

Planning Implant Placement on 3D Stereolithographic Models Applied with Immediate Loading of Implant-Supported Hybrid Protheses After Multiple Extractions: A Case Series

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Purpose: The aim of this noninterventional, retrospective case series was to evaluate the outcome of immediately loaded implants in patients with failing dentitions that require bone tabling using a bone reduction guide and a surgical guide manufactured directly on three-dimensional (3D) stereolithographic models. **Materials and Methods:** Consecutive patients with failing dentition and at least two remaining teeth who were treated in a single center between December 14, 2009 and September 23, 2013 were eligible. All patients receiving implants loaded with a hybrid prosthesis on the same day as extraction with their surgery planned on 3D models and performed using a surgical guide manufactured in a laboratory on the planning model were included. Patients who had undergone bone grafting procedures were excluded. Descriptive statistical analyses of available data were performed, including life-table calculations to derive a cumulative survival rate (CSR). **Results:** Two hundred twenty-eight patients (105 females and 123 males) received 1,657 implants (NobelActive) in 321 arches, in most cases 5 implants (range, 5 to 7) per arch. Ten preexisting implants were used. The mean insertion torque was 60.02 ± 13.1 Ncm (range, 15 to 75 Ncm). The definitive abutment was placed on the same day as surgery in all cases, and the definitive prosthesis ($n = 304$) was delivered after a mean of 7.9 ± 2.6 months. All implants were followed for 20.01 ± 11.3 months (range, 0 to 52 months) from implant insertion. Four implants (3 patients) had delayed loading, and one implant was left as a sleeping implant. Eight implants among six patients failed, two of the implants after prosthesis delivery. The CSR of the placed implants was 99.4% at implant level and 96.2% at patient level. **Conclusion:** Planning on 3D models to remove bone and place implants using custom-made bone reduction and surgical guides with immediate loading on the same day as extraction of remaining teeth was safe and effective for implant survival and rehabilitation of patients with periodontitis and failing dentition. INT J ORAL MAXILLOFAC IMPLANTS 2016;31:xxx-xxx. doi: 10.11607/jomi.4186

Key words: bone reduction guide, dental implant, extraction sockets, immediate loading, surgical guide

Traditional dental implants in patients with advanced periodontal disease can be arduous, involving multiple surgeries, long treatment times, and high treatment costs. Therefore, many patients are unable to benefit from the use of dental implants. However, during the last decade, methods have been developed to simplify treatment by reducing the number of surgeries, treatment times, and associated costs.¹⁻³

During the healing process, implants become osseointegrated, and as their primary stability, which is purely mechanical, drops, the secondary stability (ie, osseointegration) simultaneously increases. Implants are vulnerable in this phase.⁴ Modern moderately rough surfaces and grooves are osteoconductive and promote osseointegration, which maintains the high stability that was initially achieved throughout the healing process. Furthermore, modern implant designs allow for high primary stability (eg, high insertion torque ≥ 35 Ncm)⁵ and immediate loading of implants, even when placed in extraction sites (eg, failing dentitions). Immediate loading with a hybrid prosthesis is now an accepted treatment option for the full arch in both the maxilla and mandible.^{5,6} Immediate loading has achieved excellent results with various implant systems.^{6,7}

Surgical guides can facilitate the accurate placement of implants during insertion procedures.^{8,9}

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These guides were initially produced by dental laboratories on gypsum dies. However, recent advances in CAD/CAM technology utilizing stereolithographic manufacturing of the guides have improved the production and shown a higher predictability of outcomes with better planning and accurate implant placement.^{8,9}

There is some evidence that placing the definitive abutment on the day of implant insertion can improve the chances of success.² Further, patients with a failing dentition usually wish to get teeth that are functioning the same day of surgery. Patients report higher satisfaction during osseointegration of implants if they receive the prosthesis immediately compared to delayed loading protocols.¹⁰

Implants can be placed in a tilted manner in contrast to the upright position of natural teeth. Tilting implants allows the use of longer implants and is enabled by multiunit abutments. Furthermore, it spares areas such as nerves, sinuses, or vessels and allows a wider anterior-posterior spread to support the prosthesis, thereby reducing the extent of cantilevers, which can fracture and are unfavorable for loading implants.¹¹ In addition, tilting can help avoid major bone grafting. There is sufficient evidence that tilting does not adversely affect implant success.⁵

Tilted implants and immediate placement of implants to replace failing dentitions are demanding procedures. Surgical templates facilitate placement of implants in the planned position and can be created with planning software using computed tomography (CT) or cone beam computed tomography (CBCT) data. Another option would be to plan and manufacture the guides on 3D stereolithographic models. Planning implant positions with computer-based methods and stereolithographic surgical templates achieves high cumulative survival rates (CSR) for implants at 1 year of follow-up.⁹ However, to date, no study has planned the amount of bone reduction and the location of the dental implants directly on three-dimensional (3D) stereolithographic models. In such an approach, bone reduction is first performed directly on the 3D model; drilling is performed by the oral surgeon. The surgeon then performs the implant osteotomies directly on the 3D models. This is followed by fabrication of both the bone reduction guide and the surgical guides. The 3D model allows further evaluation of the planned placement according to the anatomical structure of the patient prior to actual placement and manufacture of the guide on that basis. Here, the authors performed a retrospective evaluation of implants placed and immediately loaded in a series of consecutive patients with failing dentition using both

a bone reduction and a surgical guide that were manufactured directly on 3D models.

MATERIALS AND METHODS

Patients

In the present study, the authors performed a non-interventional, retrospective analysis of survival of implants and prostheses for immediate-loading, full-arch reconstructions. Consecutive patients of both sexes who received a full-arch reconstruction via stereolithographic 3D-model-based planning in one or both arches and who displayed failing dentition of at least two teeth were included. All patients were treated at Permadontics (San Diego, California, USA) between December 14, 2009 and September 23, 2013. Exclusion criteria for the implant treatment was according to the routine procedures of the clinic and included the following: (1) uncontrolled diabetes, (2) being treated with bisphosphonates and displaying a C-terminal telopeptide/CTX level below 100, (3) smokers who refused to quit for 3 weeks prior and 3 weeks after the procedure, (4) active use of cortisone medication, (5) previous radiation treatment to the head and neck within the last 5 years, (6) advanced medical conditions that prevented general anesthesia, or (7) inadequate bone, requiring bone grafting prior to implant insertion. If one of these conditions was unknown for a patient, implant treatment was at the discretion of the primary care provider.

Planning Phase

Full presurgical and preprosthetic work-ups included taking teeth impressions and bite registrations, and a 3D scan was taken using a special scanning guide that has fiducial markers. Esthetic treatment planning, which consisted of shade, mold, tooth arrangement, vertical dimension, and arch design, was then accomplished.

Intraoral and extraoral photographs were taken of all patients. Stone casts were used to fabricate prostheses, which were modified full dentures. Prostheses were made according to the treatment design of the prosthodontist, with an emphasis on arch form, occlusal plane, and esthetics.

All patients received a CT scan to assess adequate bone width and height. Digital Imaging and Communications in Medicine (DICOM) data from the CT scans were sent electronically to a commercial laboratory (Fig 1a). The scans were reformatted to 0.2 mm to allow 3D stereolithographic models (AccuDental, 3D Systems) to be fabricated. Stereolithographic models were based on the scans. These models showed all of the important anatomical structures and the available

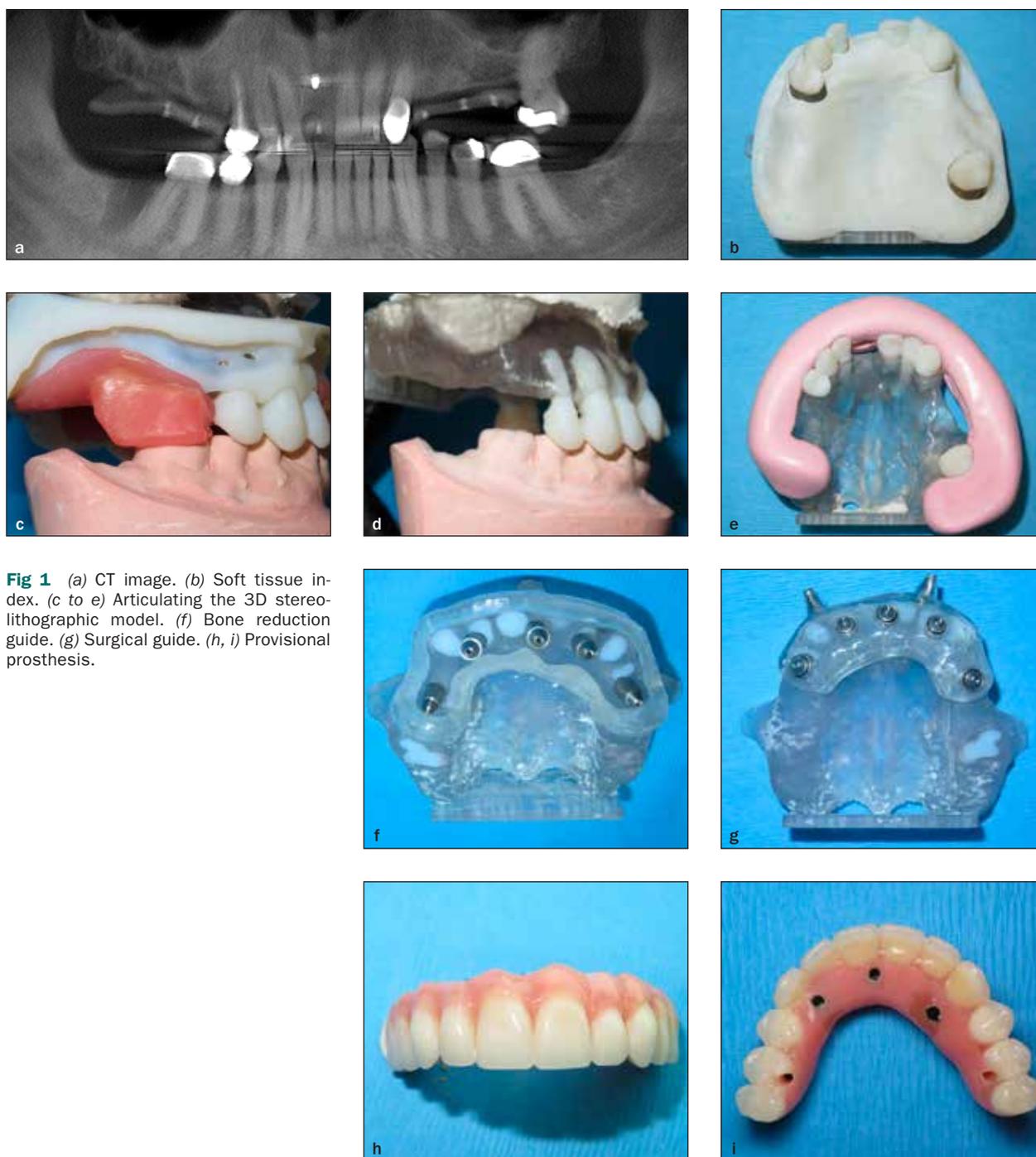


Fig 1 (a) CT image. (b) Soft tissue index. (c to e) Articulating the 3D stereolithographic model. (f) Bone reduction guide. (g) Surgical guide. (h, i) Provisional prosthesis.

bone for implant placement. If many teeth were missing, a soft tissue index was fabricated (Fig 1b). The record base was then seated on the soft tissue index to assist in the articulation of the 3D model (Fig 1c). The models were articulated, and the working stone casts were cross-articulated on the opposing stone models for fabrication of the provisional prosthesis (Fig 1d). An index of the new teeth was fabricated to place on the 3D model to help guide the placement of implants on the 3D bone model (Fig 1e). The surgeon then removed the

teeth from the model, and a precalculated amount of bone (approximately 2 to 3 mm) was removed, which created a flat platform and enabled a wider ridge for implant insertion. Implant planning was accomplished directly on the 3D bone models by the oral surgeon without using software. During planning, the anterior-posterior (A-P) spread was maximized by positioning one implant in the middle of the arch and by positioning the most posterior implants as far as possible to the distal sides. The surgeon then completed the surgery

Table 1 Patient Characteristics (n = 228)

Characteristics		No. failed implants
Age (y)		
Mean	63.1	
Range	30-89	
Sex, n (%)		
Female	105 (46.1%)	2
Male	123 (53.9%)	4
History of Smoking, n (%)		
Smoker	4 (1.8%)	4
Nonsmoker	224 (98.2%)	2

Table 2 Maxilla and Mandible Implant Characteristics

Arch treated per patient	n (%)	No. experiencing failure
Maxilla only	77 (33.8%)	
Mandible only	58 (25.4%)	
Both arches	93 (40.8%)	
No. of implants per patient ^a		
5	118 (51.8%)	
6	13 (5.7%)	
7	4 (1.8%)	
10	64 (28.1%)	
11	19 (8.3%)	
12	8 (3.5%)	
13	2 (0.9%)	
No. of implants per arch: maxilla/mandible		
5 ^b	140/130	2/2
6 ^c	20/20	2/0
7 ^d	10/1	1/0

^aIncludes 10 preexisting implants and one submerged implant.

^bIncludes one maxilla and one mandible in which preexisting implants were used.

^cIncludes two mandibles in which preexisting implants were used. One implant in one mandible was left submerged.

^dIncludes one maxilla in which preexisting implants were used.

on the model by drilling five to seven osteotomies for the implant positions.

Implant analogs at the abutment level were inserted into the 3D model. A bone reduction guide (Fig 1f) and a surgical guide (Fig 1g) were then fabricated on the stereolithographic model.

Clinical Treatment and Follow-up

All patients received full general anesthesia, and the remaining teeth were extracted. A complete periosteal flap was made, which allowed seating of the bone reduction guide over the bone, and the appropriate amount of bone was removed. The surgical guide was

then seated on the new bone platform, anchored with guide pins into the bone, and the implants (NobelActive, Nobel Biocare) were inserted according to the preplanned surgical guide. Definitive abutments (multiunit abutment, Nobel Biocare) were then inserted. These abutments were not removed and were used as the definitive abutments for the final prostheses. A full-arch impression with open trays was made, and cover caps (Healing Caps, Nobel Biocare) were placed on the abutments. The patients were then awakened and brought to the prosthetic treatment rooms.

The caps were removed, and titanium cylinders were attached to two implants, one on each side of the arch. The prefabricated provisional prosthesis was then fitted onto the cylinders, and the cylinders were acrylized to the prosthesis- at the correct vertical and centric positions. The provisional prosthesis was then sent to the laboratory, where the remaining three cylinders were attached, and the provisional prostheses went through final processing and polishing. The provisional prosthesis (Fig 1h) was delivered the same day, and the prosthetic screws were torqued to 15 Ncm (Fig 1i). The occlusion was carefully evaluated. A modified group function was obtained, in which the lateral excursions obtained contact on the canines and two premolars but not on the molars. Patients were instructed to eat a soft diet for 6 weeks. After 4 months, a definitive prosthesis was fabricated with a milled titanium bar and denture teeth. No study-specific follow-up visits were requested, as treatment and recall followed the standard procedure of the clinic.

Retrospective Analysis

All consecutive patients who met the following criteria were included in the analysis: (1) patients presented with at least two existing teeth; (2) patients had these teeth extracted, and 5 to 8 implants were inserted immediately and loaded on the same day; and (3) patients underwent the procedure using the laboratory-made surgical guide described earlier. The data, dropouts, withdrawals, and implant failures were extracted by the treating dentists and were deidentified by the clinician.

Variables Assessed

The following variables were retrieved and analyzed:

- Patient-related data including age, sex, and smoking history.
- Details of the surgical procedure, including whether the surgery used a flap or was flapless and was one-stage or two-stage. The two-stage procedure utilized a cover screw and primary flap closure with a subsequent surgery for uncovering the implant. The one-stage procedure used an abutment

Table 3 Implant Failures and Deviations

Patient ID	Sex	Age (y)	Smoker	Implant site	Dimension (mm)	Insertion torque (Ncm)	No. implants in arch	Multiunit abutment (deg)	Time to failure (mo)	Definitive prosthesis
Implant failures										
2	M	56	Y	15	4.3 × 15	50	7	17	27	Before
14	M	58	N	13	4.3 × 13	35	5	0	20	After
19	M	45	Y	15 23	5 × 8.5 4.3 × 13	50 50	5	0 17	8 8	After After
93	F	70	N	45 35	5 × 15 5 × 15	35 35	5	0 0	5 5	Before Before
133	M	30	Y	31	3.5 × 15	70	5	17	8	Before
158	F	39	Y	25	4.3 × 11.5	70	5	17	11	Before
Deviations										
								Brand	Comments	
19	M	45	Y	13	4.3 × 18	NR	5	NobelActive	2-stage, delayed loading, included in prosthesis	
24	F	60	N	23	4.3 × 13	NR	5	NobelActive	2-stage, delayed loading, included in prosthesis	
47	M	65	N	11 25	3.5 × 11 3.5 × 11	NR	6	NobelActive	2-stage, delayed loading, included in prosthesis	
76	M	63	N	43	4.3 × 15	30	6	NobelActive	Left submerged, not included in definitive prosthesis (cover screw)	
112	M	60	N	45 43 41	NR	NR	6	NR	Preexisting implant(s)	
124	F	88	N	15	NR	NR	5	NR	Preexisting implant(s)	
134	M	56	N	45	NR	NR	5	NobelActive	Preexisting implant(s)	
186	M	80	N	15 13	NR	NR	7	Straumann	Preexisting implant(s)	
226	F	76	N	32 34 36	NR	NR	6	NobelActive	Preexisting implant(s)	

NR = not reported.

ªFDI tooth-numbering system.

(healing, provisional, or definitive) placed on the day of surgery.

- Insertion torque as measured with a torque wrench.
- The type of prosthesis, the type of abutment, and if it was screw- or cement-retained.

The CSR was assessed by the actuarial life table method according to Altman on implant basis and on patient basis (ie, time to first failure). Statistical analysis was performed using SPSS Statistics, version 19 (IBM).

RESULTS

Patient and Implant Characteristics

Two hundred twenty-eight patients (105 women and 123 men) were consecutively treated with this new planning method at the same clinic between

December 14, 2009 and September 23, 2013. Patients ranged from 30 to 89 years of age at the time of surgery (Table 1), and the majority of patients were nonsmokers. Three hundred twenty-one surgical guides were used to insert 1,657 implants in both arches (Table 2). All implants were placed without bone grafting and by raising a full flap. Implants were placed in either fresh extraction or healed sites. In addition, 10 preexisting implants were used (Table 3) and remained in function over follow-up; however, they were excluded from implant-level analysis. The mean insertion torque was 60.02 ± 13.1 (range, 13 to 75) Ncm, and 49.8% of implants ($n = 817$) were inserted with an insertion torque of 70 Ncm.

The technique allowed for placement of all implant widths and lengths ranging from 3.5 to 5.0 mm in diameter and 8.5 to 18 mm in length (Table 4). In all surgeries, a hybrid prosthesis could be inserted the same day.

Table 4 Implant Dimensions

Diameter (mm)	Length (mm)					
	8.5	10.0	11.5	13.0	15.0	18.0
3.5	0	3	9	9	16 (1)	3
4.3	2	19	43 (1)	323 (2)	916 (1)	99
5.0	5 (1)	23	40	46	89 (2)	12

Numbers of patients experiencing failures are given in parentheses.

Table 5 Survival of Implants and Definitive Protheses

Time period	No. of implants/protheses	No. failed	No. withdrawn	CSR (%)
Implants				
< 1 y	1,657	6	421	99.6
1–2 y	1,230	1	693	99.6
2–3 y	536	1	327	99.4
3–4 y	208	0	157	99.4
> 4 y	51	–	–	99.4
Definitive protheses				
< 1 y	304 ^a	1	184	99.7
1–2 y	119	1	62	98.8
2–3 y	56	0	40	98.8
3 y	16	–	–	98.8

^aOne implant had failed before insertion of protheses.

However, in four patients, a total of five implants were not subjected to immediate loading. Four of those delayed loaded implants (0.2%) were loaded between 4 and 7 months following surgery, and one unloaded implant was not uncovered after the healing period but remained as a sleeper implant (Table 3).

All of the definitive abutments on the NobelActive implants were multiunit abutments (Nobel Biocare) in 0 degrees ($n = 585$, 35.5% and 4 failures), 17 degrees ($n = 972$, 59.1% and 4 failures), or 30 degrees ($n = 89$, 5.4% and no failures) and attached at the day of loading. Only screw-retained hybrid protheses were used for definitive restoration. Several patients had not received a definitive prothesis yet. Among 321 arches, 304 received a definitive prothesis. The mean time from surgery to definitive prothesis was 7.9 ± 2.6 months (range, 1 to 22 months), and the mean time from definitive prothesis to the last follow-up was 11.6 ± 11.8 months (range, 0 to 46 months).

Survival Rate

The mean follow-up time for all 1,657 implants was 20.01 ± 11.3 months (range, 0 to 52 months). The CSR of the implant was 99.4% at the implant level (Table 5). Because this was a retrospective study, one patient was lost to follow-up directly after implant insertion. The mean follow-up time for all 228 patients was 19.37 ± 11.1 months

(range, 0 to 52 months). The CSR of the implants at the patient level was 96.2%. The CSR was determined based on the first failure in a patient. Further failed implants or further follow-up results of other implants in the same patient were not taken into account.

The mean follow-up time of all definitive protheses was 11.58 ± 11.8 months (range, 0 to 46 months). The CSR of the prothesis at the level of the definitive prothesis was 98.8% at 3 years of follow-up (Table 5). Provisional protheses were not taken into account for this analysis.

Adverse Events

Eight implant failures occurred among six patients (Table 3). Five maxillary implants among four patients and three mandible implants among two patients failed. One provisional prothesis failed 6 weeks postoperatively, but all others were successful. Twenty-two provisional protheses developed fractures: six fractures during the healing phase requiring repair in the laboratory and 16 fractures at the distal aspect of the cantilever sites, some of which were trimmed and polished and others repaired in the laboratory. Two definitive protheses had to be removed due to failures of implants and were classified as failed restorations. One definitive prothesis developed a clear fracture of the titanium frame distal to the most distal abutment. Multiple tooth fractures and debonding occurred, and all were repaired in the laboratory in ≤ 2 hours.

DISCUSSION

Accurate stereolithographic bone models developed 5 to 6 years ago, with regard to occlusion, improved to the point where the authors could articulate the models. Here, the authors conducted a retrospective study of implants placed and immediately loaded using 3D stereolithographic models. Patients with failing dentition received implants and final multiunit abutments on the same day of surgery.

In addition to the benefits to the patients, 3D modeling is viewed as being particularly user-friendly among craniofacial surgeons¹² and highly reliable and accurate.¹³ Three-dimensional modeling in contrast to computer planning of implant surgery does not require specific software. Furthermore, while computer planning only allows the surgeon to see the bone structure on a two-dimensional screen, 3D models enable the surgeon to physically examine the bone structure at all angles and use this information to formulate a step-by-step approach to the implant placement. The data presented here support the concept of 3D stereolithographic models, demonstrating feasibility and a high implant survival rate. In this study, nearly all implants were immediately loaded successfully. No serious adverse events were reported,

and the minor adverse events that were reported were mainly technical complications with the provisional or definitive prostheses.

Immediate loading of dental implants in patients with advanced periodontal disease is an accepted treatment option.^{4,6,7,14} Presurgical planning directly on 3D stereolithographic models can facilitate treatment of patients in a timely manner and reduce or eliminate the need for subsequent surgeries.¹³ Additionally, patients with a failing dentition can undergo extraction and accurate bone reduction followed by immediate implant placement (in healed and extraction sites) loaded with a prosthesis on the same day.

Implants that enable high insertion torques allow for immediate loading; the threshold value for immediate loading is 35 Ncm. Only 3.2% of the implants reported here were below that value, and by splinting, immediate loading was also feasible in these cases. Implants restored with angulated multiunit abutments was a safe procedure as previously reported for tilted implants.¹⁵ The present results build on earlier data that showed favorable survival rates of 97% to 100% at 1 to 3 years of follow-up using titanium implants with an oxidized surface,^{1,9,16,17} including those of a previous study that reported a 99.6% CSR for NobelActive implants up to 29 months after loading.⁵ This study has some limitations, which include its retrospective nature, lack of comparison to other methods, limited follow-up, and limited number of endpoints. However, a substantial number of patients were followed, and a clear benefit was found. Further research is needed to better assess the accuracy of the method, costs, and time involved in using a 3D stereolithographic model and compare these with those of other digitally planned and widely accepted stereolithographic guides that were not assessed in this study.

CONCLUSIONS

This retrospective investigation showed that planning of custom-made bone reduction guides and custom-made surgical guides fabricated on 3D stereolithographic models facilitated implant placement in patients with failing dentition. The treatment regimen of extraction of failing dentition and loading on the same day using this approach was safe and effective with respect to implant survival rate.

ACKNOWLEDGMENTS

Medical writing services for this investigator-initiated study were supported by Nobel Biocare Services AG, Kloten (ZH), Switzerland, study number 2014-1274. The authors report no conflicts of interest related to this study.

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