

**A longitudinal study of the survival of All-on-4 implants in the mandible with up to 10 years of follow-up**

Paulo Malo, Miguel de Araújo Nobre, Armando Lopes, Steve M. Moss and Guillermo J. Molina  
*J Am Dent Assoc* 2011;142;310-320

---

*The following resources related to this article are available online at [jada.ada.org](http://jada.ada.org) ( this information is current as of March 29, 2011 ):*

**Updated information and services** including high-resolution figures, can be found in the online version of this article at:

<http://jada.ada.org/cgi/content/full/142/3/310>

Information about obtaining **reprints** of this article or about permission to reproduce this article in whole or in part can be found at:

<http://www.ada.org/prof/resources/pubs/jada/permissions.asp>

# A longitudinal study of the survival of All-on-4 implants in the mandible with up to 10 years of follow-up

Paulo Malo, PhD, DDS; Miguel de Araújo Nobre, RDH; Armando Lopes, DDS; Steve M. Moss, DMD; Guillermo J. Molina, DDS

**I**mmEDIATE-function protocols involving the use of implant-supported prostheses for the rehabilitation of completely edentulous mandibles are documented as having high success rates.<sup>1-5</sup> The placement of axial implants in immediate function for the treatment of fully edentulous patients has demonstrated to be a predictable procedure in the long term.<sup>6-8</sup> The loss of posterior teeth, particularly at an early age, leads to the loss of alveolar bone with a relative surfacing of the inferior alveolar nerve in the mandible, thus often prohibiting placement of implants in the posterior regions. An alternative could be the use of tilted implants, which allows for maximum use of the existing bone and placement of posterior fixed teeth with minimum cantilevers, in a region where bone height and nerve proximity does not allow for the placement of axial implants.<sup>9-11</sup>

The All-on-4 implant concept (Nobel Biocare, Göteborg, Sweden) was developed to overcome anatomical limitations in the mandible that make it challenging to treat without the use of more complex techniques.<sup>9</sup> Based on the optimal number of four implants for supporting a full-

## ABSTRACT

**Background.** Immediate-function implants have become an accepted alternative for fixed restoration protocols in edentulous mandibles on the basis of documented high success rates. The All-on-4 concept (Nobel Biocare, Göteborg, Sweden), a surgical and prosthetic protocol for immediate function involving the use of four implants to support a fixed prosthesis in patients with completely edentulous mandibles, represents one of these protocols. The authors conducted a study to document long-term follow-up of the All-on-4 concept.

**Methods.** This longitudinal study included 245 patients with a total of 980 immediate-function implants (four per patient), all placed in the anterior region, to support fixed full-arch mandibular prostheses. The inclusion criterion was having an edentulous mandible, or a mandible with hopeless teeth, in need of fixed implant restorations.

**Results.** A total of 21 implants failed in 13 patients, giving cumulative patient-related and implant-related success rates of 94.8 percent and 98.1 percent, respectively, at five years, and 93.8 percent and 94.8 percent, respectively, with up to 10 years of follow-up. The prostheses' survival rate was 99.2 percent with up to 10 years of follow up.

**Conclusions.** The results support the conclusion that use of the All-on-4 immediate-function implant concept in completely edentulous mandibles is viable in the long term.

**Clinical Implications.** High prosthesis survival rates can be achieved by the use of four implants to support a full-arch fixed prosthesis in the mandible.

**Key Words.** Dental implants; implant angulation; complete arch; immediate function; immediate load; mandible.

*JADA 2011;142(3):310-320.*

Dr. Malo is the head, Malo Clinic Lisbon, Lisboa, Portugal.

Mr. Nobre is the director, Research and Development Department, Malo Clinic Lisbon, Avenida dos Combatentes, 43, 9° C, Ed. Green Park, 1600-042, Lisboa, Portugal, e-mail "mnobre@maloclinics.com". Address reprint requests to Mr. Nobre.

Dr. Lopes is the director, Oral Surgery Department, Malo Clinic Lisbon, Lisboa, Portugal.

Dr. Moss is an oral surgeon, Oral Surgery Department, Malo Advanced Oral Rehabilitation, Rutherford, N.J.

Dr. Molina is a prosthodontist, Oral Surgery Department, Malo Advanced Oral Rehabilitation, Rutherford, N.J.

arch prosthesis in an edentulous jaw, the concept benefits from the posterior tilting of the two distal implants with a maximum of a two-tooth distal cantilever in the final prosthesis.<sup>9</sup>

Besides the advantages described above, the use of tilted implants facilitates the achievement of the desired position of the implants from a prosthetic point of view<sup>10</sup> and creates a favorable interimplant distance.<sup>11</sup> Moreover, using finite element analysis, one can conclude that there is a biomechanical advantage in using splinted tilted distal implants rather than axial implants supporting distal cantilever units when comparing the coronal stress.<sup>12</sup> The protocol described in this article is an easy-to-use technique involving the use of a simple guide for optimal positioning and inclination of the implants, providing for superior loading conditions.

Findings of a previous study by members of our research team,<sup>9</sup> which involved a follow-up of up to three years, demonstrated that the complete prosthetic rehabilitation of the edentulous mandible by means of the All-on-4 concept is possible with good outcomes in the short and medium terms. The purpose of this article is to present the clinical outcome of the All-on-4 concept with a follow-up of up to 10 years. The research hypothesis we investigated in this study was the rehabilitation of completely edentulous mandibles via the All-on-4 concept.

## METHODS

We wrote this article according to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines.<sup>13</sup> This longitudinal study was performed in the Malo Clinic Lisbon, a private clinic in Portugal, and was approved by an independent ethical committee.

From May 1999 to November 2004, 245 patients (96 men and 149 women; mean age, 59 years; age range, 23 to 85 years) underwent mandibular rehabilitation with immediately loaded full-arch prostheses supported by four implants, all placed anterior to the mental foramina—in total, 980 implants. The inclusion criterion was edentulous mandibles, or mandibles with hopeless teeth, in need of fixed implant restorations as requested by the patient. We included patients consecutively if they accepted the treatment and provided written informed consent. We excluded from the study any patients who had implants that had been placed in periodontally compromised areas (an extraction socket of a periodontally compromised tooth), patients who had implants placed in extraction sockets in which more than two-thirds of the implant had been inserted in the extraction

socket, and patients who had bony dehiscences or fenestrations at the time of surgery.

As for the opposing dentition, 100 patients had an implant-supported fixed prosthesis, 31 patients had natural teeth, 21 patients had fixed prosthetics over natural teeth, 30 patients had a combination of natural teeth and implant-supported fixed prosthetics, and 63 patients had removable prostheses.

The types of implants inserted were distributed as follows: Brånemark System Mk II implants (Nobel Biocare) (n = 42), Brånemark System Mk III implants (Nobel Biocare) (n = 530), B Brånemark System Mk IV implants (Nobel Biocare) (n = 358) and Brånemark System NobelSpeedy implants (Nobel Biocare) (n = 50).

**Surgical protocol.** The patients provided a medical history and underwent clinical observation and complementary radiographic examinations with an orthopantomographic scan (for bone height evaluation) and a computerized tomographic scan (for evaluation of bone volume and anatomical structures such as the dental nerve).

Two of the authors (P.M. and A.L.) performed the surgical procedures after administering local anesthetic to the patients in the form of articaine hydrochloride (72 milligrams per 1.8 milliliters with epinephrine (0.018 mg/1.8 mL) 1:100,000. The clinicians sedated all patients with diazepam (Valium 10 mg, Roche, Amadora, Portugal) before performing surgery. Patients received the following drug therapy:

- antibiotics (amoxicillin, 875 mg, and clavulanic acid, 125 mg) one hour before surgery and daily for six days thereafter;
- cortisone medication (prednisolone, 5 mg) daily in a regression mode (15 to 5 mg) from the day of surgery until four days after surgery;
- anti-inflammatory medication (ibuprofen, 600 mg) for four days postoperatively starting on day four;
- analgesics (clonixine, 300 mg) on the day of surgery and postoperatively for the first three days if needed;
- antacid medication (omeprazole, 20 mg) on the day of surgery and daily for six days postoperatively.

The clinicians (P.M. and A.L.) inserted the implants according to standard procedures, except that they used underpreparation when needed to achieve a final torque of more than 32 newtons per centimeter before the final seating

**ABBREVIATION KEY.** **A:** Axial implant. **CSR:** Cumulative success rate. **T:** Tilted implant.

of the implant. The length of the implants (all anterior to the foramina) ranged from 10 to 18 millimeters.

The two most anterior implants followed the direction of the jaw's anatomy; in cases involving severe mandibular resorption, this meant a lingual tilting. The clinicians inserted two additional implants just anterior to the foramina and were tilted distally about 30° and up to 45° when needed relative to the occlusal plane. This arrangement allowed for good implant anchorage, short cantilever length and large interimplant distance (as described by Fortin and colleagues<sup>10</sup> and Malo and colleagues<sup>11</sup>). The posterior implants, which were 4 mm in diameter, typically emerged at the second premolar position. Anterior implants were either 3.75 mm or 4.00 mm in diameter.

The clinicians positioned the lower corner of the implant neck at bone level and established bicortical anchorage whenever possible. They readapted the soft tissues and sutured them back into position with 4-0 nonresorbable suture. For anterior implants, they placed straight multiunit abutments (Nobel Biocare); for posterior implants, they used 30° angulated abutments. When needed, they used 17° abutments in the anterior implants. The clinicians chose these abutment angulations so that the prosthetic screw-access holes were in an occlusal or lingual location. They informed patients that they should keep the surgical area cool and under minimal pressure for the first 48 hours after the surgery, and that they were to ingest only soft and cold foods during that period.

**Immediate provisional prosthetic protocol.** The clinicians inserted complete arch acrylic resin (PalaXpress Ultra, Heraeus Kulzer, Hanau, Germany) prostheses on the day of surgery (n = 245). High-density acrylic resin prostheses (PalaXpress Ultra, Heraeus Kulzer) with titanium cylinders (Nobel Biocare) were manufactured at the dental laboratory, and the clinicians inserted them on the same day, usually two to three hours postsurgically. Anterior occlusal contacts and canine guidance during lateral movements were preferred in the provisional prosthesis. The clinicians used no cantilevers in the provisional bridges. The emergence positions of the screw-access holes at the posterior implants of the prostheses normally were at the level of the second premolar, and the prostheses were designed to hold a minimum of 10 teeth owing to the favorable position achieved by the posterior tilting of the distal implants.

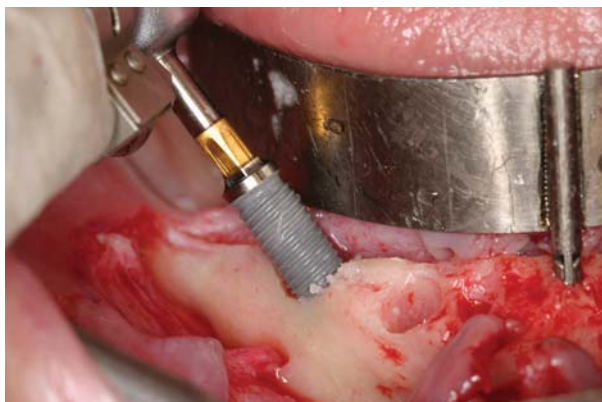
**Final prosthetic protocol.** According to the patient's desires, the clinician replaced the provisional prosthesis with either a metal-ceramic implant-supported fixed prosthesis with a titanium framework and all-ceramic crowns (Nobel-Procera titanium framework, NobelProcera crowns and Nobel Rondo pressed ceramics, all manufactured by Nobel Biocare), or a metal-acrylic resin, implant-supported fixed prosthesis with a titanium framework (NobelProcera titanium framework) and acrylic resin prosthetic teeth (PalaXpress Ultra). In this final prosthesis, the occlusion mimicked the natural dentition. The final prosthesis typically was delivered by the clinician six months after surgery.

Figures 1 through 4 depict representative patients whose mandibles were treated with the All-on-4 (Nobel Biocare) concept and a Malo Clinic Ceramic Bridge (Malo Clinic Ceramics, Lisbon, Portugal) as the definitive prosthesis and who underwent five years of follow-up.

**Dropout rate and implant success criteria.** Thirty-two patients withdrew from the study: four patients in the first six months, seven patients between six months and one year, nine patients between one and two years, six patients between two and three years, six patients between three and four years, and one patient between five and six years. We gauged implant success according to the Malo Clinic Lisbon success criteria:<sup>14</sup>

- the implant fulfilled its intended function as support for reconstruction;
- the implant was stable when tested individually and manually;
- no signs of infection around the implant were observable;
- no radiolucent areas around the implants were evident;
- the implant demonstrated a good esthetic outcome;
- the implant allowed the construction of an implant-supported fixed prosthesis that provided patient comfort and allowed for good hygienic maintenance.

We classified as failures the implants that were removed. We computed success as both patient-related (that is, by using the patient as the unit of analysis and considering the first incidence of implant failure) and implant-related by using the Life Table Analysis Package for SPSS (SPSS Advanced Statistics, Version 17.0, SPSS, Rochester, N.Y.). We estimated hazard ratios by using the Cox proportional hazards regression model. As indicator variables for the outcome variable, we used "survival" with "implant type," "implant sur-



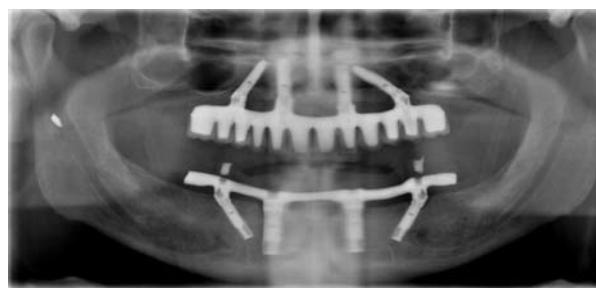
**Figure 1.** Intraoral photograph of a patient's posterior implant placement with a 30° inclination. The clinician placed the edentulous guide (Nobel Biocare, Göteborg, Sweden) into a 2-millimeter osteotomy made at the midline of the mandible, then bent the titanium band so that the occlusal centerline of the opposing jaw was followed. By doing this, the clinician could guide the implants to be placed in the center of the opposing prosthesis and concurrently could find the optimal position and inclination for best implant anchorage and prosthetic support.



**Figure 2.** Intraoral photograph representative of the patient depicted in Figure 1, whose edentulous mandible was treated with the All-on-4 concept (Nobel Biocare, Göteborg, Sweden) with five years of follow-up. The patient had a definitive prosthesis (Malo Clinic Ceramic Bridge, Malo Clinic Ceramics, Lisbon, Portugal).



**Figure 3.** Extraoral photograph of the same patient depicted in Figures 1 and 2, in maximum smile.



**Figure 4.** Orthopantomographic scan of the patient depicted in Figures 1 through 3, who was treated by means of the All-on-4 concept (Nobel Biocare, Göteborg, Sweden) in the edentulous mandible and underwent five years of follow-up.

face," "implant diameter," "implant length," "sex," "age," "systemic condition," "therapy with bisphosphonates" and "smoking status"; in addition, we estimated the odds ratios (ORs) and corresponding 95 percent confidence intervals (CIs) (SPSS, Version 17.0). We generated survival curves to demonstrate visually the monitoring of survival changes across time between patients in different implant groups (SPSS, Version 17.0).

**Complications.** We assessed the mechanical complication factors of fracture or loosening of mechanical and prosthetic components. We assessed the biological factors of presence of pain, fistula formation or other signs of infection; soft-tissue inflammation (registered as present or absent); bone resorption (assessed through the use of periapical radiographs); and implant stability (assessed by removing the

bridge and manually applying lateral forces to the implant).

## RESULTS

Table 1 presents the distribution of enrolled patients (and their implants), with a total of 245 patients who had 980 implants in immediate function.

Table 2 presents the overall medical and habit statuses of the patients included in the study. A total of 54 patients had one systemic condition each, and five patients had comorbidities: four patients who had cardiovascular and autoimmune diseases and one patient who had cardiovascular disease and osteoporosis that was being treated with a bisphosphonate.

**Implant success.** A total of 21 implants in 13 patients were lost, with a higher incidence of failures in the first six months of function. The cumulative patient-related and implant-related success rates after five years of follow-up were

TABLE 1

### Distribution of enrolled patients and implants, according to year of enrollment in the study.

YEAR OF ENROLLMENT	NO. OF PATIENTS	NO. OF IMPLANTS
1999	2	8
2000	17	68
2001	11	44
2002	24	96
2003	117	468
2004	74	296
<b>TOTAL</b>	<b>245</b>	<b>980</b>

TABLE 2

### Overall medical and habit status of the patients included in the study.

STATUS	NUMBER OF PATIENTS	NUMBER OF IMPLANTS
<b>Medical</b>		
Osteoporosis being treated with bisphosphonates	4	20
Cardiovascular disease	35	140
Autoimmune disease	6	24
Diabetes	5	20
Neurological diseases	3	12
Positive for human immunodeficiency virus	1	4
<b>TOTAL</b>	<b>54</b>	<b>220*</b>
<b>Habit</b>		
Smoker	61	244
Nonsmoker	184	736
<b>TOTAL</b>	<b>245</b>	<b>980</b>

\* Four patients shared more than one condition, leading to a total of 220 rather than 216.

94.8 percent and 98.1 percent, respectively, and 93.8 percent and 94.8 percent, respectively, in a follow-up of up to 10 years (Table 3 and Table 4, page 316). We noted a higher percentage of failures in patient-related and implant-related analyses for the MkII implants when compared with the MkIII, MkIV and Nobelspeedy implants (Table 5, page 316). The survival rate of the prostheses was 99.2 percent.

#### Description of the failures and remedies.

In nine patients who each lost one implant, along with the two patients who each lost two implants, the prosthesis remained in function

during a healing period of four to six months, until new implants were inserted and loaded immediately without further complications. Two patients lost all four implants: one patient after 22 months of follow-up and another patient after 71 months (two implants) and 89 months (two implants) of follow-up. For both of these patients, we removed the implants and, after a healing period of about four months, repeated the procedure. Both treatments remained stable at the end of the follow-up of this study, with 12 months and 16 months of follow-up for the respective patients. We did not account for the reinserted implants in the success analysis of this study. Table 6 (page 317) illustrates the distribution of implant losses.

There were differences in medical status between those who lost implants and the rest of the study population, with osteoporosis affecting 7.7 percent and 1.3 percent, respectively; cardiovascular diseases affecting 7.7 percent and 2.2 percent, respectively; autoimmune diseases affecting 7.7 percent and 2.2 percent, respectively; comorbidities affecting 15.4 percent and 1.3 percent, respectively; diabetes affecting 7.7 percent and 1.8 percent, respectively; and smoking habits being observed in 38.5 percent and 21.6 percent, respectively. The majority of implant failures occurred in patients who had either a medical condition or a smoking habit (84.7 percent), while only 30.4 percent of the rest of the study population had these conditions.

Implant losses occurred in one of four patients who had osteoporosis and was receiving bisphosphonate therapy; in one of four patients who had diabetes; in one of six patients who had cardiovascular diseases; in one of six patients who had autoimmune diseases; in two of five patients who had comorbidities; in three of 49 patients who were smokers; and in four of 158 healthy patients. In the survival analysis computed by means of the Cox proportional hazards regression model, the variable "systemic condition" (namely, the presence of diabetes) emerged as a risk factor for implant loss with an OR of 21.14 (95 percent CI, 1.96-228.47;  $P = .012$ ) after we adjusted for the other variables of interest.

#### Biological complications and remedies.

In one patient, we observed at the first follow-up that the bone around the four immediately loaded implants was showing signs of breakdown: implant mobility and radiolucent areas present apically to the implant that were visible on the radiograph. We used a rigorous maintenance protocol with monthly controls. The clinician removed the prosthesis temporarily, disin-

fected the area, and applied chlorhexidine and hyaluronic acid gels around the implants. Then the clinician reattached the bridge and controlled the occlusion. The patient received instruction in special care measures, including consumption of a soft diet, use of antibiotics and use of anti-inflammatory drugs. At the control appointment three months later, the implants exhibited good bone apposition on radiographs. The implants since have passed the eight-year follow-up without any problem and are classified as survivors.

At the four-year follow-up in four patients and five implants, we observed incident cases of peri-implant pathology with peri-implant pockets of 6 mm. We resolved the situations for two patients and two implants through nonsurgical treatment (removal of debris and irrigation with chlorhexidine). In a third patient, persistent biological complications around the implants led to the failure of one implant (position no. 23) after 33 months. The patient had diabetes and cardiovascular problems with previous episodes of stroke. After nonsurgical and surgical interventions, the biological complications resolved, and the patient's condition has remained stable for the last 34 months. In a fourth patient, peri-implant pathology led to the loss of one implant (position no. 20) and the need for treatment of another implant (position no. 29) with surgical intervention after nonsurgical treatment failed.

#### Mechanical complications and remedies.

Prosthetic screw loosening in the provisional prosthesis occurred in 12 patients. These situations were resolved by means of retightening the screws, controlling the occlusion and advising the patients not to overload the prosthesis (not to ingest food that could require a significant masticatory effort). In the definitive prosthesis, we diagnosed abutment loosening in two patients and excessive wear marks in the prosthesis of another patient, all caused by parafunctional habits. These situations were resolved by retightening the abutments and manufacturing a nightguard. No further mechanical complications were observed.

TABLE 3

### Patient-related cumulative success rate for the All-on-4\* mandibular treatment.

DURATION OF TREATMENT	TOTAL	FAILED	WITHDRAWN	NOT YET COMPLETED FOLLOW-UP	CSR†%
Placement to Six Months	245	6	4	0	97.6
Six Months to One Year	235	0	7	0	97.6
One to Two Years	228	2	9	0	96.7
Two to Three Years	217	1	5	0	96.2
Three to Four Years	211	1	6	1	95.8
Four to Five Years	203	1	0	28	95.3
Five to Six Years	174	1	1	79	94.8
Six to Seven Years	93	1	0	67	93.8
Seven to Eight Years	25	0	0	11	93.8
Eight to Nine Years	14	0	0	10	93.8
Nine to 10 Years	4	0	0	2	93.8
10 to 11 Years	2	0	0	2	93.8

\* The All-on-4 concept is manufactured by Nobel Biocare, Göteborg, Sweden.  
† CSR: Cumulative success rate.

## DISCUSSION

**Treatment protocols.** The 94.8 percent (patient-related) and 98.1 percent (implant-related) cumulative success rates at five years and the 93.8 percent (patient-related) and 94.8 percent (implant-related) cumulative success rates at up to 10 years for the immediate loading protocol are comparable with results for two-stage protocols<sup>15-17</sup> and delayed loading protocols.<sup>5,18-21</sup>

Regarding the two-stage technique, Adell and colleagues (1990)<sup>15</sup> reported results between 81 and 99 percent at five years, between 89 and 98 percent at 10 years and about 86 percent after 15 years of follow-up. Ekelund and colleagues<sup>16</sup> reported implant survival rates of 98.9 percent after 20 years of follow-up. Astrand and colleagues<sup>17</sup> reported a result of 99.2 percent for the rehabilitation of both arches (maxilla and mandible) after 20 years of follow-up.

For delayed loading, several studies involving long-term follow-ups have been published. Cehreli and colleagues,<sup>18</sup> in a clinical trial in which they compared implants used as support

TABLE 4

### Implant-related cumulative success rates for the All-on-4\* mandibular implants.

DURATION OF TREATMENT	TOTAL	FAILED	WITHDRAWN	NOT YET COMPLETED FOLLOW-UP	CSR†%
Placement to Six Months	980	7	16	0	99.3
Six Months to One Year	957	0	28	0	99.3
One to Two Years	929	5	36	0	98.8
Two to Three Years	888	1	20	0	98.6
Three to Four Years	867	1	27	4	98.5
Four to Five Years	835	1	0	114	98.4
Five to Six Years	720	2	4	319	98.1
Six to Seven Years	395	1	0	274	97.9
Seven to Eight Years	120	2	0	50	96.3
Eight to Nine Years	68	1	0	46	94.8
Nine to 10 Years	21	0	0	13	94.8
10 to 11 Years	8	0	0	8	94.8

\* The All-on-4 concept is manufactured by Nobel Biocare, Göteborg, Sweden.  
 † CSR: Cumulative success rate.

TABLE 5

### Patient-related and implant-related survival analysis according to type of implant.

TYPE OF IMPLANT*	NO. OF IMPLANTS FAILED/ TOTAL NO. OF IMPLANTS	% SURVIVAL (PERCENTAGE)
<b>Patient-Related Analysis</b>		
MkII	4/13	69.2
MkIII	6/169	96.5
MkIV	2/123	98.4
Nobelspeedy	1/20	95.0
<b>Implant-Related Analysis</b>		
MkII	5/42	88.1
MkIII	9/530	98.3
MkIV	3/358	99.2
Nobelspeedy	4/50	92.0

\* All implant products were manufactured by Nobel Biocare, Göteborg, Sweden.

for removable dentures that were placed using either immediate-function or two-stage surgical protocols, reported a result of 100 percent. Eric-

sson and colleagues<sup>5</sup> reported a result of 100 percent after five years of follow-up for a total of 88 implants placed with a delayed-loading approach and for 30 implants placed using a two-stage surgical approach in the intermentonian area. Engstrand and colleagues,<sup>19</sup> in a follow-up study of the Brånemark Novum system (Nobel Biocare) for the treatment of patients with completely edentulous mandibles, reported an estimated implant survival rate of 93.3 percent in 285 implants at five years of follow-up, on the basis of the Kaplan-Meier survival estimate. Finally, Wolfinger and colleagues<sup>20</sup> reported an implant survival rate of 91 percent in 130 implants, attributing these results to “generous” inclusion criteria and a learning curve.

The differences in survival rates were more marked in the MkII implants than in the other three implant types (Figure 5). However, the differences were not statistically significant when tested. In a study involving 3.3-mm implants in posterior

regions,<sup>22</sup> the MkIII and Nobelspeedy implants emerged as strong protective factors against implant loss in comparison with the MkII implants (OR = 0.14), a fact that we could not confirm statistically in our study.

**Complications.** The number of complications was low, and the complications themselves did not differ from those normally encountered in oral rehabilitation in which implants are used as support for a fixed prosthesis. The clinicians who carried out the procedures in our study (P.M. and A.L.) later addressed the two major complications (two patients who lost all four implants and, consequently, prosthetic function) by means of the same procedure and their condition remained stable up to the completion of the follow-up period described in this study. In the situations in which the participants lost one or two implants, all prostheses survived on the remaining implants until further implants were loaded. The use of four loaded implants seems to be a good strategy with the protocol we describe here, as it allows for the failure of one or two implants without necessarily meaning failure of the prosthesis. The use of tilted implants did not compromise

the outcome in the long-term follow-up period. Actually, the tilted implants demonstrated fewer failures ( $n = 9$ ) than did the axial implants ( $n = 12$ ).

#### Medical conditions and habits.

We observed a higher percentage of medical conditions and smoking habits in the patients who lost implants compared with the rest of the study population, with implant failures occurring in only 15.3 percent of the healthy patients. Moreover, the presence of diabetes emerged as a risk factor for implant loss (OR = 21.14; 95 percent CI, 1.96-228.47;  $P = .012$ ) (Cox proportional hazards regression model). This result suggests that people with medical conditions or smoking habits are at increased risk of implant failure in the short and long term.

#### Diabetes.

Regarding diabetes, several investigators have observed the negative impact that this condition may have on dental implant treatment, such as lower success rates or a higher risk of peri-implant pathology. Salvi and colleagues,<sup>23</sup> on the basis of a meta-analysis, concluded that poorly controlled diabetes could have a negative effect on a

TABLE 6

### Loss of All-on-4\* mandibular implants.

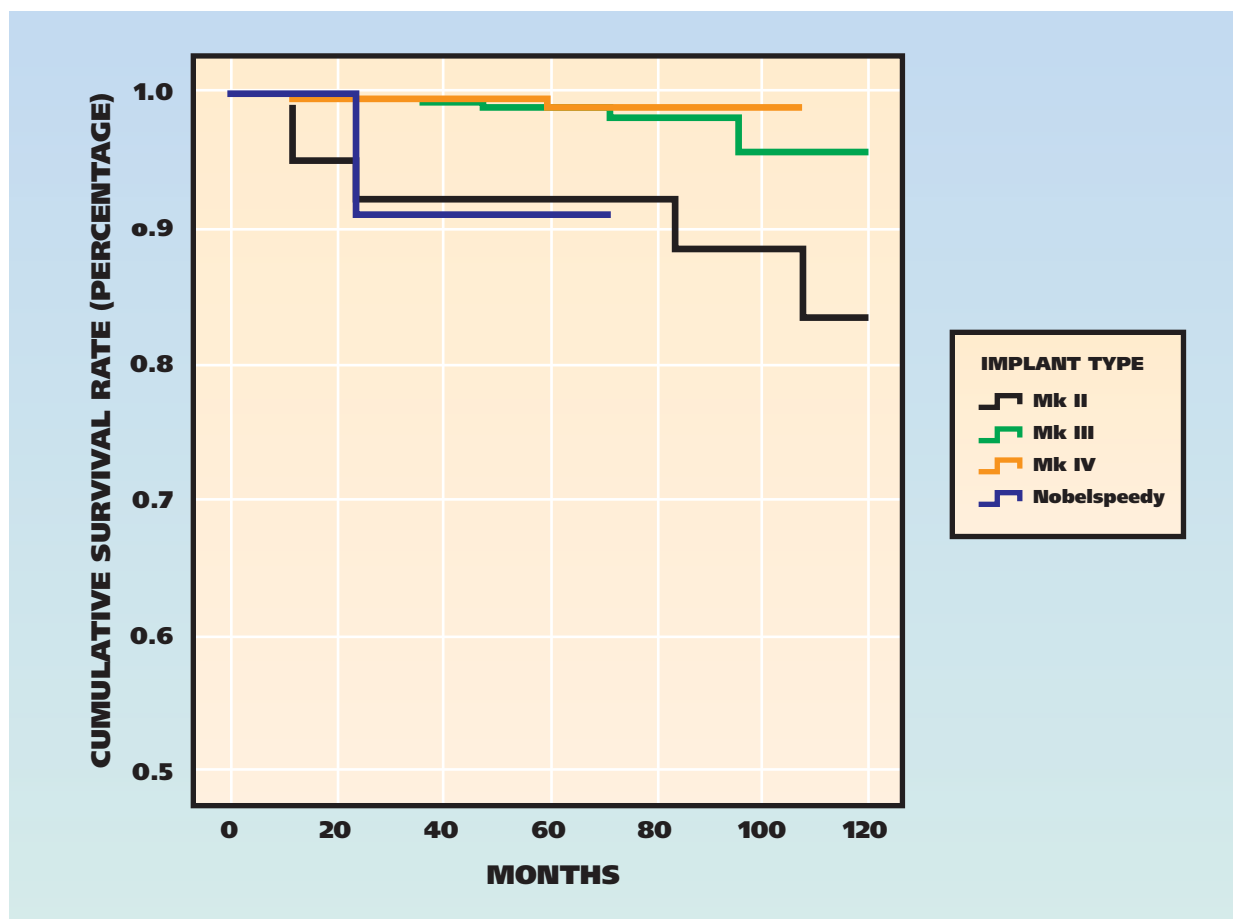
PATIENT	SEX	AGE (YEARS)	TYPE OF IMPLANT,† DIAMETER LENGTH (mm‡), SURFACE	IMPLANT POSITION AND ANGLE§	TIME OF LOSS (MONTHS AFTER PLACEMENT)	OBSERVATIONS
1	Female	61	MKII 3.75 ×	25, A	1	None
2	Female	77	MKII 3.75 ×	25, A	99	Bisphosphonate medication
2	Female	77	MKII 3.75 ×	20, T	81	Bisphosphonate medication
3	Female	71	MKII 3.75 ×	21, T	22	None
4	Male	70	MKIII 4 × 15	20, T	1	Smoker, hypothyroidism
5	Female	73	MKIII 3.75 ×	26, A	3	Arrhythmia
6	Female	55	MKIII 4 × 13	26, A	89	Type 2 diabetes
6	Female	55	MKIII 4 × 15	28, T	89	Type 2 diabetes
6	Female	55	MKIII 4 × 13	23, A	71	Type 2 diabetes
6	Female	55	MKIII 4 × 15	21, T	71	Type 2 diabetes
7	Female	53	MKIII 4 × 15	28, T	6	Smoker
8	Male	47	MKIV 4 × 15	20, T	53	Smoker
9	Male	52	MKIII 3.75 × 15 Tiunite	23, A	33	Smoker, Type 2 diabetes, history of stroke
10	Female	52	MKIII 4 × 15	26, A	43	None
11	Female	59	MKIV 4 × 15	26, A	2	None
11	Female	59	MKIV 4 × 15	23, A	2	None
12	Female	37	MKII 4 × 15	23, A	3	Smoker
13	Female	64	Nobel speedy 4 × 15 Tiunite	25, A	22	Bisphosphonate therapy, hypertension
13	Female	64	Nobel speedy 4 × 15 Tiunite	29, T	22	Bisphosphonate therapy, hypertension
13	Female	64	Nobel speedy 4 × 15 Tiunite	24, A	22	Bisphosphonate therapy, hypertension
13	Female	64	Nobel speedy 4 × 15 Tiunite	20, T	22	Bisphosphonate therapy, hypertension

\* The All-on-4 implant concept is manufactured by Nobel Biocare, Göteborg, Sweden.

† All implant products were manufactured by Nobel Biocare.

‡ mm: Millimeters.

§ T: Tilted implant. A: Axial implant.



**Figure 5.** Survival curves for the different types of implants placed in patients receiving the All-on-4 mandibular concept (Nobel Biocare, Göteborg, Sweden). All implant types are manufactured by Nobel Biocare.

patient's periodontal and peri-implant conditions. Klokkevold and Han<sup>24</sup> concluded that type 2 diabetes may have an adverse effect on implant survival and success. Also, the risk of peri-implant pathology increases with the presence of diabetes, compromising the implant's success in the long term.<sup>25,26</sup> Our observations are in agreement with the findings in these reports as well as with those of earlier reports regarding medically compromised patients<sup>27,28</sup>; thus, the clinician should take into consideration the patient's systemic condition before beginning treatment with dental implants, informing the patient of the higher risk of experiencing implant failure.

**Bisphosphonate therapy.** Treatment with bisphosphonates has been considered to be a risk factor for osteonecrosis in several reports in the literature, including reviews,<sup>29-31</sup> retrospective studies<sup>32,33</sup> and a case report.<sup>34</sup> Despite this line of evidence, there also are reports—including one case report,<sup>35</sup> one retrospective study<sup>36</sup> and one systematic review<sup>37</sup>—in which

investigators did not observe any particular effect of bisphosphonates on the outcome of implant success. Lazarovici and colleagues<sup>38</sup> suggested that a prolonged follow-up period is needed to detect any development of bisphosphonate-related osteonecrosis of the jaw that is associated with dental implants, and it is possible that this could explain the result of the systematic review<sup>37</sup> whose authors found no difference in the short-term implant survival rates between patients who had received bisphosphonate therapy for less than five years and patients who had not received the medication. The results from our study, with six implant failures in two patients (in a total of four patients who had 20 implants and were receiving bisphosphonate therapy) add to the knowledge from previously published reports. This is another situation that the practitioner and the patient should consider before beginning implant therapy, as it may constitute a possible risk factor for an unsuccessful treatment outcome.

**Smoking.** Smoking usually is linked to higher incidences of implant failures, biological complications or both, with a relatively high consensus in the literature on the adverse effect on implant rehabilitations. The results from two meta-analyses<sup>39,40</sup> revealed a significant enhanced risk of implant failure among smokers compared with nonsmokers (OR = 2.64 and 2.25 for patient-related failures and implant-related failures, respectively).<sup>39</sup> Another meta-analysis revealed a significant relationship between smoking and the risk of implant failure, more particularly for the implants located in the maxillary arch (OR = 2.06).<sup>40</sup> The results from our study also are in agreement with those of these previous reports, with five of the 61 patients who were smokers experiencing implant failure as opposed to four of the 184 patients who did not smoke. For these reasons, we suggest that practitioners should inform patients who smoke of the risk of implant failure associated with smoking and should prescribe a more strict maintenance protocol, together with smoking-cessation interventions if possible.

**Summary and further research.** These results support the hypothesis that the prosthetic rehabilitation of the edentulous mandible through the All-on-4 concept is possible, with an implant survival distribution similar to those of other treatment protocols. The dropout rate for our study was small (32 patients, or 13 percent of the sample size) and accounts for a lack of follow-up bias. A follow-up program is considered of great importance, as it is impossible for an implant to survive without maintenance.<sup>41,42</sup> The implants of one patient exhibited signs of breakdown at the first follow-up visit, and salvaging those implants required extraordinary measures. Future research should focus on the documentation of this protocol with a larger sample size of patients with implants who are followed for 10 years.

## CONCLUSIONS

The high success rates of All-on-4 implants (98.1 percent at 5 years and 94.8 percent up to 10 years) and the low rate of marginal bone resorption demonstrate the long-term viability of the concept of fixed mandibular full-arch prostheses supported by four immediately loaded implants. The tilting of the posterior implants allows the final prostheses to hold as many as 12 teeth with only a short cantilever (one molar) and a favorable interimplant distance without compromising the long-term successful outcome. ■

**Disclosure.** None of the authors reported any disclosures.

The authors would like to acknowledge Mr. Sandro Catarino for his help in data management and the outstanding team at Malo Clinic Lisbon, Portugal.

- Esposito M, Grusovin MG, Achille H, Coulthard P, Worthington HV. Interventions for replacing missing teeth: different times for loading dental implants. *Cochrane Database Syst Rev* 2009;(1): CD003878.
- Schnitman PA, Wöhrle PS, Rubenstein JE, DaSilva JD, Wang NH. Ten-year results for Brånemark implants immediately loaded with fixed prostheses at implant placement. *Int J Oral Maxillofac Implants* 1997;12(4):495-503.
- Balshi TJ, Wolfinger GJ. Immediate loading of Brånemark implants in edentulous mandibles: a preliminary report. *Implant Dent* 1997;6(2):83-88.
- Randow K, Ericsson I, Nilner K, Petersson A, Glantz PO. Immediate functional loading of Brånemark dental implants: an 18-month clinical follow-up study. *Clin Oral Implants Res* 1999;10(1):8-15.
- Ericsson I, Randow K, Nilner K, Peterson A. Early functional loading of Brånemark dental implants: 5-year clinical follow-up study. *Clin Implant Dent Relat Res* 2000;2(2):70-77.
- Chiapasco M, Gatti C. Implant-retained mandibular overdentures with immediate loading: a 3- to 8-year prospective study on 328 implants. *Clin Implant Dent Relat Res* 2003;5(1):29-38.
- Degidi M, Piattelli A. 7-year follow-up of 93 immediately loaded titanium dental implants. *J Oral Implantol* 2005;31(1):25-31.
- Balshi SF, Wolfinger GJ, Balshi TJ. A prospective study of immediate functional loading, following the Teeth in a Day protocol: a case series of 55 consecutive edentulous maxillas. *Clin Implant Dent Relat Res* 2005;7(1):24-31.
- Malo P, Rangert B, Nobre M. "All-on-Four" immediate-function concept with Branemark system implants for completely edentulous mandibles: a retrospective clinical study. *Clin Implant Dent Relat Res* 2003;5(suppl 1):2-9.
- Fortin Y, Sullivan RM, Rangert B. The Marius implant bridge: surgical and prosthetic rehabilitation for the completely edentulous upper jaw with moderate to severe resorption: a 5-year retrospective clinical study. *Clin Implant Dent Relat Res* 2002;4(2):69-77.
- Malo P, Rangert B, Nobre M. All-on-4 immediate-function concept with Brånemark System implants for completely edentulous maxillae: a 1-year retrospective clinical study. *Clin Implant Dent Relat Res* 2005;7(suppl 1):S88-S94.
- Zampelis A, Rangert B, Heijl L. Tilting of splinted implants for improved prosthodontic support: a two-dimensional finite element analysis (published correction appears in *J Prosthet Dent* 2008;99[3]:167). *J Prosthet Dent* 2007;97(suppl 6):S35-S43.
- STROBE Statement: Strengthening the Reporting of Observational Studies in Epidemiology. "www.strobe-statement.org". Accessed Jan. 14, 2011.
- Malo P, de Araújo Nobre M. Flap vs. flapless surgical techniques at immediate implant function in predominantly soft bone for rehabilitation of partial edentulism: a prospective cohort study with a follow-up of 1 year. *Eur J Oral Implantol* 2008;1(4):293-304.
- Adell R, Eriksson B, Lekholm U, Brånemark PI, Jemt T. Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. *Int J Oral Maxillofac Implants* 1990;5(4):347-359.
- Ekelund JA, Lindquist LW, Carlsson GE, Jemt T. Implant treatment in the edentulous mandible: a prospective study on Brånemark system implants over more than 20 years. *Int J Prosthodont* 2003;16(6):602-608.
- Astrand P, Ahlqvist J, Gunne J, Nilson H. Implant treatment of patients with edentulous jaws: a 20-year follow-up. *Clin Implant Dent Relat Res* 2008;10(4):207-217.
- Cehreli MC, Uysal S, Akca K. Marginal bone level changes and prosthetic maintenance of mandibular overdentures supported by 2 implants: a 5-year randomized clinical trial. *Clin Implant Dent Relat Res* 2010;12(2):114-121.
- Engstrand P, Gröndahl K, Ohnneil LO, et al. Prospective follow-up study of 95 patients with edentulous mandibles treated according to the Brånemark Novum concept. *Clin Implant Dent Relat Res* 2003;5(1):3-10.
- 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(2):250-257.

21. Malo P, Rangert B, Dvårsäter L. Immediate function of Bråne-mark implants in the esthetic zone: a retrospective clinical study with 6 months to 4 years of follow-up. *Clin Implant Dent Relat Res* 2000;2(3):138-146.
22. Malo P, de Araújo Nobre M. Implants (3.3 mm diameter) for the rehabilitation of edentulous posterior regions: a retrospective clinical study with up to 11 years of follow-up (published online ahead of print Aug. 3, 2009). *Clin Implant Dent Relat Res*.
23. Salvi GE, Carollo-Bittel B, Lang NP. Effects of diabetes mellitus on periodontal and peri-implant conditions: update on associations and risks. *J Clin Periodontol* 2008;35(8 suppl):398-409.
24. Klokkevoeld PR, Han TJ. How do smoking, diabetes, and periodontitis affect outcomes of implant treatment? (published correction appears in *Int J Oral Maxillofac Implants* 2008;23[1]:56). *Int J Oral Maxillofac Implants* 2007;22(suppl):173-202.
25. Lindhe J, Meyle J; Group D of European Workshop on Periodontology. Peri-implant diseases: Consensus Report of the Sixth European Workshop on Periodontology. *J Clin Periodontol* 2008;35(8 suppl):282-285.
26. Heitz-Mayfield LJ. Peri-implant diseases: diagnosis and risk indicators. *J Clin Periodontol* 2008;35(8 suppl):292-304.
27. Esposito M, Hirsch JM, Lekholm U, Thomsen P. Biological factors contributing to failures of osseointegrated oral implants, II: etiopathogenesis. *Eur J Oral Sci* 1998;106(3):721-764.
28. Weyant RJ. Characteristics associated with the loss and peri-implant tissue health of endosseous dental implants. *Int J Oral Maxillofac Implants* 1994;9(1):95-102.
29. Flichy-Fernández AJ, Balaguer-Martínez J, Peñarocha-Diogo M, Bagán JV. Bisphosphonates and dental implants: current problems. *Med Oral Patol Oral Cir Bucal* 2009;14(7):E355-E360.
30. Serra MP, Llorca CS, Donat FJ. Oral implants in patients receiving bisphosphonates: a review and update. *Med Oral Patol Oral Cir Bucal* 2008;13(12):E755-E760.
31. Scully C, Madrid C, Bagan J. Dental endosseous implants in patients on bisphosphonate therapy. *Implant Dent* 2006;15(3):212-218.
32. Kasai T, Pogrel MA, Hossaini M. The prognosis for dental implants placed in patients taking oral bisphosphonates. *J Calif Dent Assoc* 2009;37(1):39-42.
33. Grant BT, Amenedo C, Freeman K, Kraut RA. Outcomes of placing dental implants in patients taking oral bisphosphonates: a review of 115 cases. *J Oral Maxillofac Surg* 2008;66(2):223-230.
34. Wang HL, Weber D, McCauley LK. Effect of long-term oral bisphosphonates on implant wound healing: literature review and a case report. *J Periodontol* 2007;78(3):584-594.
35. Torres J, Tamimi F, Garcia I, et al. Dental implants in a patient with Paget disease under bisphosphonate treatment: a case report. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009;107(3):387-392.
36. Bell BM, Bell RE. Oral bisphosphonates and dental implants: a retrospective study. *J Oral Maxillofac Surg* 2008;66(5):1022-1024.
37. Madrid C, Sanz M. What impact do systemically administered bisphosphonates have on oral implant therapy? A systematic review. *Clin Oral Implants Res* 2009;20(suppl 4):87-95.
38. Lazarovici TS, Yahalom R, Taicher S, Schwartz-Arad D, Peleg O, Yarom N. Bisphosphonate-related osteonecrosis of the jaw associated with dental implants. *J Oral Maxillofac Surg* 2010;68(4):790-796.
39. Strietzel FP, Reichart PA, Kale A, Kulkarni M, Wegner B, Kuchler I. Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis. *J Clin Periodontol* 2007;34(6):523-544.
40. Hinode D, Tanabe S, Yokoyama M, Fujisawa K, Yamauchi E, Miyamoto Y. Influence of smoking on osseointegrated implant failure: a meta-analysis. *Clin Oral Implants Res* 2006;17(4):473-478.
41. Bauman GR, Mills M, Rapley JW, et al. Implant maintenance: debridement and peri-implant home care. *Compendium* 1991;12(9):644, 646, 648.
42. de Araújo Nobre M, Cintra N, Malo P. Peri-implant maintenance of immediate function implants: a pilot study comparing hyaluronic acid and chlorhexidine. *Int J Dent Hygiene* 2007;5(2):87-94.