Planning implant placement on 3D stereo-lithographic models applied with immediate loading of implant supported hybrid prostheses after multiple extractions:
A case series

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Abstract

Purpose: Immediate loading of implants with hybrid prostheses may be beneficial for patients with failing dentition. The success of computer-based planning of implant position and production of stereo-lithographic surgical templates has also been demonstrated. Alternatively, 3D stereo-lithographic models may be used for implant treatment planning, however long-term data has not yet been reported. The aim of this non-interventional, retrospective case series was to evaluate the outcome of immediately loaded implants in patients with failing dentitions that require bone tablingusing a bone reduction guide and a surgical guide manufactured directly on 3D 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 lab 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 and twenty-eight patients (105 females and 123 males) received 1,657 implants (NobelActive) in 321 jaws, in most cases 5 implants (range 5-7) per jaw. Ten pre-existing implants were used. The mean insertion torque was 60.02 ± 13.1 Ncm (range 15-75 Ncm). The final abutment was placed on the same day as surgery in all cases and the final 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 0-52 months) from implant insertion. Four implants (3 patients) had delayed loading and one implant was left as a sleeping implant. Eight implants among 6 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.
Conclusions: Planning on 3D models to remove bone and place implants ~~with a~~ 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.

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

Introduction

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; simultaneously, the secondary stability (i.e., osseointegration) 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 (e.g., high insertion torque ≥ 35 N cm) (5) and immediate loading of implants, even when placed in extraction sites (e.g., 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). These guides were initially produced by dental labs on gypsum dies. However, recent advances in CAD/CAM technology utilizing stereo-lithographic 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 use of longer implants and is enabled by “multi-unit-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 CT or CBCT data. Another option would be to plan and manufacture the guides on 3D stereo-lithographic models. Planning implant positions with computer-based methods and stereo-lithographic 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 ~~placed~~ the location of the dental implants directly on three-dimensional (3D) stereo-lithographic models. In such an approach bone reduction is first performed directly on the 3 D model 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, we 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.

Patients and Methods

Patients

In the present study, we performed a non-interventional, retrospective analysis of survival of implants and prostheses for immediate-loading, full-arch reconstructions. Consecutive patients of both genders who received a full-arch reconstruction via stereo-lithographic 3D-model-based planning in one or both jaws and who displayed failing dentition of at least two teeth were included. All patients were treated at Permadontics (San Diego, CA, 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 pre-surgical and pre-prosthetic work-ups included taking teeth impressions and bite registrations and a 3D scan was taken using a special scanning guide that has fiduciary markers. Aesthetic treatment planning which consisted of shade, mold, tooth arrangement, vertical dimension, and arch design was then accomplished.

Intra- and extra-oral 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 aesthetics.

All patients received a CT scan to assess adequate bone width and height. DICOM data from the CT scans were sent electronically to a commercial laboratory (Figure 1A). The scans were reformatted to 0.2 mm to allow 3D stereo-lithographic models (AccuDental®, 3D Systems, Inc., USA) to be fabricated. Stereo-lithographic models were based on the scans. These models showed all of the important anatomical structures and the available bone for implant placement. If many teeth were missing, a soft tissue index was fabricated. (Figure 1B). The record base was then seated on the soft tissue index to assist in the articulation of the 3D model (Figure 1C). The models were articulated, and the working stone casts were cross-articulated on the opposing models for fabrication of the provisional prosthesis (Figure 1D). An index of the teeth was fabricated to place on the 3D model to help guide the placement of implants on the 3D bone model (Figure 1E). The surgeon then removed the teeth from the model, and a pre-calculated amount of bone (approximately 2-3 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 on the model by drilling five to seven osteotomies for the implant positions.

Implant analogues at the abutment level were inserted into the 3D model. A bone reduction guide (Figure 1F) and a surgical guide (Figure 1G) were then fabricated on the stereo-lithographic 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, Göteborg, Sweden) were inserted according to the pre-planned surgical guide. Final abutments (multi-unit 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 lab, where the remaining three cylinders were attached, and the provisional prostheses went through final processing and polishing. The provisional prosthesis (Figure 1H) was delivered the same day, and the clinical screws were torqued to 15 N cm. (Figure 1I). The occlusion was carefully evaluated. A modified group function was obtained, in which the lateral excursions obtained contact on the cuspids 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, 5-8 implants inserted immediately and loaded on the same day; and 3) patients underwent the procedure using the lab-made surgical guide described above. The data, dropouts, withdrawals, and implant failures were extracted by the treating dentists and were de-identified by the clinician.

Variables assessed

The following variables were retrieved and analyzed. 1) Patient-related data including age, gender, and smoking history. 2) Details of the surgical procedure, including whether the surgery used a flap or was flapless, 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 (healing, provisional, or final) placed on the day of surgery. 3) Insertion torque as measured with a torque wrench. 4) The type of prosthesis, the type of abutment and if it was screw- or cement-retained.

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

Results

Patient and implant characteristics

Two hundred and twenty-eight patients (105 females and 123 males) 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 non-smokers. Three hundred and twenty-one surgical guides were used to insert 1,657 implants in both jaws (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 pre-existing implants were used (Table 5) 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 13-75) N cm, and 49.8% of implants (n = 817) were inserted with an insertion torque of 70 N cm.

Technique allowed for placement all implant widths and lengths ranging from 3.5 to 5.0 mm in diameter and 8.5 to 18 mm in length (Table 3). In all surgeries, a hybrid prosthesis could be inserted the same day. 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 to 7 months following surgery, and one unloaded implant was not uncovered after the healing period but remained as a sleeper implant (Table 5).

All of the final abutments on the NobelActive implants were multi-unit abutments (Nobel Biocare) in 0° (n = 585, 35.5% and 4 failures), 17° (n = 972, 59.1% and 4 failures), or 30° (n = 89, 5.4% and no failures) and attached at the day of loading. Only screw-retained hybrid prostheses were used for final restoration. Several patients did not receive a final prosthesis, yet. Among 321 jaws, 304 received a final prosthesis. The mean time from surgery to final prosthesis was 7.9 ± 2.6 months (range 1-22 months), and the mean time from final prosthesis to the last follow up was 11.6 ± 11.8 months (range 0-46 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 4). 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 final prostheses was 11.58 ± 11.8 months (range 0 to 46 months). The CSR of the prosthesis at the level of the final prosthesis was 98.8% at 3 years of follow-up (Table 4). Provisional prostheses were not taken into account for this analysis.

Adverse Events

Eight implant failures occurred among six patients (Table 5). Five maxillary implants among four patients failed, and three mandible implants among two patients. One provisional prosthesis failed 6 weeks postoperatively, but all others were successful. Twenty-two provisional prostheses developed factures: 6 through and through 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 final prostheses had to be removed due to failures of implants and were classified as failed restorations. One definitive prosthesis 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. Furthermore, one definitive prosthesis developed a clear fracture of the titanium frame distal to the most distal abutment

Discussion

Accurate stereolithographic bone models developed 5-6 years ago, with regards to occlusion improved to the point where we could articulate the models. Here, we conducted a retrospective study of implants placed and immediately loaded using 3D stereo-lithographic models. Patients with failing dentition received implants and final multi-unit 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 cranio-facial surgeons (12) 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 enables 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 stereo-lithographic 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 minor adverse events were reported mainly technical complications with the provisional or final prostheses.

Immediate loading of dental implants in patients with advanced periodontal disease is an accepted treatment option (4, 6, 7, 14). Pre-surgical planning directly on 3D stereo-lithographic 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 ~~and~~ immediate implant placement (in healed and extraction sites) loaded with a prosthesis on the same day.

Implants which enable high insertion torques allow for immediate loading; the threshold value for immediate loading is 35 N cm. 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 multi-unit 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 97-100% at 1 to 3 years of follow 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 3D stereo-lithographic model and compare these with those of other digitally planned and widely accepted stereolithographic guides that were not assessed in this study.

In conclusion, this retrospective investigation showed that planning of custom made bone reduction guides and custom-made surgical guides fabricated on 3D stereo-lithographic 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.

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Figure legends

Figure 1A) Panoramic view of CBCT.

Figure 1B) Stereolithographic model with soft tissue index.

Figure 1C) Articulated Stereolithographic model with soft tissue index and was bite rim.

Figure 1D) Articulated Stereolithographic model with bite rim and soft tissue index removed.

Figure 1E) Silicone index of existing teeth.

Figure 1F) Abutment level lab analogues and bone reduction guide.

Figure 1G) Surgical guide seated on the 3D model.

Figure 1H) Facial view of the provisional Prosthesis.

Figure 1I) Occlusal surface of the provisional prosthesis.

Table 1. Patient characteristics

Characteristics (n = 228)	
Age (years)	
Mean	63.1
Range	30-89
Gender, n (%); no. failed implants	
Female	105 (46.1%); 2
Male	123 (53.9%); 4
History of Smoking, n (%); no. failed implants	
Smoker	4 (1.8%); 4
Non-smoker	224 (98.2%); 2

Table 2. Jaw implant characteristics

Jaws treated per patient, n (%)	
Maxilla only	77 (33.8%)
Mandible only	58 (25.4%)
Both jaws	93 (40.8%)
No. of implants per patients, n (%)[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 jaw: maxilla, mandible; n (no. experiencing failure)	
5[b]	140 (2), 130 (2)
6[c]	20 (2), 20
7[d]	10(1), 1

[a] Includes 10 pre-existing and one submerged implants.

[b] Includes one maxilla and one mandible jaw in which pre-existing implants were used.

[c] Includes two mandible jaws in which pre-existing implants were used. One implant in one mandible jaw was left submerged.

[d] Includes one maxilla jaw in which pre-existing implants were used.

Table 3. 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 4. Survival of implants and final prostheses

Time Period	No.	Failed	Withdrawn	CSR (%)
		Implants		
<1 year	1657	6	421	99.6
1-2 years	1230	1	693	99.6
2-3 years	536	1	327	99.4
3-4 years	208	0	157	99.4
>4 years	51	--	--	99.4
		Final Prostheses		
<1 year	304[a]	1	184	99.7
1-2 years	119	1	62	98.8
2-3 years	56	0	40	98.8
3 years	16	--	--	98.8

[a] One implant had failed before insertion of prostheses.

Table 5. Implant failures and deviations

Implant Failures

Patient ID	Sex	Age	Smoker	Site	Dimension	Insertion Torque	No. implants in jaw	Multi-unit abut	Time to Failure	Final Prosthesis
2	M	56	Y	Max1	4.3×15	50	7	17°	27	Before
14	M	58	N	Max2	4.3×13	35	5	0°	20	After
19	M	45	Y	Max1	5×8.5	50	5	0°	8	After
				Max4	4.3×13	50		17°	8	After
93	F	70	N	Man1	5×15	35	5	0°	5	Before
				Man5	5×15	35		0°	5	Before
133	M	30	Y	Man3	3.5×15	70	5	17°	8	Before
158	F	39	Y	Max5	4.3×11.5	70		17°	11	Before

Deviations

Patient ID	Sex	Age	Smoker	Site	Dimension	Insertion Torque	No. implants in jaw	Brand	Comments
19	M	45	Y	Max2	4.3×18	NR	5	NobelActive	2-stage, delayed loading, included in prosthesis
24	F	60	N	Max4	4.3×13	NR	5	NobelActive	2-stage, delayed loading, included in prosthesis
47	M	65	N	Max3	3.5×11	NR	6	NobelActive	2-stage, delayed loading, included in prosthesis
				Max5	3.5×11				
76	M	63	N	Man2	4.3×15	30	6	NobelActive	Left submerged, not included in final prosthesis (cover screw)
112	M	60	N	Man1 Man2 Man3	NR	NR	6	NR	Pre-existing implant(s)

124	F	88	N	Max1	NR	NR	5	NR	Pre-existing implant(s)
134	M	56	N	Man1	NR	NR	5	NobelActive	Pre-existing implant(s)
186	M	80	N	Max1 Max2	NR	NR	7	Straumann	Pre-existing implant(s)
226	F	76	N	Man4 Man5 Man6	NR	NR	6	NobelActive	Pre-existing implant(s)

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Figure 1A

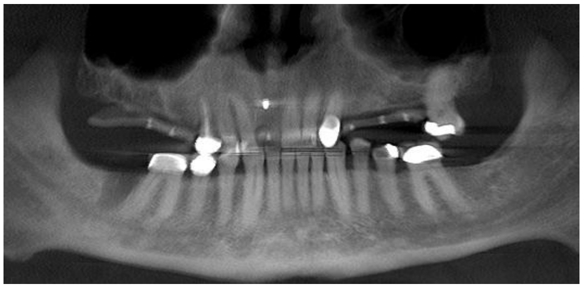

Figure 1B

Figure 1C

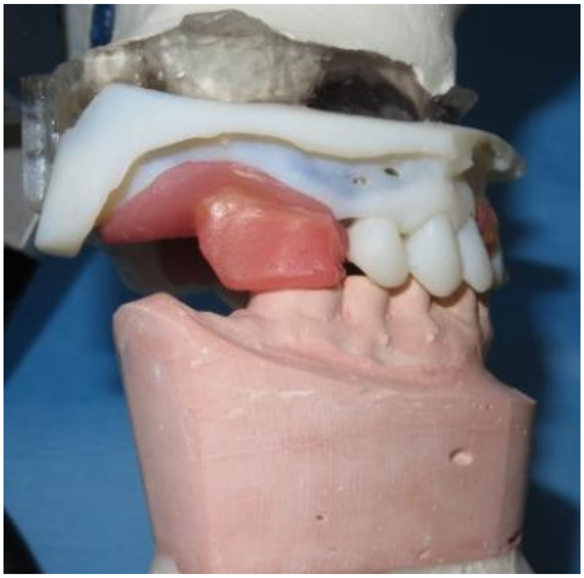

Figure 1D

Figure 1E

Figure 1F

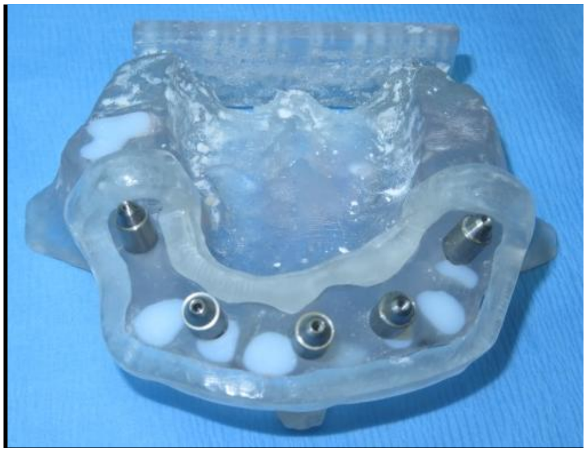

Figure 1G

Figure 1H

Figure 1I