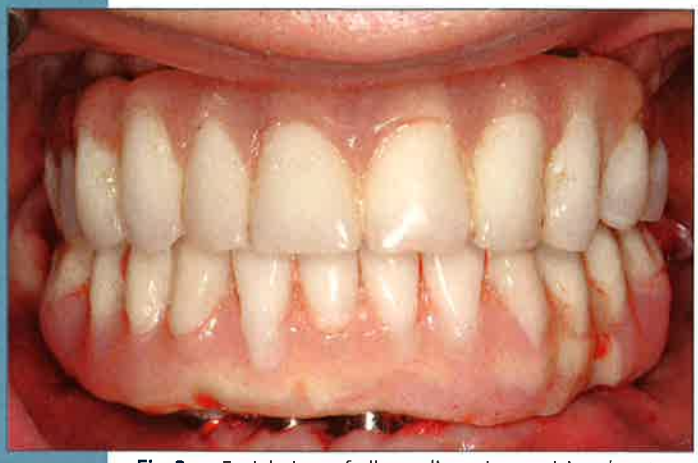


Fig 3a Facial view of all–acrylic resin provisional restorations delivered immediately after implant placement.

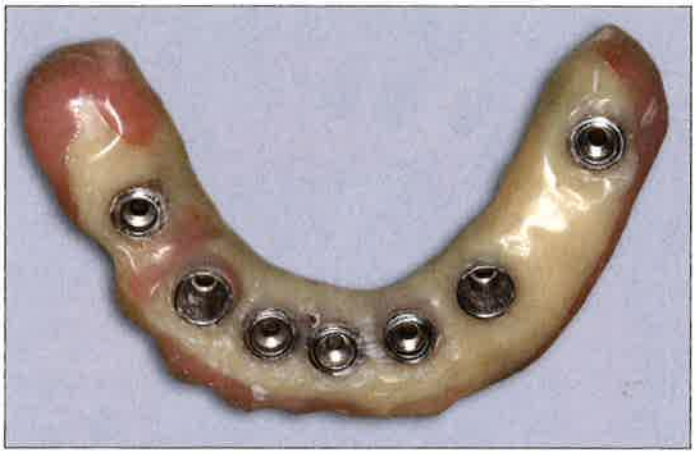
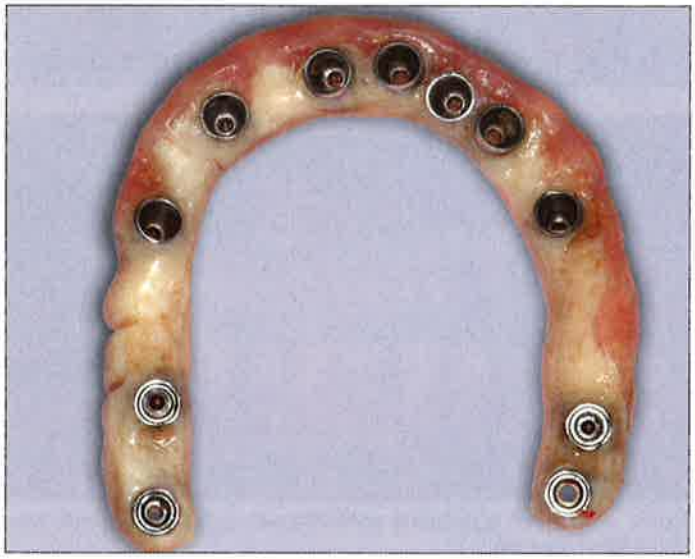


Fig 3b View of underside of mandibular full-arch all–acrylic resin provisional restoration.

Fig 3c View of underside of maxillary full-arch all–acrylic resin provisional restoration.



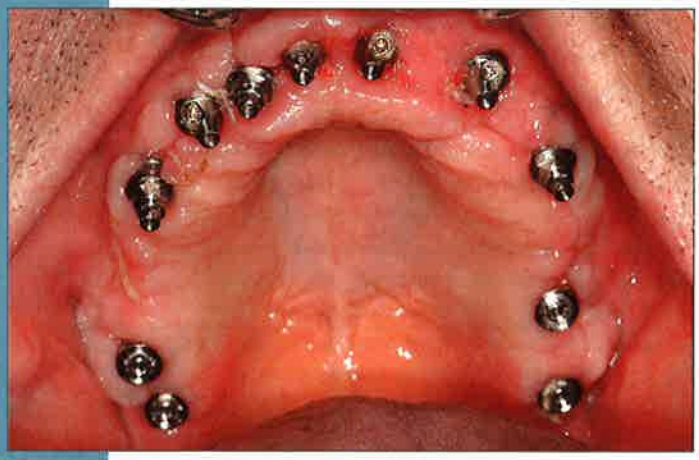


Fig 4a Maxillary arch with implant abutments after healing.

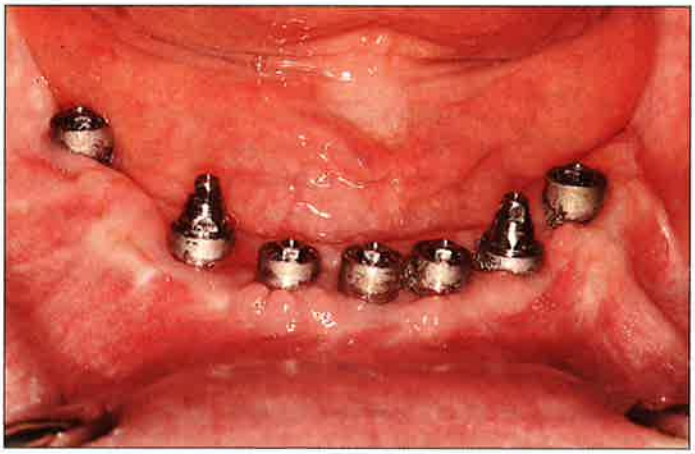
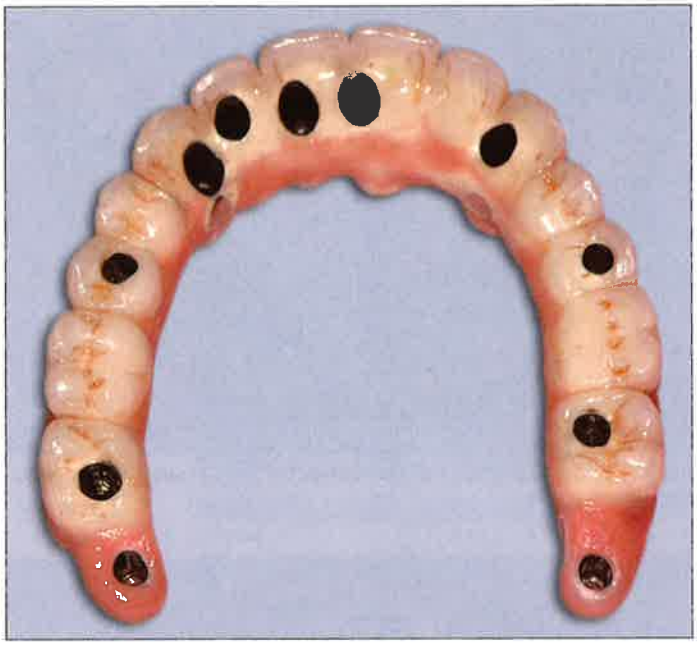


Fig 4b Mandibular arch with implant abutments after healing.



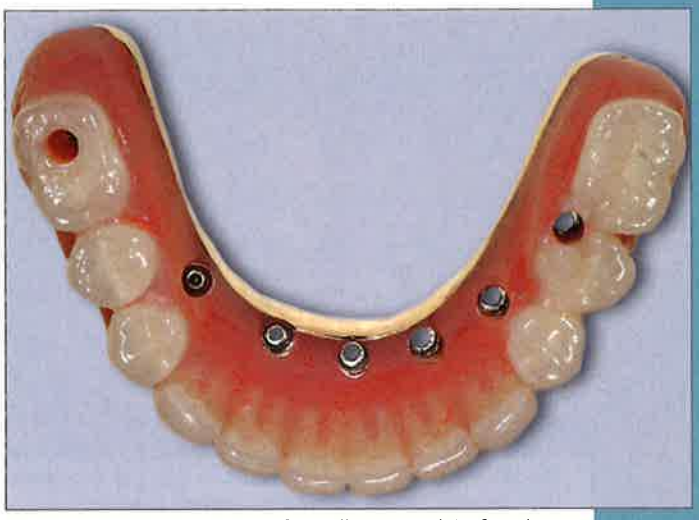


Fig 5a *(left)* Occlusal view of maxillary porcelain-fused-to-gold screw-retained definitive implant restoration.
Fig 5b *(above)* Occlusal view of mandibular screw-retained implant restoration, a gold bar with acrylic resin denture teeth.

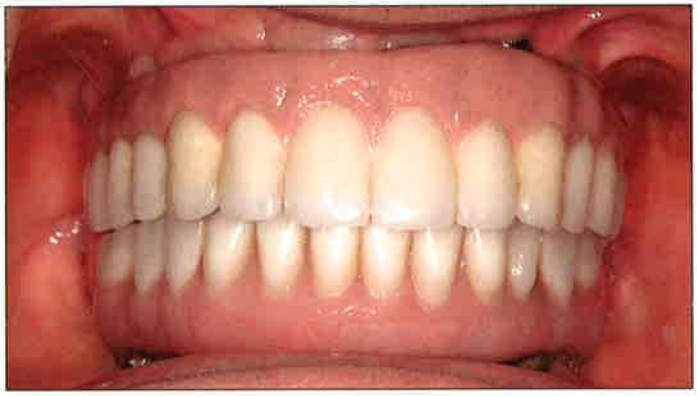


Fig 5c Facial view of definitive restorations in centric relation and maximum intercuspation.

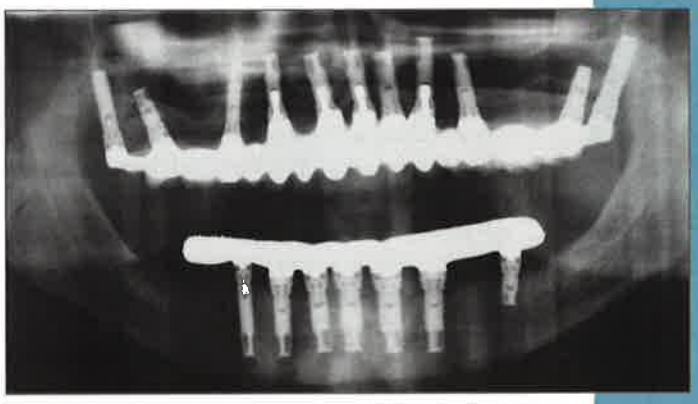


Fig 5d Postoperative panoramic radiograph illustrating maxillary and mandibular definitive frameworks in place.

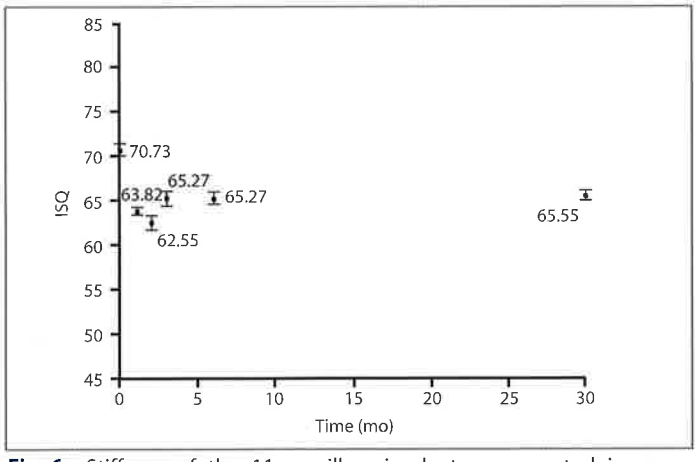


Fig 6 Stiffness of the 11 maxillary implants, represented in mean implant stability quotient (ISQ) values ± SE at surgery (0) and 1, 2, 3, and 30 months postsurgery.

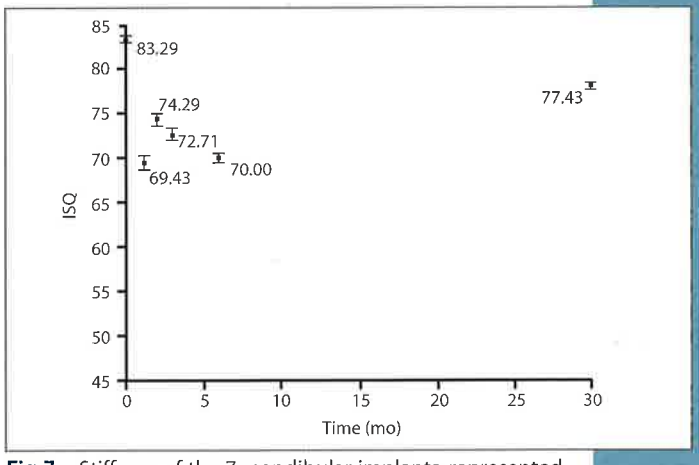


Fig 7 Stiffness of the 7 mandibular implants, represented in mean implant stability quotient (ISQ) values ± SE at surgery (0) and 1, 2, 3, and 30 months postsurgery.

Table 2 Individual implant stability at each testing period

Location (tooth no.)	Implant stability (ISQ)					
	Surgery date	1 mo	2 mo	3 mo	6 mo	30 mo
1(18)	62	59	54	55	57	59
2(17)	55	52	49	50	54	54
4(15)	78	68	66	68	67	70
6(13)	70	64	69	69	71	74
7(12)	73	68	67	73	71	67
8(11)	72	64	67	72	69	67
9(21)	77	69	69	73	69	71
11(23)	72	68	71	73	69	69
13(25)	80	70	68	69	68	69
15(27)	61	64	56	62	65	62
16(28)	78	56	52	54	58	59
20(35)	87	60	67	65	73	79
22(33)	79	74	74	72	68	77
23(32)	83	63	72	72	69	77
25(41)	84	68	75	71	67	75
26(42)	83	72	74	73	69	77
28(44)	82	73	77	79	67	76
30(46)	85	76	81	77	77	81

Table 3 Mean implant stability comparison between diabetic patient and generic population

Population	Sample size	Average ISQ			
		At implant placement	At 1 mo	At 2 mo	At 3 mo
Diabetic patient	18	75.61	66.00	67.11	68.17
Generic population	276	70.35	66.38	68.01	68.82

(ISQ) Implant stability quotient.

mean implant stability in the maxilla, there was an increase in mean stability to 74.29 ± 0.62 ISQ at the 2-month checkpoint. The 3- and 6-month follow-up visits revealed a decrease in mean stability to 72.21 ± 0.64 ISQ and 70.00 ± 0.53 ISQ, respectively. However, at the 30-month postoperative evaluation, the mean stability increased to 77.43 ± 0.28 ISQ. The panoramic radiograph taken at 30 months from the time of initial implant placement demonstrated stable bone levels (Fig 5d).

In Table 3 the mean implant stability for the 18 implants in this diabetic patient over the first 3 months is compared to the similar implant stability measurements in a generic population using the same measurement protocol.[19] The mean stability at implant placement was higher in the diabetic patient than in the generic population. In the first 30 days after implant placement is when the largest difference in stability occurs between the diabetic patient and the generic population. The decrease in implant stability in the generic population is 3.97 ISQ (5.6%), while the decrease in the diabetic patient is 9.61 ISQ (12.7%).

DISCUSSION

It has been documented that controlled diabetic patients are candidates for dental implants.[9–14] Various 2-stage reports[10,25,26] illustrate a decrease in success rate around 1 year after implant placement, suggesting that the risk of implant failure is associated with the uncovering of implants and with the early phases of implant loading.[8] It also has been suggested that the microvascular disease leading to a diminished immune response and reduced bone turnover might be a contributing factor to implant failure.[11]

The present patient data do not indicate implant failure associated with loading in this controlled diabetic patient. This report shows implant survival of immediately loaded implants in a full-mouth reconstruction with 100% survival over the first 30 months. In the past, it was theorized that immediate loading of implants was not a viable treatment option, particularly in patients whose immune response and bone turnover was delayed. Because of this assumption, 1 more implant was placed in both the maxilla and the mandible than required by the standard treatment protocol for full-mouth reconstruction at this private practice. The critical healing period associated with immediately loaded implants in a general population was determined to be 2 months.[19] The 100% survival rate of the 18 implants in this diabetic patient suggests that if controlled mechanical stimuli are applied to each implant, it can be beneficial for implant survival; however, more than a single patient report is necessary to validate this suggestion.

This information is reported as a single patient report based on findings from previous research. Wolfinger et al reported on the significance of keeping the same provisional prosthesis in place during the initial healing period.[15] This suspicion was confirmed in 2005 in a report that identified the critical healing period based on implant stability measurements.[19] The prosthesis was removed only during the postoperative measurement visits. To minimize implant failure from misfit strain possibly applied to the reconstruction during the critical healing period testing, it was decided to include only 1 diabetic patient in this study. Particularly in diabetic patients, where bone turnover is delayed and the critical healing period is magnified, the authors did not want to cause implant failure by removing and placing the provisional prosthesis simply for the testing protocol used for this report.

It was reported that a drop in ISQ of 10 points would indicate a failing implant.[18] In the current diabetic patient, 7 of the 18 implants showed a decrease in ISQ of 10 points or more between implant placement and the 30-day follow-up period. However, none of the implants failed. The larger decrease associated with this patient can be correlated to his diabetic condition and the effects it has on the bone remodeling process. The stability data associated with this patient and the decrease would suggest that immediate loading would not lead to osseointegration; however, a sufficient number of implants and a stiff provisional prosthesis are possible reasons why the implants did indeed achieve osseointegration.

Immediate placement of implants into extraction sites has been used successfully for over a decade with the conventional 2-stage approach and the TIAD protocols in the general population. Therefore, the immediate extraction of teeth and placement of implants was applied for this patient as well, acknowledging the slower healing process and bone turnover rates.

During the course of this treatment, the patient returned for periodic oral hygiene with observation of the soft tissue response to the implant prosthesis. Excellent soft and hard tissue response was recorded. Radiographs taken at 30 months demonstrated stable bone levels from the time of initial implant placement.

CONCLUSION

Definitive guidelines with objective criteria including type of diabetes, age at onset, and level of long-term metabolic control have not yet been determined for an immediate loading protocol. Screening for diabetes and ensuring that implant patients are under good metabolic control are recommended to increase the chances of successful osseointegration.

In this report, it was identified that an immediate loading protocol in a diabetic patient can lead to successful osseointegration despite the effects the disease has on the bone remodeling process. There is a noted difference in the bone remodeling process between the general population and the diabetic patient, according to RFA and stability measurements, particularly in the first 30 days after implant placement. This metabolic difference, however, does not result in a difference in survival rates for osseointegration.

ACKNOWLEDGMENTS

The authors would like to thank the staff at Prosthodontics Intermedica for their kind and very gentle treatment of this patient; Robert Winkleman and the staff of dental technicians at Fort Washington Dental Lab for fabrication of the definitive prostheses; and Chris Raines for preparation of manuscript illustrations.

REFERENCES

1. Diabetes in America, ed 2 [publication 95-1468]. Bethesda, MD: National Diabetes Data Group, National Institutes of Health, 1995.
2. Murrah VA. Diabetes mellitus and associated oral manifestations: A review. J Oral Pathol 1985;14:271–281.
3. Emrich LJ, Shlossman M, Genco RJ. Periodontal disease in non-insulin dependent diabetes mellitus. J Periodontol 1991;62:123–131.
4. Smith RA, Berger R, Dodson TB. Risk factors associated with dental implants in healthy and medically compromised patients. Int J Oral Maxillofac Implants 1992;7:367–372.
5. Rothwell BR, Richard EL. Diabetes mellitus: Medical and dental considerations. Spec Care Dent 1984;4: 58–65.
6. Krakauer JC, McKenna MJ, Buderer NF, Rao DS, Whitehouse FW, Parfitt AM. Bone loss and bone turnover in diabetes. Diabetes 1995;44:775–782.
7. Margonar R, Sakakura CE, Holzhausen M, Pepato MT, Alba RC, Marcantonio E. The influence of diabetes mellitus and insulin therapy on biomechanical retention around dental implants: A study in rabbits. Implant Dent 2003;12:333–339.
8. Beikler T, Flemmig TF. Implants in the medically compromised patient. Crit Rev Oral Biol Med 2003; 14:305–316.
9. Balshi TJ, Wolfinger GJ. Dental implants in the diabetic patient: A retrospective study. Implant Dent 1999;8:355–359.
10. Fiorellini JP, Chen PK, Nevins M, Nevins ML. A retrospective study of dental implants in diabetic patients. Int J Periodontics Restorative Dent 2000;20:366–373.
11. Olson JW, Shernoff AF, Tarlow JL, Colwell JA, Scheetz JP, Bingham SF. Dental endosseous implant assessments in a type 2 diabetic population: A prospective study. Int J Oral Maxillofac Implants 2000;15:811–818.
12. Abdulwassie H, Dhanrajani PJ. Diabetes mellitus and dental implants: A clinical study. Implant Dent 2002;11:83–86.
13. Farzad P, Andersson L, Nyberg J. Dental implant treatment in diabetic patients. Implant Dent 2002; 11:262–267.
14. Peled M, Ardekian L, Tagger-Green N, Gutmacher Z, Machtei EE. Dental implants in patients with type 2 diabetes mellitus: A clinical study. Implant Dent 2003;12:116–122.
15. Wolfinger GJ, Balshi TJ, Rangert B. Immediate functional loading of Brånemark System implants in edentulous mandibles: Clinical report of the results of developmental and simplified protocols. Int J Oral Maxillofac Implants 2003;18:250–257.
16. Balshi SF, Wolfinger GJ, Balshi TJ. A prospective study of immediate functional loading, following the Teeth in a Day protocol: A case report of 55 consecutive edentulous maxillas. Clin Implant Dent Relat Res 2005;7:24–31.
17. Meredith N. A review of nondestructive test methods and their application to measure the stability and osseointegration of bone-anchored endosseous implants. Crit Rev Biomed Eng 1998;26:275–291.
18. Sennerby L, Meredith N. Resonance frequency analysis: Measuring implant stability and osseointegration. Compend Contin Educ Dent 1998;19:493–502.
19. Balshi SF, Allen FD, Wolfinger GJ, Balshi TJ. A resonance frequency analysis assessment of maxillary and mandibular immediately loaded implants. Int J Oral Maxillofac Implants 2005;20:584–594.
20. Balshi TJ. The Biotes conversion prosthesis: A provisional fixed prosthesis supported by osseointegrated titanium fixtures for restoration of the edentulous jaw. Quintessence Int 1985;16:667–677.
21. Balshi TJ, Wolfinger GJ. Immediate placement and implant loading for expedited patient care: A patient report. Int J Oral Maxillofac Implants 2002; 17:587–592.
22. Johannson P, Strid K. Assessment of bone quality from cutting resistance during implant surgery. Int J Oral Maxillofac Implants 1994;9:279–288.
23. Lekholm U, Zarb G. Patient selection and preparation. In: Brånemark P-I, Zarb G, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–220.
24. Balshi TJ, Wolfinger GJ. Teeth in a Day for the maxilla and mandible: A case report. Clin Implant Dent Relat Res 2003;5:11–16.
25. Morris HF, Ochi S, Winkler S. Implant survival in patients with type 2 diabetes: Placement to 36 months. Ann Periodontol 2000;5:157–165.
26. Shernoff AF, Colwell JA, Bingham SF. Implants for type 2 diabetic patients: Interim report. VA implants in diabetes study group. Implant Dent 1994;3:183–185.