The All-on-Four Immediate Function Treatment Concept With NobelActive Implants: A Retrospective Study

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The All-on-Four treatment concept provides patients with an immediately loaded fixed prosthesis supported by 4 implants. This single-center retrospective study evaluated the concept while using the NobelActive implant (Nobel Biocare, Gothenburg, Sweden). Seven hundred eight implants placed in 165 subjects demonstrated a cumulative survival rate of 99.6% (99.3% in maxilla and 100% in the mandible) for up to 29 months of loading. The definitive prosthesis survival rate was 100%.

Key Words: All-on-Four, NobelActive implants

INTRODUCTION

A common condition in elderly patients is the occurrence of edentulism, which can be the result of many factors such as poor oral hygiene, dental caries, and periodontal disease. There are also those patients who face edentulism due to a terminal nonrestorable dentition. The edentulous condition has been shown to have a negative impact on oral health–related quality of life. Clinicians are faced with the growing need to offer solutions to this population due to an increase in their life expectancy and to fabricate prostheses that provide a replacement for the loss of natural teeth, allowing optimum satisfaction and improved quality of life.

The routine treatment for edentulism has been conventional dentures. National epidemiological survey data in the United States suggested that the adult population in need of 1 or 2 dentures would increase from 35.4 million adults in 2000 to 37.0 million adults in 2020. Clinical studies have reported that patients with dentures have shown only a marginal improvement in the quality of life when compared with implant therapy. The common reasons for dissatisfaction in patients using dentures are pain, areas of discomfort, poor denture stability, and difficulties in eating as well as lack of or compromised retention capability. Many patients wearing complete dentures complain about poor masticatory performance, loss of function, decreased motor control of the tongue, reduced bite force, and diminished oral sensory function. A review of the literature noted that prostheses supported by osseointegrated dental implants significantly improved the quality of life for
edentulous patients when compared with conventional dentures.\textsuperscript{11–15} Immediate loading of implant-supported, full-arch prostheses for these patients in the mandible or maxilla has been documented as a predictable procedure.\textsuperscript{16–20} Excellent success rates for immediately loaded, fixed prosthetic reconstructions\textsuperscript{19–26} and long-term follow-up results have been reported in the literature.\textsuperscript{27–29} Immediate loading of implant-supported fixed full-arch prostheses for these cases in the edentulous maxilla and mandible has been associated with a high level of satisfaction for patients in terms of esthetics, phonetics, and functionality.\textsuperscript{17–20,30–34} Dental implants are traditionally placed in the vertical position. However, in the completely edentulous jaw as well as in the postextraction patient, problems such as minimum bone volume, poor bone quality, and the need for bone-grafting procedures prior to implant placement create some challenging conditions. For these situations, it has been demonstrated that distal tilting of implants may be advantageous. Tilting preserves relevant anatomical structures and allows for placement of longer implants with good cortical anchorage in optimal positions for prosthetic support.\textsuperscript{35,36} Strain gauge measurements performed by Krekmanov reported no significant difference between tilted and nontilted implants, and theoretical models showed an increased prosthetic base due to the inclination of implants, which in turn can reduce the force acting over the implants.\textsuperscript{36} Tilting also increases the inter-implant space, reduces cantilever length in jaws,\textsuperscript{21,31,36,37} and reduces the need for bone augmentation. Good clinical outcomes have been reported in various studies using tilted implants.\textsuperscript{31,32,35,38–40}

The All-on-Four treatment concept provides edentulous arches and immediate/postextraction subjects with an immediately loaded, fixed prosthesis using 4 implants: 2 axially oriented implants in the anterior region and 2 tilted posterior implants.\textsuperscript{31,32,37} The principle involves the use of 4 implants restored with straight and angled multiunit abutments, which support a provisional, fixed, immediately loaded, full-arch prosthesis placed on the same day of surgery. The All-on-Four treatment has been developed to maximize the use of available bone and allows immediate function. Overall, published data on the All-on-Four concept reported cumulative survival rates between 92.2\% and 100\%.\textsuperscript{31–34,37,40–42}

The All-on-Four concept has been reported predominantly in the literature with the NobelSpeedy or the Branemark System dental implants. The purpose of this study was to evaluate the All-on-Four concept using an implant (NobelActive) with a tapered body and a variable thread design for up to 29 months of loading.

\textbf{Materials and Methods}

This is a retrospective single-center study. Subjects with totally edentulous arches and/or in need of extraction of the remaining compromised teeth were rehabilitated with the NobelActive implants. The first implant in the study was placed on February 21, 2008, and the last implant was placed on September 12, 2009. Each subject received an immediately loaded, fixed, complete-arch provisional prosthesis on the day of implant placement according to the All-on-Four technique. The definitive prostheses were delivered within 6 to 8 months after implant insertion. An actuarial life table method was used to determine implant cumulative survival rate.

Patients treated with the technique and therefore included in the retrospective analysis met the following criteria:

- jaw bone profile for the placement of at least 4 implants of at least 10 mm in length in either healed or immediate extraction sites
• good general health with acceptable oral hygiene
• implants achieved stability at insertion

Patients could not be treated according to the technique if they had insufficient bone quality and quantity for placement of endosseous implants, exhibited severe parafunctional habits, or had a compromised medical history that would affect implant placement (eg, bisphophonates, chemotherapy).

Surgical protocol
A cone-beam computerized tomographic scan (CBCT; I-CAT cone beam CT scan, Imaging Science Corp, Hatfield, Penn) was taken prior to surgery, and the bone profile, which included the bone quality and bone volume, was assessed by 2 experienced clinicians (C.A.B. and G.T.K.). In the vast majority of cases, the patient was administered intravenous (conscious) sedation using fentanyl citrate 0.5 mg/mL (fentanyl; Hospira, Lake Forest, Ill), diazepam 5 mg/mL injection (Valium; Hospira), as well as nitrous oxide oxygen inhalation. This was in addition to articaine hydrochloride 4% and epinephrine bitartrate 1:100 000 (Septodont, Paris, France), local anesthesia that was administered in both block and infiltration technique. A few of the patients were administered general anesthesia based on their preexisting medical profile.

Patients were started on a course of antibiotic (penicillin VK 250 mg, Dispensing Solutions, Santa Ana, Calif), 4 times a day, 2 days prior to the surgical procedure in cases in which teeth had to be extracted. Postoperatively, all patients were given the same antibiotic 4 times per day over a period of 10 days. If patients were allergic to penicillin, clindamycin tablets (clindamycin HCL 150 mg, Dispensing Solutions) were given using a similar dosage regimen. In addition, hydrocodone bitartrate and acetaminophen 7.5 mg/750 mg (Vicodin, Dispensing Solutions) were also used as an analgesic along with anti-inflammatory medication, methylprednisolone, 4-mg dose pack (Medrol, Dispensing Solutions). At the end of the procedure, bupivacaine 0.5% with 1:200 000 epinephrine (bupivacaine, Cook-Waite, Greensboro, NC) was also administered for its analgesic-sparing effect.

Implant placement
NobelActive implants were inserted by (C.A.B.) according to the manufacturer’s guidelines (manual No. 21279-GB085, Nobel Biocare Services 2008). Each subject received 2 distally tilted implants in the posterior region followed by 2 anterior implants in either the maxilla or the mandible. In the maxilla, the tilted implants were positioned just anterior to the maxillary sinus and in the mandible; the tilted implants were positioned anterior to the mental foramen.

Implant placement was assisted by the All-on-Four surgical guide (Nobel Biocare; Figure 4). The guide was placed into a 2-mm osteotomy made at the midline of the mandible and/or maxilla, and the titanium band was contoured so that the occlusal centerline of the opposing jaw was followed. The guide allowed for optimal positioning, alignment, parallelism, and inclination of the implants for subsequent anchorage and prosthetic support. The drill protocol followed the manufacturer’s guidelines (All-on-Four procedures and products, manual No. 16896 Lot GB 0603, Nobel Biocare Services, 2006). The implant sites were usually underprepared avoiding countersinking to engage as maximum cortical support bone as possible. The recommended drill sequences for soft bone type IV, medium type II and type III, and dense type I bone were followed. A manual surgical torque wrench (Nobel Biocare) was used to check the final torque of the implant, which was carefully documented (Table 1). In cases of immediate implant placement, the soft
tissues were readapted to obtain a primary closure around the abutments and fresh extraction sites and then sutured back into position with interrupted resorbable 4.0 chromic sutures (Salvin Dental Specialties, Charlotte, NC). Local bone grafting to cover exposed threads and/or other osseous defects associated with extraction sockets was performed at 64% of implant sites with demineralized bone matrix gel (Dyna graft-D, Keystone Dental, Boston, Mass), and 1% of implant sites were grafted with autogenous bone from the local surgical area.

Straight, 17° multiunit abutment, internal (Nobel Biocare), and 30° angulated multiunit abutments, internal (Nobel Biocare), were used to achieve relative parallelism of the implants so that a rigid prosthesis would seat in a passive manner.

Open-tray multiunit impression copings (Nobel Biocare) were placed on the abutments, and an impression was made with a custom open tray using precision impression material (Flexitime, Heraeus Kulzer, Hanau, Germany). Patients were instructed to avoid brushing and to use warm water rinses for the first postoperative week. A cold or room-temperature soft diet for the first 24 hours following surgery was recommended, followed by a semisolid diet for the next 3 months. Patients were given antibiotics and analgesics as listed in the surgical protocol. A CBCT scan was taken immediately postoperatively to verify the implant positions and the prosthetic components.

**Prosthetic protocol**

A provisional denture was prefabricated with heat-cured acrylic resin (Ivocap high-impact acrylic, Ivoclar Vivadent, Schaan, Liechtenstein) prior to the surgical procedure. Immediately following surgery, the denture was modified to the master model in the laboratory. Fabrication was completed using cold-curing material (Probase, Ivoclar Vivadent). This provisional all-acrylic resin prosthesis was seated within 3 to 4 hours of completion of surgery on the same day. The patients were scheduled for routine follow-up visits after surgery at 1 week, 2 weeks, 4 weeks, and 3 months postoperative and on a yearly basis. At the 3-month appointment, fabrication of the definitive prosthesis was initiated.

Periapical digital radiographs using a parallel technique were obtained at the 3-month appointment and thereafter on a yearly basis from the date of the surgery (Figures 7, 13, 14, 20, and 29). Implants were checked by visual observation for plaque and bleeding on probing at the follow-up intervals. Periapical radiographs and plaque and bleeding indices at various follow-up intervals are part of routine care for patients at the clinic and not a part of the analysis in this study.

The definitive prostheses consisted of a milled titanium frame with a wrap-around heat-cured acrylic resin (Ivocap high-impact acrylic). All restorations were performed by 1 clinician (G.T.K.).

**Survival criteria**

The modified Albrektsson criteria used in this investigation are the following: an implant was regarded successful when there was (1) no radiolucency around the implant; (2) no signs of infection, pain, or ongoing pathological processes at the implant site; (3) the

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Torque values (implant insertion)</th>
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<tbody>
<tr>
<td>Ncm</td>
<td>n</td>
</tr>
<tr>
<td>&lt;35</td>
<td>14</td>
</tr>
<tr>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>36–45</td>
<td>53</td>
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<td>41</td>
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<tr>
<td>66–70</td>
<td>471</td>
</tr>
<tr>
<td>Not recorded*</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>708</td>
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*Implants achieved primary stability, although torque was not noted in numerical values.
implant was restored and functionally loaded; and (4) the prosthesis was stable for multiple implants supporting a complete arch prosthesis. An implant was classified surviving when it remained in the jaw and was functionally loaded even though all the individual success criteria were not fulfilled. A failed implant was an implant that had fractured beyond repair or could not be classified as a successful or surviving implant.44

Statistics

A single reviewer abstracted the relevant data from medical records of the patients who were treated consecutively with the All-on-Four technique and entered them into a spreadsheet (Excel 2007, Microsoft, Redmond, Wash). An actuarial life table45 was used to calculate the cumulative survival rate. Statistical analysis was done in SPSS 17.0 (SSPS, Chicago, Ill) using the Fisher exact test to determine the level of significance ($P < .05$) comparing the survival rates of the arches as well as the various implant sizes.

Results

One hundred sixty-five patients (72 men and 93 women) with a mean age of 59 (SD ± 11 years) have been included in the analysis. Seven hundred eight implants restoring both jaws (109 maxillae and 68 mandibles) have been placed. Four hundred thirty-six implants have been placed in the maxilla and 272 in the mandible. Twelve patients were treated in both jaws. Each prosthesis was supported by 4 implants. Most of the implants were seated with a minimum of 35-Ncm torque. Two percent (n = 14) of the implants were seated at a torque of <35 Ncm (Table 1). All implants achieved primary stability at placement. Four hundred twenty-four implants were placed in extraction sites immediately after tooth extraction, and 284 were placed in healed sites. Local bone grafting was performed at 65% of the implant sites; no bone grafting was reported in 35% of the sites. Implant distribution according to implant type and implant length is outlined in Tables 2 and 3, respectively. Implant follow-up occurred up to 29 months. Acrylic provisional restorations were placed within 3 to 4 hours of surgery, with occlusal contact limited to the anterior area only.

Two anterior implants failed in 2 different patients at the 1-month and 7-month time points due to mobility. In a third patient, 1 tilted implant failed at the 4-month time point due to mobility. All 3 implants failed during the provisional prosthesis phase. All of the 3 implants have been replaced, and no further complications have been noted in these patients. None of the implant failures compromised the prosthesis function, and no relation was found between implant failure and the opposing dentition.
Two patients aged 70 and 68 years were lost to follow-up at the 1-year and less than 3-month visit. These patients passed away due to natural causes. Two additional patients were lost to follow-up at the 3-month follow-up visit. Therefore, a total of 16 implants have been lost to follow-up. One hundred sixty-two patients in the study have completed the 6-month follow-up and have had their definitive prostheses (174) delivered. Three jaws were lost to follow-up prior to definitive prosthetic delivery, and 1 jaw was lost to follow-up after definitive prosthetic delivery. One hundred fifty-six patients have completed the 1-year follow-up.

The overall implant survival rate was 99.6% (1 year; Table 4) with no significant difference between the maxillae and mandibles (99.3% vs 100%, \( P = .06 \), Fisher exact test). The 4.3-mm-diameter implants were most frequently used, with a survival rate of 100% (99.2% for 3.5 mm and 99.2% for 5.0 mm; Figure 1). No total arch failures have occurred to date, providing a definitive prosthesis survival rate of 100%. The life table analysis demonstrating the cumulative survival rate is reported in Table 4.

Figures 2 through 8 demonstrate a case in postextraction sites of the mandible and maxilla with immediate implant placement, Figures 9 through 14 show a case in healed sites of a patient with a severely atrophic edentulous maxilla. The patient has been edentulous for 50 years. Figures 15 through

<table>
<thead>
<tr>
<th>TABLE 3</th>
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<tbody>
<tr>
<td>Implant size (NobelActive TiUnite)*</td>
</tr>
<tr>
<td>Implant Diameter</td>
</tr>
<tr>
<td>3.5</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>13</td>
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<td>15</td>
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<td>4.3</td>
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<td>5.0</td>
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<td>10</td>
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<td>15</td>
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<td>18</td>
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<td>436 (3)</td>
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</table>

*( ) indicates failed implants/replaced.

### Table 4

Cumulative survival analysis*

<table>
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<tr>
<th>Placed/Followed Implants</th>
<th>Failed Implants</th>
<th>Time Not Passed</th>
<th>Lost to Follow-up</th>
<th>CSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implant insertion »» 3 months</td>
<td>708</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>3 months »» 6 months</td>
<td>703</td>
<td>1</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>6 months »» 12 months</td>
<td>694</td>
<td>1</td>
<td>0</td>
<td>29</td>
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<tr>
<td>12 months »» 18 months</td>
<td>664</td>
<td>0</td>
<td>336</td>
<td>4</td>
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<tr>
<td>18 months »» 24 months</td>
<td>324</td>
<td>0</td>
<td>240</td>
<td>0</td>
</tr>
<tr>
<td>»» 24 months</td>
<td>84</td>
<td>0</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

*CSR indicates cumulative survival rate.
20 show a case displaying terminal nonrestorable dentition of the maxilla and mandible with extraction and immediate implant reconstruction, and Figures 21 through 29 show a case of a patient with an edentulous maxilla reconstructed with the All-on-Four technique.

No complications were reported during surgery or immediately after surgery.

**DISCUSSION**

The overall survival rate was 99.6% (1 year), with no significant difference between the maxillae and mandibles. Three implants failed over a period of 29 months of loading. The prosthesis survival rate was 100%. This is in accordance with studies on biomechanical measurements, which demonstrated that tilted implants, when part of a prosthetic support, do not have a negative effect on the load distribution. In addition, a biomechanical rationale in tilting distal implants allows a reduction in cantilever length due to the more posterior position of the tilted implants, resulting in a more favorable stress distribution.

The methodology of using tilted implants maximizing the use of the available bone without grafting has been reported, leading to successful clinical outcomes. This is in comparison to the traditional implant treatment in which insufficient bone in the posterior region requires bone-grafting procedures involving greater chair time for the patient as well as increased cost and increased number of procedures.

**FIGURE 1.** Cumulative survival rate in relation to implant diameter.

**FIGURE 2.** Case 1: maxillary and mandibular all-on-Four technique in extraction sites with immediate implant placement. Preoperative computerized tomography scan.
The results of this study are comparable with studies of other implant systems using the All-on-Four concept in the maxilla. Maló et al.\textsuperscript{32} reported a high survival rate of 97.6\% in a 1-year retrospective study in which 128 Bränemark implants (Nobel Biocare AB, Goteborg, Sweden) were immediately loaded in 32 patients. Each jaw received 2 axial and 2 distal implants (All-on-Four) supported by a fixed all-acrylic prosthesis in the completely edentu-
**FIGURE 9.** Case 2: 50-year history of a severely atrophic edentulous maxilla reconstructed with the All-on-Four technique. Preoperative computerized tomography scan.

**FIGURES 10–14.** Case 2: 50-year history of a severely atrophic edentulous maxilla reconstructed with the All-on-Four technique. **FIGURE 10.** Implants in final position. **FIGURE 11.** Fixed implant bridge removed to demonstrate soft-tissue health at 1 year. **FIGURE 12.** Clinical view at 1 year. **FIGURE 13.** Postoperative radiographs at 1 year demonstrating stable bone levels. **FIGURE 14.** Postoperative radiographs at 2 years demonstrating stable bone levels.
Testori et al.\(^2\) reported a 98.8% implant survival and a 100% prosthetic survival rate using a different type of implant system, angulation of the implant-abutment connection for the tilted implants, and a different type of technique for the fabrication of the final prosthesis. In this prospective, multicenter center study, 41 patients received an immediately placed full-arch fixed bridge supported each by 4 axial and 2 distally tilted Ossesotite NT implants (3i, Implant Innovations, Palm Beach, Fla) in the edentulous maxilla.\(^2\) Aparacio et al.\(^3\) reported a survival rate of 100% for tilted implants, 96.5% survival for axial implants, and a prosthetic survival rate of 100% after 5 years when 101 Branemark implants were placed in the severely resorbed maxilla of 25 patients (59 axially placed and 42 in a tilted direction). Each patient received 2 to 5 implants with at least 1 tilted implant.\(^3\) Calandriello et al.\(^3\) reported a survival rate of 96.7% in a 1-year prospective clinical study when 60 MKIV and Replace select implants (Nobel Biocare AB) were placed in the atrophic maxilla of 18 patients. In this study, 12 partial- and 7 full-arch, fixed prostheses were supported by a total of 33 axially placed and 27 tilted implants.\(^3\)

The results of this study are in accordance with other studies reporting good
survival rates in the mandible. In a 1-year retrospective clinical study, Maló et al.\textsuperscript{31} reported an implant survival of 96.7% and 98.2% (2 groups) and a prosthetic survival rate of 100% when 176 Branemark implants were placed in 44 patients. An immediately loaded complete-arch all-acrylic prosthesis was supported by 4 implants (All-on-Four) in each completely edentulous mandible.\textsuperscript{31}

Another study reported a 100% implant and prosthetic survival rate when 96 MKIV or the NobelSpeedy Groovy implants (Nobel Biocare AB) were placed in 24 edentulous patients treated in the mandible according to the All-on-Four concept.\textsuperscript{1} In addition, a 100% implant survival and prosthetic survival rate was reported in a prospective study when 80 Branemark implants were placed in 20 patients with a extremely atrophic mandible. Each patient received 2 axially placed and 2 tilted implants, supporting a fixed full-arch prosthesis (All-on-Four concept).\textsuperscript{40}

Previously published literature reporting survival rates using the All-on-Four concept in both the mandible and maxilla is similar to the results of this analysis. In a pilot study, a survival rate of 98.9% was reported in a case series when 189 NobelSpeedy implants were placed in 46 patients, supporting 53 full-arch, all-acrylic prostheses (44 maxillae, 9 mandibles) using the All-on-Four concept.\textsuperscript{33} Maló et al.\textsuperscript{34} reported a survival rate of 97.2% and 100% in the maxilla and mandible in a 1-year prospective study when 92 NobelSpeedy implants were placed in 23 consecutively treated patients. Each jaw was restored by a immediate fixed full-arch prosthesis according to the All-on-Four concept.\textsuperscript{34} Pomares\textsuperscript{41} reported a 96.9%
implant survival (96.7% in the maxilla and 97.2% in the mandible) and a 100% prosthetic survival rate in a prospective study when 127 MKIII Groovy implants were placed in 20 patients (restoring 19 maxillae and 9 mandibles) using the All-on-Four or All-on-Six concept. A survival rate of 98.4% and 99.7% (maxilla and mandible) at the end of 1 year was reported in another single-cohort study in which 173 edentulous patients received 2 distal and 2 anterior axial MKIV or NobelSpeedy Groovy implants. In this study, each patient received a full-arch fixed prosthesis supported by 2 distal and 2 axial implants (All-on-Four).49

Other long-term studies using the concept are comparable to the data in this analysis. Implant survival rates from the follow-up of results of the previously mentioned studies from Maló et al31,32 with a longer follow-up demonstrated a survival rate of 96.2% in the mandible up to 9 years and 97.7% in the maxilla up to 5 years of follow-up.37 Citing the published literature, it was

Figures 21–25. Case 4: edentulous maxilla reconstructed with the All-on-Four technique. Figure 21. Preoperative clinical photograph. Figure 22. Preoperative clinical photograph of the edentulous maxilla. Figure 23. Preoperative panoramic radiograph demonstrating the edentulous maxilla. Figure 24. The abutments and premounted abutment holders adjusting for relative parallelism. Figure 25. (a) The final position of the implants, abutments, and healing caps. (b) The mucoperiosteal flaps repositioned and sutured with 4-0 chromic interrupted sutures.
noted that the overall cumulative survival rate of 99.6% (1 year) in this study for the new implant system (NobelActive) while using the All-on-Four concept offers an attractive solution to clinicians treating edentulous and/or immediate extraction patients.

**Conclusion**

The overall survival rate using the All-on-Four immediate function treatment concept using an implant with a tapered body and a variable thread design can be considered a viable treatment concept for patients pre-

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**Figures 26–29.** Case 4: edentulous maxilla reconstructed with the All-on-Four technique. **Figure 26.** (a, b) The tissue and occlusal views of the all-acrylic fixed provisional implant bridge. **Figure 27.** Postoperative panoramic radiograph taken immediately after implant placement. **Figure 28.** Clinical photograph with the definitive prosthesis in place. **Figure 29.** Postoperative radiographs at 1 year with the definitive fixed implant prosthesis in place.
senting with edentulous arches and/or immediate placement.

**Note**

Dr Babbush has a consulting agreement with Nobel Biocare AB Sweden for ongoing clinical studies and continuing education courses.

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