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# The All-on-four concept for fixed full-arch rehabilitation of the edentulous maxilla and mandible: a longitudinal study in Japanese patients with 3–17-year follow-up and analysis of risk factors for survival rate

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## Abstract

**Purpose**  Implant-supported immediately loaded fixed full-arch rehabilitation via All-on-four treatment yields good long-term results for both the maxilla and the mandible. However, the risk factors affecting long-term implant survival are unknown, and the long-term prognosis of All-on-four concept procedures in Japanese individuals has not been elucidated. We aimed to determine the cumulative implant survival rate after 3–17-year follow-up and identify the associated risk factors.

**Methods**  We analysed 561 cases (307 maxillae, 254 mandibles) with 2364 implants (1324 maxillae, 1040 mandibles) that received All-on-four treatment. We investigated the cumulative implant- and patient-level survival rates and various risk factors for implant failure. Statistical analysis was performed using the log-rank test for differences in Kaplan–Meier curves, univariate analysis using the Chi-square test, and multivariate analysis for risk factors affecting the survival rate.

**Results**  The cumulative survival rate was 94.4% by patient level and 97.4% by implant level for the maxilla, and 96.7% by patient level and 98.9% by implant for the mandible, with up to 17 years of follow-up. The maxillary survival rate at the implant level was significantly lower ($p < 0.05$). Furthermore, the maxillary survival rate within 24 months was significantly lower at the implant level ($p < 0.01$). Multivariate analysis revealed that the maxilla was the most significant risk factor ($p < 0.01$).

**Conclusions**  All-on-four treatment yielded high long-term survival rates in Japanese patients. However, the maxilla showed a significantly lower cumulative survival rate than the mandible, while early failure was significantly higher. Furthermore, the maxilla was a significant risk factor influencing the survival rate.

**Keywords**  All-on-four, Immediate loading, Implant failure, Survival rate, Edentulous

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## Background

For edentulous or dentulous patients with severe, full-arch periodontitis that makes preservation difficult, Malo et al. avoided guided bone regeneration. Instead, they performed implant insertion, devising what is now known as the All-on-four concept, in which immediate loading is performed. They reported mandibular cases treated with the procedure in 2003 [1] and maxillary cases in 2005 [2]. Although there are differences in the survival rates of the maxilla and mandible depending on the follow-up period, recent clinical studies have also reported implant survival rates of 94.7% (5–13 years) in the maxilla and 93% (10–18 years) in the mandible, indicating favourable long-term progress [3, 4]. Furthermore, in a comparison of immediate loading and delayed loading for fixed full-arch rehabilitation, the 10-year survival rate was 93.3% for immediate loading and 94.9% for delayed loading. That is, full-arch immediate load treatment based on the All-on-four concept has been established as a reliable option for fixed prosthesis placement in edentulous patients for both the maxilla and mandible [5]. However, there have been reports of early implant failure due to immediate loading and subsequent damage/breakage of prosthetic devices [5–8]. A systematic review also reported that although there was no difference between the survival rates of immediate loading and conventional loading, the failure rate of implants was high (risk ratio=1.92) [9]. Furthermore, to date, there have been few studies on risk factors that affect the survival rate of immediate-loaded full-arch implants. Moreover, there are no reports on the long-term prognosis of All-on-four concept treatment in Japanese individuals. Thus, in this study, we treated the maxilla and mandible with the All-on-four concept with the aim of investigating the cumulative implant survival rate after 3–17 years and examining the risk factors that affect the survival rate.

## Methods

### Study population

In this study, we enrolled patients who underwent tooth extraction, All-on-four concept-based implant insertion and immediately loaded fixed full-arch denture fitting at a private rehabilitation centre (Malo Dental and Medical Tokyo, Tokyo, Japan) as a treatment for edentulous jaws or partially edentulous jaws with remaining teeth in poor condition between September 2005 and March 2019.

The exclusion criteria were patients who did not undergo follow-up at the private practice and those with zygomatic implants.

This study was approved by the ethics committee for research involving human subjects (ethics review committee number 11000688 approval, approval number 21-055-A), and all patients provided written informed consent for study inclusion.

### Surgical protocol

The surgical procedures for the All-on-four concept were performed in accordance with those detailed previously by Malo et al. [3, 4] Surgery was performed under local infiltration anaesthesia (2% lidocaine, including 1/80,000 adrenaline). The surgical protocol is outlined below and in Fig. 1:

1. In patients with remaining teeth, these teeth are extracted.
2. A longitudinal incision is made on the mucosa distal to the first molars on both sides, and a transverse incision is made on the mucosa on the alveolar crest slightly on the lingual/palatal side to form a mucoperiosteal flap.
3. If necessary, shaping of the alveolar bone and jawbone is performed for the purpose of securing the clearance required for prosthetic device fabrication and levelling the base surface of the prosthetic device.
4. For the maxillary sinus, a portion of the anterior wall of the maxillary sinus is excised using a round-burr tip, and a probe is used to explore the same area to confirm the morphology of the anterior maxillary sinus. For the mandible, the mental foramen is clearly indicated, and a probe is inserted in the mesial direction along the bone surface and used to confirm the nerve running morphology.
5. Insertion of the implant starts from the posterior end on both sides. The posterior implant should have a diameter of ≥ 4.0 mm. The implantation position and tilt angle are determined using a standardized surgical guide (All-on-four Guide, Nobel Biocare AG, Kloten, Switzerland).
6. The leading tip of the implant embedded in the posterior slope should be placed in the region of the mouth equivalent to the canines. Therefore, care should be taken not to cause interference, and the anterior implant should be placed in the area corresponding to the middle and lateral incisors. The anterior implant should have a diameter of ≥ 3.3 mm.
7. In principle, four implant bodies are inserted. However, if it is not possible to place an implant with a length of ≥ 10 mm, or if an initial fixation of ≥ 35 Ncm cannot be obtained, additional implants should be placed nearby if necessary and possible.
8. When inserting the implant, attach a straight or 17° angled abutment anteriorly and a 30° angled abutment posteriorly and suture them.
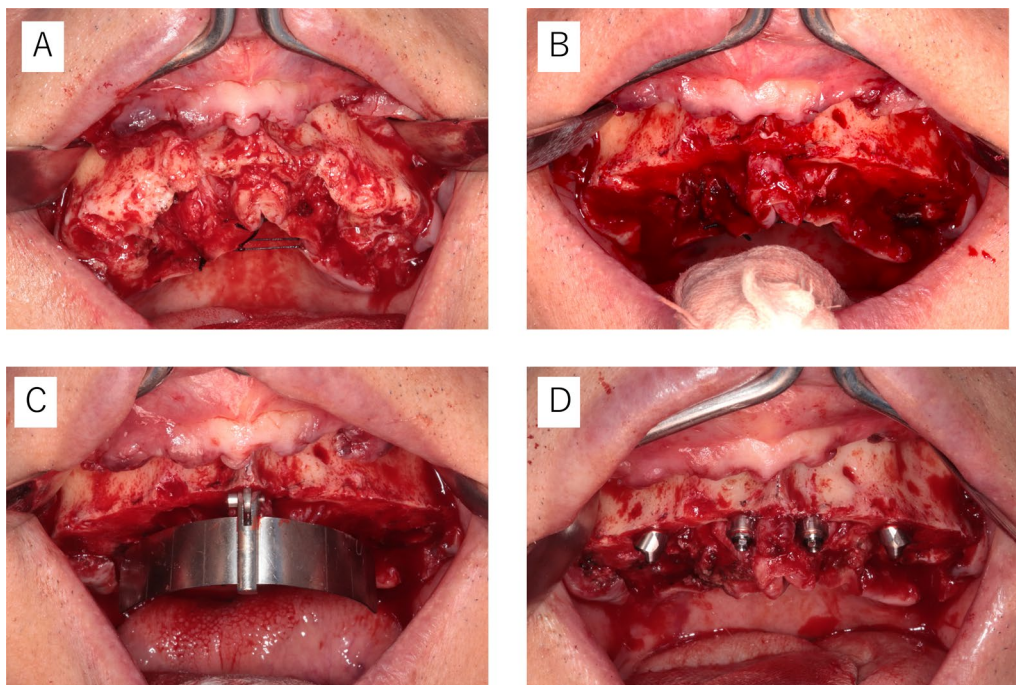
**Fig. 1** Surgical protocol. **a** After extraction tooth. **b** After bone reduction. **c** Placed the All-on-4 Guide. **d** Placed implants and abutment

To prevent postoperative infection, patients received amoxicillin 250 mg four times daily for 5 days and 0.2% benzethonium chloride mouthwash four times a day for 2 weeks, as well as loxoprofen sodium 60 mg three times a day for 5 days as an analgesic. Sutures were removed 2 weeks postoperatively.

**Prosthetic protocol**
The prosthetic protocol is outlined in Fig. 2. Briefly, copings for open-tray impressions were connected to form a device with which impressions and bite registrations were taken. Using the indirect method, a temporary prosthesis was fabricated by inserting reinforcement wires cast from a Co–Cr alloy into a titanium temporary cylinder and acrylic resin (PROVISTA, Sun Medical Co., Ltd., Shiga, Japan). This prosthesis was attached to the patient on the same day.

The final prosthesis was fabricated 6 months after the provisional prosthesis. The final prosthesis was either fabricated as a titanium framework with ceramic crowns (IPS e.max Press, Ivoclar Vivadent, Schaan, Liechtenstein) or with acrylic resin crowns (anterior teeth [Bioblend, Dentsply Sirona, Bensheim, Germany] and posterior teeth [LIVDENT GRACE, GC Co., Tokyo, Japan]).

**Follow-up and maintenance protocol**
The patients were instructed to maintain a soft-food diet for 2–3 months postoperatively. Follow-up clinical appointments were performed at 7 days, 14 days, and 1, 2, 3, 4, 5, and 6 months. After wearing the final prosthesis, follow-up was performed every 3–6 months, during which clinical parameters were evaluated, and oral hygiene instructions were given.

**Clinical outcomes**
We evaluated the following clinical outcomes:

1) 3–17-year cumulative survival rate (implant and patient levels): implant survival criteria were classified as failure if the implants were removed due to movement and inflammatory symptoms, such as persistent pain, swelling, and abscesses. For patient-level cumulative survival, failure was defined as the loss of one or more of the implants in a patient.
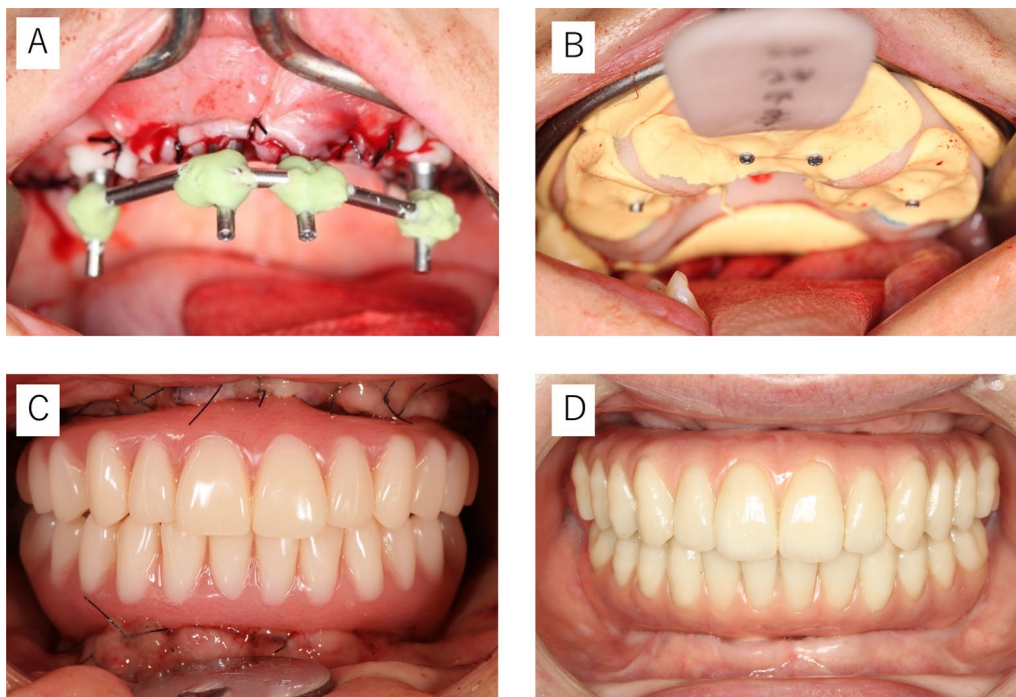2) Patient profile of implant failure and early implant failure

**Fig. 2** Prosthetic protocol. **a** Pretreatment of impression (connected to each impression coping). **b** Impression. **c** Immediate loading with provisional restoration after operation. **d** Final restoration

3) Investigation of risk factors (implant-related and patient-related factors) related to survival rate
4) Implant-related factors: type of implant, implant length, primary stability, and angle of implant placement.
5) Patient-related factors: sex, systemic disease, smoking habit (number of cigarettes smoked, $\geq 10$ cigarettes/day), and treatment area (maxilla/mandible).

### Statistical analysis

The cumulative survival rate was analysed using the Kaplan–Meier method, and comparisons of survival rates between groups were performed using the log-rank/Wilcoxon test. The various risk factors influencing implant survival rate (implant failure) were analysed univariately using the Chi-square test, followed by multivariate analysis using logistic regression analysis. In addition, odds ratios (OR) were calculated for the risk factors. All statistical analyses were performed using IBM SPSS Statistics 20 for Windows (International Business Machines Corp, Armonk, NY, USA). $p < 0.05$ was considered to indicate statistical significance.

### Results

Patient and implant data and characteristics are shown in Tables 1, 2, 3.

**Table 1** Descriptive patient data

|  | Number |
| --- | --- |
| Total | 561 |
| Sex |  |
| Male | 287 |
| Female | 274 |
| Age (years; mean ± SD) | 57.2 ± 10.4 |
| Observation period (months; mean ± SD) | 105.7 ± 44.5 |
| Smoker |  |
| Yes | 200 |
| No | 361 |
| Systemic disease |  |
| Healthy | 332 |
| Diabetes | 19 |
| Osteoporosis | 4 |
| Circulatory diseases | 93 |
| Combined* | 14 |
| Other** | 99 |

*Combined: systemic disease combination of diabetes and circulatory disease ($n = 13$); osteoporosis and circulatory disease ($n = 1$)

**For example, dyslipidemia, asthma, thyroid disease

A total of 561 patients (307 maxillae, 254 mandibles) and 2364 implants (1324 maxillae, 1040 mandibles) were included. Maxillary cases included 156 males and 151

**Table 2** Descriptive implant data

|  | Number |
|---|---|
| **Implants** | |
|  Total | 2364 |
|  Maxilla | 1324 |
|  Mandibula | 1040 |
| **Implant systems** | |
|  Nobel speedy groovy | 1925 |
|  Straumann bone level tapered | 278 |
|  Nobel parallel CC | 52 |
|  Nobel replace tapered groovy | 50 |
|  Brånemark system Mk IV TiUnite | 32 |
|  Nobel replace tapered | 23 |
|  Nobel active | 4 |
| **Implant angulation** | |
|  Straight | 1242 |
|  Tilted | 1122 |
| **Implant length (mm)** | |
|  7 | 20 |
|  8 | 8 |
|  8.5 | 26 |
|  10 | 111 |
|  11.5 | 100 |
|  12 | 59 |
|  13 | 292 |
|  14 | 53 |
|  15 | 564 |
|  16 | 135 |
|  18 | 802 |
|  20 | 127 |
|  22 | 60 |
|  25 | 7 |

females, with an average age of $57.2 \pm 10.4$ years and an average follow-up period of $105.7 \pm 44.5$ months. Mandibular cases included 131 males and 123 females, with an average age of $55.1 \pm 10.6$ years and an average follow-up period of $108.3 \pm 42.6$ months.

## Cumulative implant survival rate

The number of failed implants was 22 and 7 in the maxilla and mandible, respectively, and the number of patients was 11 and 6 in the maxilla and mandible, respectively. The number of implants and patients who failed within 24 months were 19 implants (0–12 months: 15 implants, 12–24 months: four implants), nine patients (0–12 months: eight patients, 12–24 months: one patient) in the maxilla and three implants (breakdown; 0–12 months: three implants, 12–24 months: 0 implants), three patients (breakdown; 0–12 months: three patients, 12–24 months: 0 patients) in the mandible. Furthermore,

the number of implants that failed at $\geq 24$ months and the number of patients were as follows: three implants (breakdown; 24–36 months: one implant, 168–180 months: two implants), two patients (breakdown; 24–36 months: one patient, 168–180 months: one patient) in the maxilla and four implants (breakdown; 24–36 months: one implant, 72–84 months: one implant, 132–144 months: two implants), three patients (breakdown; 24–36 months: one patient, 72–84 months: one patient, 132–144 months: one patient) in the mandible (Tables 4, 5, 6, 7).

The cumulative implant survival rate over 3–17 years was 94.4% at the patient level and 97.4% at the implant level for the maxilla. For the mandible, the cumulative survival rates were 96.7% at the patient level and 98.9% at the implant level. The cumulative survival rate in the maxilla was significantly lower at the implant level than in the mandible ($p < 0.05$), but not significantly different at the patient level (Figs. 3 and 4).

## Patient profile of implant failure and early implant failure

The details of implant failure cases for the maxilla and mandible are presented in Tables 8 and 9.

The survival rate was then classified into within 24 months and after 24 months. The maxillary survival rate within 24 months was 97.1% at the patient level and 98.6% at the implant level. After 24 months, the survival rate was 99.3% at the patient level and 99.8% at the implant level ($p < 0.05$ and $< 0.01$, respectively).

The mandibular survival rate within 24 months was 98.8% at the patient level and 99.7% at the implant level. After 24 months, the survival rate was 98.8% at the patient level and 99.6% at the implant level, with no significant difference (Table 10).

Furthermore, a comparison of the maxilla and mandible regarding implant failure within 24 months resulted in a higher risk of early failure in the maxilla (implant level, $p < 0.01$).

## Risk factors related to survival rate
### Implant-related factors
*Implant type (Table 11)*   Regarding differences in survival rate according to implant type, the Nobel Speedy Groovy implant (Nobel Biocare AG, Kloten, Switzerland) had survival rates of 98.3% and 99.2% for maxillary and mandibular implants, respectively; the Bone Level Tapered implant (Straumann AG, Basel, Switzerland) had survival rates of 99.3% and 100% for maxillary and mandibular implants, respectively; the Nobel Parallel CC implant (Nobel Biocare AG, Kloten, Switzerland) had survival rates of 97.8% and 100% for maxillary and mandibular implants, respectively; and the Nobel Replace Tapered Groovy implant had survival rates of 94.7% and 100% for maxillary and

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**Table 3** Patient and implant-related characteristics

| Patient-related | $n = 561$ (%) |
|---|---|
| Sex | |
|     Male | $n = 287$ (51.2) |
|     Female | $n = 274$ (48.8) |
| Age at placement, mean (SD) | 57.2 (10.4) |
| Observation period, mean (SD) | 105.7 (44.5) |
| Smoker | |
|     Yes | $n = 200$ (35.7) |
|     No | $n = 361$ (64.3) |
| Systemic disease | |
|     Healthy | $n = 332$ (59.2) |
|     Diabetes | $n = 19$ (3.4) |
|     Osteoporosis | $n = 4$ (0.7) |
|     Circulatory diseases | $n = 93$ (16.6) |
|     Combined* | $n = 14$ (2.5) |
|     Other** | $n = 99$ (17.6) |
| **Implant-related** | $n = 2364$ (%) |
| Jaw | |
|     Maxilla | 1324 (56.0) |
|     Mandibula | 1040 (44.0) |
| Implant systems | |
|     Nobel speedy groovy | 1925 (81.4) |
|     Straumann bone level tapered | 278 (11.8) |
|     Nobel parallel CC | 52 (2.2) |
|     Nobel replace tapered groovy | 50 (2.1) |
|     Brånemark system Mk IV TiUnite | 32 (1.4) |
|     Nobel replace tapered | 23 (1.0) |
|     Nobel active | 4 (0.2) |
| Implant angulation | |
|     Straight | 1242 (52.5) |
|     Tilted | 1122 (47.5) |
| Implant length (mm) | |
|     < 10 mm | 54 (2.3) |
|     10 mm ≤ , < 15 mm | 615 (26.0) |
|     15 mm ≤ , < 18 mm | 699 (29.6) |
|     18 mm ≤ | 996 (42.1) |

*Combined: systemic disease combination of diabetes and circulatory disease ($n = 13$); osteoporosis and circulatory disease ($n = 1$)

**For example, dyslipidemia, asthma, thyroid disease

mandibular implants, respectively. No significant differences were observed among the survival rates according to implant type for either the maxilla or the mandible.

*Implant length (Table 12)* Regarding the differences in survival rate according to implant length, implants of < 10 mm in length had survival rates of 97.3% and 94.1% for maxillary and mandibular implants, respectively; implants of 10 mm ≤ , < 15 mm had survival rates of 97.8% and 100% for maxillary and mandibular implants, respectively; implants of 15 mm ≤ , < 18 mm had survival rates of 99.1% and 99.2% for maxillary and mandibular implants, respectively; and implants of 18 mm ≤ had survival rates of 98.3% and 99.3% for maxillary and mandibular implants, respectively. Implant lengths < 15 mm showed significantly higher survival rates in the mandible ($p < 0.05$), but no significant differences were observed in the maxilla.

**Table 4** Survival rate and number of implants depending on the investigation interval (implant level in the maxilla)

| Investigation interval (months) | Number of implants | Failed implants | Survival rate intervals (%) |
|---|---|---|---|
| 0 <, ≤ 12 | 1324 | 15 | 100–98.9 |
| 12 <, ≤ 24 | 1309 | 4 | 98.9–98.6 |
| 24 <, ≤ 36 | 1305 | 1 | 98.6–98.5 |
| 36 <, ≤ 48 | 1304 | 0 | 98.5 |
| 48 <, ≤ 60 | 1222 | 0 | 98.5 |
| 60 <, ≤ 72 | 1116 | 0 | 98.5 |
| 72 <, ≤ 84 | 978 | 0 | 98.5 |
| 84 <, ≤ 96 | 835 | 0 | 98.5 |
| 96 <, ≤ 108 | 693 | 0 | 98.5 |
| 108 <, ≤ 120 | 552 | 0 | 98.5 |
| 120 <, ≤ 132 | 449 | 0 | 98.5 |
| 132 <, ≤ 144 | 403 | 0 | 98.5 |
| 144 <, ≤ 156 | 351 | 0 | 98.5 |
| 156 <, ≤ 168 | 253 | 0 | 98.5 |
| 168 <, ≤ 180 | 180 | 2 | 98.5–97.4 |
| 180 <, ≤ 192 | 68 | 0 | 97.4 |
| 192 < | 8 | 0 | 97.4 |

**Table 6** Survival rate and number of implants depending on the investigation interval (patient level in the maxilla)

| Investigation interval (months) | Number of patients | Failed patients | Survival rate intervals (%) |
|---|---|---|---|
| 0 <, ≤ 12 | 307 | 8 | 100–97.4 |
| 12 <, ≤ 24 | 299 | 1 | 97.4–97.1 |
| 24 <, ≤ 36 | 298 | 1 | 97.1–96.7 |
| 36 <, ≤ 48 | 297 | 0 | 96.7 |
| 48 <, ≤ 60 | 282 | 0 | 96.7 |
| 60 <, ≤ 72 | 257 | 0 | 96.7 |
| 72 <, ≤ 84 | 223 | 0 | 96.7 |
| 84 <, ≤ 96 | 189 | 0 | 96.7 |
| 96 <, ≤ 108 | 155 | 0 | 96.7 |
| 108 <, ≤ 120 | 124 | 0 | 96.7 |
| 120 <, ≤ 132 | 100 | 0 | 96.7 |
| 132 <, ≤ 144 | 90 | 0 | 96.7 |
| 144 <, ≤ 156 | 78 | 0 | 96.7 |
| 156 <, ≤ 168 | 58 | 0 | 96.7 |
| 168 <, ≤ 180 | 42 | 1 | 96.7–94.4 |
| 180 <, ≤ 192 | 16 | 0 | 94.4 |
| 192 < | 5 | 0 | 94.4 |

**Table 5** Survival rate and number of implants depending on the investigation interval (implant level in the mandible)

| Investigation interval (months) | Number of implants | Failed implants | Survival rate intervals (%) |
|---|---|---|---|
| 0 <, ≤ 12 | 1040 | 3 | 100–99.7 |
| 12 <, ≤ 24 | 1037 | 0 | 99.7 |
| 24 <, ≤ 36 | 1037 | 1 | 99.7–99.6 |
| 36 <, ≤ 48 | 1036 | 0 | 99.6 |
| 48 <, ≤ 60 | 956 | 0 | 99.6 |
| 60 <, ≤ 72 | 899 | 0 | 99.6 |
| 72 <, ≤ 84 | 787 | 1 | 99.6–99.5 |
| 84 <, ≤ 96 | 707 | 0 | 99.5 |
| 96 <, ≤ 108 | 555 | 0 | 99.5 |
| 108 <, ≤ 120 | 461 | 0 | 99.5 |
| 120 <, ≤ 132 | 381 | 0 | 99.5 |
| 132 <, ≤ 144 | 339 | 2 | 99.5–98.9 |
| 144 <, ≤ 156 | 301 | 0 | 98.9 |
| 156 <, ≤ 168 | 184 | 0 | 98.9 |
| 168 <, ≤ 180 | 117 | 0 | 98.9 |
| 180 <, ≤ 192 | 49 | 0 | 98.9 |
| 192 < | 4 | 0 | 98.9 |

**Table 7** Survival rate and number of implants depending on the investigation interval (patient level in the mandible)

| Investigation interval (months) | Number of patients | Failed patients | Survival rate intervals (%) |
|---|---|---|---|
| 0 <, ≤ 12 | 254 | 3 | 100–98.8 |
| 12 <, ≤ 24 | 251 | 0 | 98.8 |
| 24 <, ≤ 36 | 251 | 1 | 98.8–98.4 |
| 36 <, ≤ 48 | 250 | 0 | 98.4 |
| 48 <, ≤ 60 | 233 | 0 | 98.4 |
| 60 <, ≤ 72 | 219 | 0 | 98.4 |
| 72 <, ≤ 84 | 191 | 1 | 98.4–97.9 |
| 84 <, ≤ 96 | 171 | 0 | 97.9 |
| 96 <, ≤ 108 | 133 | 0 | 97.9 |
| 108 <, ≤ 120 | 110 | 0 | 97.9 |
| 120 <, ≤ 132 | 91 | 0 | 97.9 |
| 132 <, ≤ 144 | 81 | 1 | 97.9–96.7 |
| 144 <, ≤ 156 | 72 | 0 | 96.7 |
| 156 <, ≤ 168 | 45 | 0 | 96.7 |
| 168 <, ≤ 180 | 29 | 0 | 96.7 |
| 180 <, ≤ 192 | 12 | 0 | 96.7 |
| 192 < | 1 | 0 | 96.7 |

*Primary stability (Table 13)* The survival rates according to primary stability at implantation are as follows: implants with a value of < 35 Ncm had survival rates of 99.1% and 100% for the maxilla and mandible, respectively; implants with a value of 35–50 Ncm had survival rates of 97.0% and 98.8% for maxillary and mandibular implants, respectively; and implants with a value of > 50 Ncm had survival rates of 98.7% and 99.5% for maxillary and mandibular implants, respectively. No significant differences were observed in the survival rates accord-
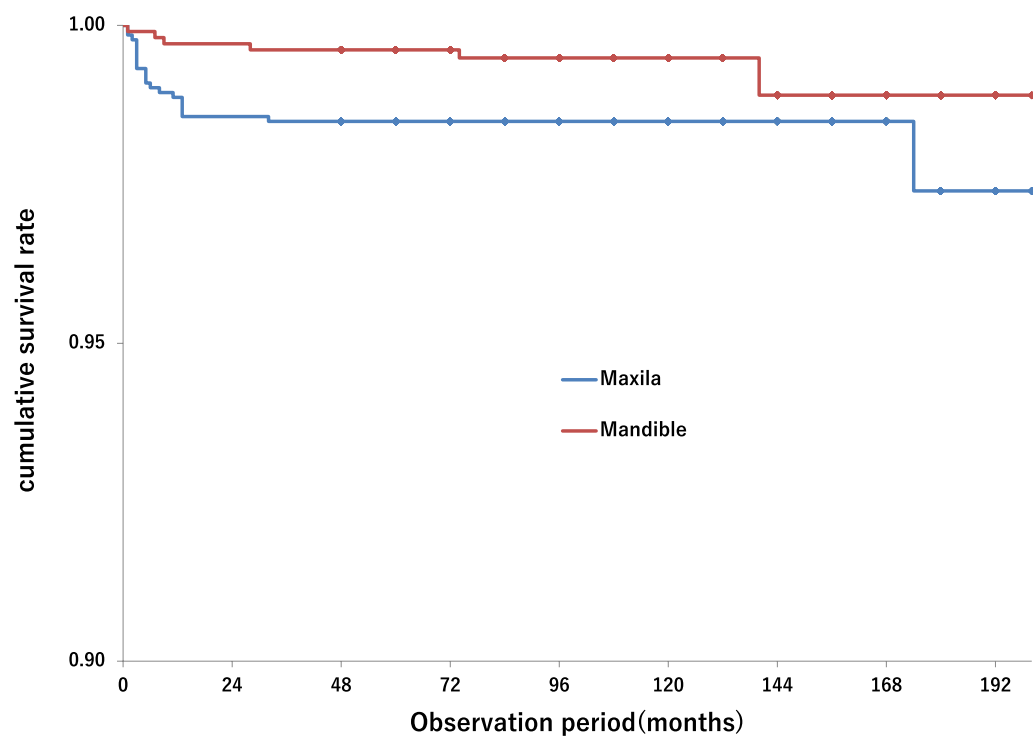
**Fig. 3** Kaplan–Meier curves in the implant level. The log-rank test showed a significant difference between the maxilla and mandible ($p=0.0320$)
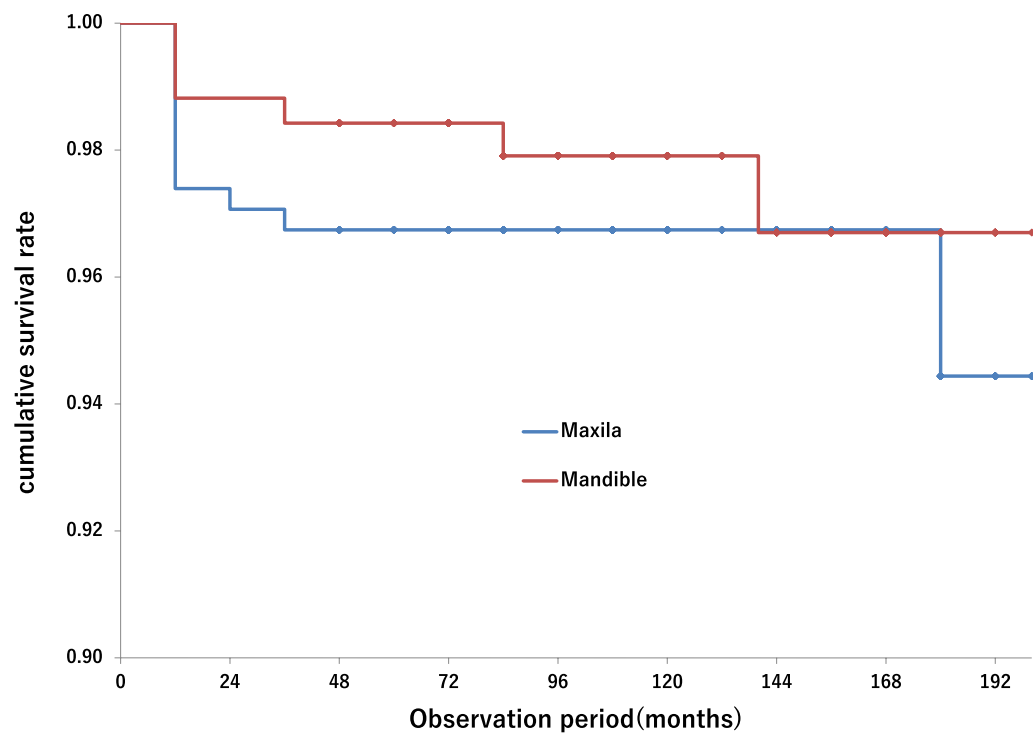


**Fig. 4** Kaplan–Meier curves in the patient level. The log-rank test showed no significant difference between the maxilla and mandible ($p=0.42$)

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**Table 8** Implant failure case in the maxilla

| Case | Age | Sex | Smoking | Systemic disease | Surgical procedure (number of implants) | Type of implant | Diameter (mm) | Length (mm) | Initial torque value (Ncm) | Direction | Time to implant failure (month) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 56 | M | – | – | All-on-four (4) | Nobel speedy groovy | 4.0 | 18 | 45 | Tilted | 5 |
| 2 | 51 | M | + | – | All-on-four (4) | Nobel replace tapered groovy | 4.3 | 16 | 45 | Straight | 3 |
| | | | | | | Nobel speedy groovy | 4.0 | 18 | 35 | Tilted | 3 |
| | | | | | | Nobel speedy groovy | 4.0 | 18 | 45 | Tilted | 3 |
| 3 | 36 | M | + | – | All-on-four (4) | Nobel speedy groovy | 4.0 | 18 | 45 | Tilted | 2 |
| 4 | 64 | F | – | – | All-on-four + 1 (5) | Nobel speedy groovy | 4.0 | 18 | 30 | Tilted | 174 |
| | | | | | | Nobel speedy groovy | 4.0 | 10 | 35 | Straight | 174 |
| 5 | 62 | M | – | HT | All-on-four (4) | Nobel speedy groovy | 4.0 | 18 | 50 ≦ | Tilted | 8 |
| 6 | 52 | F | – | – | All-on-four + 1 (5) | Nobel speedy groovy | 4.0 | 11.5 | 45 | Straight | 1 |
| | | | | | | Nobel speedy groovy | 4.0 | 13 | 45 | Tilted | 1 |
| 7 | 66 | F | + | – | All-on-four (4) | Nobel speedy groovy | 4.0 | 10 | 50 ≦ | Straight | 3 |
| | | | | | | Nobel speedy groovy | 4.0 | 15 | 50 ≦ | Tilted | 6 |
| | | | | | | Nobel speedy groovy | 4.0 | 10 | 50 ≦ | Straight | 3 |
| | | | | | | Nobel speedy groovy | 4.0 | 15 | 50 ≦ | Tilted | 3 |
| 8 | 73 | M | – | Hepatitis C | All-on-four (4) | Nobel speedy groovy | 4.0 | 11.5 | 50 ≦ | Straight | 11 |
| 9 | 60 | M | + | – | All-on-four (4) | Nobel speedy groovy | 4.0 | 13 | 50 ≦ | Straight | 13 |
| | | | | | | Nobel speedy groovy | 4.0 | 18 | 50 ≦ | Tilted | 13 |
| | | | | | | Nobel speedy groovy | 4.0 | 13 | 50 ≦ | Straight | 13 |
| | | | | | | Nobel speedy groovy | 4.0 | 18 | 50 ≦ | Tilted | 13 |
| 10 | 60 | M | – | HT | All-on-four (4) | Straumann bone level tapered | 4.1 | 18 | 50 ≦ | Tilted | 32 |
| 11 | 66 | F | – | Arrhythmia | All-on-four + 1 (5) | Nobel parallel CC | 3.75 | 8.5 | 40 | Straight | 5 |
| | | | | Osteoporosis | | Nobel speedy groovy | 4.0 | 10 | 45 | Straight | 5 |

**Table 9** Implant failure case in the mandible

| Case | Age | Sex | Smoking | Systemic disease | Surgical procedure (number of implants) | Type of implant | Diameter (mm) | Length (mm) | Primary stability (N cm) | Direction | Time to implant failure (month) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 63 | M | + | Stomach cancer | All-on-four (4) | Nobel speedy groovy | 4.0 | 18 | 45 | Tilted | 74 |
| 2 | 58 | M | + | – | All-on-four (4) | Nobel speedy groovy | 4.0 | 15 | 35 | Tilted | 1 |
| 3 | 67 | F | – | – | All-on-four + 2 (6) | Nobel speedy groovy | 4.0 | 18 | 50 ≦ | Tilted | 140 |
|   |   |   |   |   |   | Nobel speedy groovy | 4.0 | 7 | 40 | Straight | 140 |
| 4 | 55 | M | + | Hepatic dysfunction | All-on-four (4) | Nobel speedy groovy | 4.0 | 15 | 50 ≦ | Straight | 7 |
| 5 | 38 | M | + | DM | All-on-four (4) | Nobel speedy groovy | 4.0 | 15 | 50 ≦ | Tilted | 9 |
| 6 | 47 | M | + | – | All-on-four (4) | Nobel speedy groovy | 4.0 | 18 | 50 ≦ | Tilted | 28 |

**Table 10** Time to implant failure

|  |  | Patient level (%) | *p* value | Implant level (%) | *p* value |
|---|---|---|---|---|---|
| Maxilla |  |  |  |  |  |
|  | ≤ 24 months | 97.1 | 0.037* | 98.6 | 0.0014** |
|  | > 24 months | 99.3 |  | 99.8 |  |
| Mandible |  |  |  |  |  |
|  | ≤ 24 months | 98.8 | 0.99 | 99.7 | 0.99 |
|  | > 24 months | 98.8 |  | 99.6 |  |
| Maxilla | ≤ 24 months | 97.1 | 0.15 | 98.6 | 0.009** |
| Mandible | ≤ 24 months | 98.8 |  | 99.7 |  |

*$p < 0.05$, **$p < 0.01$: Chi-square test

ing to primary stability for either the maxilla or the mandible.

*Angle of implant placement (Table 14)*    The survival rates of implants placed in the axial direction were 98.6% and 99.6% for the maxilla and mandible, respectively. The survival rates of tilted implants were 98.0% and 99.0% for the maxilla and mandible, respectively. No significant differ-ence in survival rates due to the placement angle of the implant was observed for either the maxilla or the man-dible.

### Patient-related factors

*Sex (Table 15)*    For the maxilla, male patients had sur-vival rates of 95.5% at the patient level and 98.2% at the implant level. Female patients had rates of 97.4% at the patient level and 98.5% at the implant level.

For the mandible, male patients had survival rates of 96.2% at the patient level and 99.1% at the implant level. Female patients had survival rates of 99.2% at the patient level and 99.6% at the implant level.

No significant differences were observed for either the maxilla or the mandible.

*Systemic disease (Table 16)*    In this study, we investigated the survival rate of implants with diabetes mellitus [10, 11], cardiovascular disease [10, 12, 13], and osteoporosis [14], which have been reported as causes of implant fail-ure and peri-implantitis, as the main systemic diseases.

**Table 11** Type of implant to survival rate

|  | Number of implant placement | Number of implant failure | Survival rate (%) | *p* value |
|---|---|---|---|---|
| *Maxilla* |  |  |  |  |
| Nobel speedy groovy | 1064 | 18 | 98.3 | – |
| Straumann bone level tapered | 143 | 1 | 99.3 | 0.59 |
| Nobel parallel CC | 46 | 1 | 97.8 | 0.73 |
| Nobel replace tapered groovy | 38 | 2 | 94.7 | 0.31 |
| Nobel replace tapered | 19 | 0 | 100 | 0.56 |
| Brånemark System Mk IV TiUnite | 11 | 0 | 100 | 0.66 |
| Nobel active | 3 | 0 | 100 | 0.82 |
| *Mandible* |  |  |  |  |
| Nobel speedy groovy | 861 | 7 | 99.2 | – |
| Straumann bone level tapered | 135 | 0 | 100 | 0.29 |
| Brånemark System Mk IV TiUnite | 21 | 0 | 100 | 0.68 |
| Nobel replace tapered groovy | 12 | 0 | 100 | 0.76 |
| Nobel parallel CC | 6 | 0 | 100 | 0.82 |
| Nobel replace tapered | 4 | 0 | 100 | 0.86 |
| Nobel active | 1 | 0 | 100 | 0.92 |
| *Total* |  |  |  |  |
| Nobel speedy groovy | 1925 | 25 | 98.7 | – |
| Straumann bone level tapered | 278 | 1 | 99.6 | 0.17 |
| Nobel parallel CC | 52 | 1 | 98.1 | 0.69 |
| Nobel replace tapered groovy | 50 | 2 | 96.0 | 0.43 |
| Brånemark System Mk IV TiUnite | 32 | 0 | 100 | 0.51 |
| Nobel replace tapered | 23 | 0 | 100 | 0.58 |
| Nobel active | 4 | 0 | 100 | 0.82 |

*$p < 0.05$, **$p < 0.01$: Chi-square test

**Table 12** Implant length to survival rate

|  | Number of implant placed | Number of implant failure | Survival rate (%) | *p* value |
|---|---|---|---|---|
| *Maxilla* |  |  |  |  |
| < 10 mm | 37 | 1 | 97.3 | – |
| 10 mm ≤ , < 15 mm | 409 | 9 | 97.8 | 0.70 |
| 15 mm ≤ , < 18 mm | 342 | 3 | 99.1 | 0.85 |
| 18 mm ≤ | 536 | 9 | 98.3 | 0.85 |
| *Mandible* |  |  |  |  |
| < 10 mm | 17 | 1 | 94.1 | – |
| 10 mm ≤ , < 15 mm | 206 | 0 | 100 | 0.10 |
| 15 mm ≤ , < 18 mm | 357 | 3 | 99.2 | 0.048* |
| 18 mm ≤ | 460 | 3 | 99.3 | 0.022* |
| *Total* |  |  |  |  |
| < 10 mm | 54 | 2 | 96.3 | – |
| 10 mm ≤ , < 15 mm | 615 | 9 | 98.5 | 0.21 |
| 15 mm ≤ , < 18 mm | 699 | 6 | 99.1 | 0.049* |
| 18 mm ≤ | 996 | 12 | 99.3 | 0.12 |

*$p < 0.05$, **$p < 0.01$: Chi-square test

**Table 13** Primary stability to survival rate

|  | Number of implant placed | Number of implant failure | Survival rate (%) | *p* value |
|---|---|---|---|---|
| *Maxilla* |  |  |  |  |
| < 35 Ncm | 113 | 1 | 99.1 | – |
| 35 Ncm ≤ , < 50 Ncm | 334 | 10 | 97.0 | 0.37 |
| 50 Ncm ≤ | 877 | 11 | 98.7 | 0.91 |
| *Mandible* |  |  |  |  |
| < 35 Ncm | 31 | 0 | 100 | – |
| 35 Ncm ≤ , < 50 Ncm | 248 | 3 | 98.8 | 0.76 |
| 50 Ncm ≤ | 761 | 4 | 99.5 | 0.37 |
| *Total* |  |  |  |  |
| < 35 Ncm | 144 | 1 | 99.3 | – |
| 35 Ncm ≤ , < 50 Ncm | 582 | 13 | 97.8 | 0.23 |
| 50 Ncm ≤ | 1638 | 15 | 99.1 | 0.78 |

*$p < 0.05$, **$p < 0.01$: Chi-square test

For the maxilla, healthy participants had survival rates of 96.0% at the patient level and 97.8% at the implant level. Patients with systemic disease had survival rates of 96.9% at the patient level and 99.1% at the implant level.

For the mandible, healthy participants had survival rates of 98.1% at the patient level and 99.4% at the implant level. Patients with systemic disease had survival rates of 97.0% at the patient level and 99.3% at the implant level.

**Table 14** Angle of implant placement to survival rate

|  | Number of implant placed | Number of implant failure | Survival rate (%) | *p* value |
|---|---|---|---|---|
| *Maxilla* |  |  |  |  |
| Straight | 710 | 10 | 98.6 | 0.57 |
| Tilted | 614 | 12 | 98.0 |  |
| *Mandible* |  |  |  |  |
| Straight | 532 | 2 | 99.6 | 0.41 |
| Tilted | 508 | 5 | 99.0 |  |
| *Total* |  |  |  |  |
| Straight | 1242 | 12 | 99.0 | 0.22 |
| Tilted | 1122 | 17 | 98.5 |  |

*$p < 0.05$, **$p < 0.01$: Chi-square test

No significant differences were observed for either the maxilla or the mandible.

*Smoking (Table 17)* For both the maxilla and mandible, smokers had implant survival rates of 95.5% at the patient level and 97.9% at the implant level, whereas non-smokers had implant survival rates of 97.8% at the patient level and 99.2% at the implant level. Survival rates at the implant level were significantly lower for smokers ($p = 0.0086 < 0.01$).

For the maxilla, smokers had implant survival rates of 96.2% at the patient level and 97.3% at the implant level, whereas non-smokers had implant survival rates of 96.6% at the patient level and 98.9% at the implant level. Smokers had significantly lower survival rates than non-smokers at the implant level ($p < 0.05$).

For the mandible, smokers had implant survival rates of 94.8% at the patient level and 98.7% at the implant level, whereas non-smokers had implant survival rates of 99.4% at the patient level and 99.7% at the implant level. Smokers had significantly lower survival rates than non-smokers at the patient level ($p < 0.05$).

### Risk factors for survival rate multivariate analysis

The risk factors influencing the survival rate are shown in Table 18. To identify the risk factors for survival rate (implant failure), logistic regression analyses were performed at both the implant and patient levels. The factor with the greatest influence on survival was the maxilla in the treatment area, with an OR of 1.98 at the patient level and 5.68 at the implant level, which was significantly different ($p = 0.0034$, implant level). However, smoking was not statistically significant, although the OR was 1.98 at the patient level and 2.58 at the implant level ($p = 0.39$, $p = 0.37$, respectively).

**Table 15** Sex to survival rate

|  | Number of patients | Number of implants | Patient level (number of patient failure) | *p* value | Implant level (number of implant failure) | *p* value |
|---|---|---|---|---|---|---|
| *Maxilla* | | | | | | |
| Male | 156 | 658 | 95.5% (7) | 0.58 | 98.2% (12) | 0.81 |
| Female | 151 | 666 | 97.4% (4) | | 98.5% (10) | |
| *Mandible* | | | | | | |
| Male | 131 | 532 | 96.2% (5) | 0.25 | 99.1% (5) | 0.48 |
| Female | 123 | 508 | 99.2% (1) | | 99.6% (2) | |
| *Total* | | | | | | |
| Male | 287 | 1190 | 95.8% (12) | 0.11 | 98.6% (17) | 0.36 |
| Female | 274 | 1174 | 98.2% (5) | | 99.0% (12) | |

*$p < 0.05$, **$p < 0.01$: Chi-square test

**Table 16** Systemic disease to survival rate

|  | Number of patients | Number of implant placed | Patient level (number of patient failure) | *p* value | Implant level (number of implant failure) | *p* value |
|---|---|---|---|---|---|---|
| *Maxilla* | | | | | | |
| Presence | 130 | 564 | 96.9% (4) | 0.92 | 99.1% (5) | 0.09 |
| Absence | 177 | 760 | 96.0% (7) | | 97.8% (17) | |
| *Mandible* | | | | | | |
| Presence | 99 | 408 | 97.0% (3) | 0.89 | 99.3% (3) | 0.84 |
| Absence | 155 | 632 | 98.1% (3) | | 99.4% (4) | |
| *Total* | | | | | | |
| Presence | 229 | 972 | 96.9% (7) | 0.97 | 99.2% (8) | 0.14 |
| Absence | 332 | 1392 | 97.0% (10) | | 98.5% (21) | |

*$p < 0.05$, **$p < 0.01$: Chi-square test

**Table 17** Smoking to survival rate

|  | Number of patients | Number of implant placed | Patient level (number of patient failure) | *p* value | Implant level (number of implant failure) | *p* value |
|---|---|---|---|---|---|---|
| *Maxilla* | | | | | | |
| Smoker | 104 | 446 | 96.2% (4) | 0.86 | 97.3% (12) | 0.037* |
| Non smoker | 203 | 878 | 96.6% (7) | | 98.9% (10) | |
| *Mandible* | | | | | | |
| Smoker | 96 | 392 | 94.8% (5) | 0.019* | 98.7% (5) | 0.065 |
| Non smoker | 158 | 648 | 99.4% (1) | | 99.7% (2) | |
| *Total* | | | | | | |
| Smoker | 200 | 838 | 95.5% (9) | 0.13 | 97.9% (17) | 0.0086** |
| Non smoker | 361 | 1526 | 97.8% (8) | | 99.2% (12) | |

*$p < 0.05$, **$p < 0.01$: Chi-square test

## Discussion

### Cumulative implant survival rate for full-arch rehabilitation

In this study, the survival rate of implants after $\geq 3$ years was 96.4% at the patient level and 98.3% at the implant level for the maxilla, and 98.1% at the patient level and 99.3% at the implant level for the mandible.

In a systematic review [15] of the survival rate of implants in fixed prosthetic treatment with implants for edentulous cases, under the conventional loading protocol, the maxillary survival rate was 94.95–100% (2–15-year follow-up), and the mandibular survival rate was 96.47–100% (3–15-year follow-up). The early loading

**Table 18** Risk factors for survival rate multivariate analysis (odds ratio)

| | Risk factor | Odds ratio | *p* value |
|---|---|---|---|
| *Implant-related factors* | | | |
| Implant length | < 10 mm | 1.97 | > 0.05 |
| Primary stability | < 35 Ncm | 0.54 | > 0.05 |
| Angle of implant placement | Tilted | 1.57 | > 0.05 |
| *Patient-related factors for patient-level* | | | |
| Treatment area | Maxilla | 1.54 | > 0.05 |
| Sex | Male | 1.40 | > 0.05 |
| Systemic disease | Presence | 1.01 | > 0.05 |
| Smoking | Smoking | 1.98 | > 0.05 |
| *Patient-related factors for implant-level* | | | |
| Treatment area | Maxilla | 5.68 | < 0.01** |
| Sex | Male | 2.35 | > 0.05 |
| Systemic disease | Presence | 0.51 | > 0.05 |
| Smoking | Smoking | 2.58 | > 0.05 |

*$p < 0.05$, **$p < 0.01$: logistic regression analysis

protocol had survival rates of 94.7–100% for maxillary implants (1–3-year follow-up) and 98.51–100% for mandibular implants (1–2-year follow-up). Finally, under the immediate loading protocol, the survival rates were 90.43–100% (follow-up period: 1–10 years) for the maxilla and 90–100% (follow-up period: 1–10 years) for the mandible. The survival rate of implants in treatment based on the All-on-four concept was reported to be 94.7% (5–13 years) in the maxilla and 93% (10–18 years) in the mandible at the implant level [3, 4]. In the latest review, it was reported to be 93.9–100% for the maxilla (up to 13 years) and 91.7–100% for the mandible (up to 18 years) [16]. Furthermore, in a recent systematic review, the mean cumulative residuals over 72–132 months were as high as 94–98% [17]. The results of the present study are consistent with those of previous studies, including systematic reviews, and suggest that the All-on-four concept may be a beneficial treatment method in the Japanese population.

Some studies reported [18, 19] no significant difference between the survival rates of maxillary and mandibular implants in treatment based on the All-on-four concept. However, in the present study, similar to the report by Ping et al. [20] (maxilla: 92.8%, mandible: 99.0%, mean follow-up period: 2.8 years), the survival rate of implants in the maxilla was significantly lower than that of implants in the mandible at the implant level. The findings of the present study differed from those of Malo et al. probably because of the different observation periods and the influence of skeletal patterns and bone quality due to differences in the race of the patients.

Multiple factors are involved in implant failure, and, in accordance with their timing, we can divide failure occurrences into early and late failures. Early failure is primarily due to failure to achieve osseointegration. Late failure is said to be caused by a bacterial infection or excessive burden after achieving osseointegration. Failures that occur prior to the final superstructure installation are classified as early failures. Those that occur after installation (loading) are classified as late failures. However, some studies have classified the period within 1 year after the final superstructure installation as the early period and the period after 1 year as the late period [21, 22]. This classification cannot be applied in the present study, because immediate loading treatment was performed. Therefore, in the present study, we examined the difference in survival rate using the timepoint of 24 months as a reference point.

In the present study, there were 22 implant failures in 11 cases in the maxilla and seven failures in six cases in the mandible. In particular, for maxillary implants, 19 implants (86.4%) in nine cases failed early, i.e., within 24 months (1–13 months) of implantation. That is, the survival rate within 24 months was significantly low at both the patient and implant levels. Maló et al. [14] reported implant failure in 19 of 968 implants after 5 years in maxillary cases treated based on the All-on-four concept. Among those 19, 16 (84.2%) failed within 12 months after implantation. That is, a trend similar to that of the present study was observed. In addition, there was a tendency for multiple maxillary implant failures per patient, with an average of 2.1 per patient. This tendency is called cluster failures [13, 23] (a phenomenon in which failures of implant treatment are concentrated in a certain group of patients rather than occurring uniformly in all patients). Implant-related factors include mechanically polished surface texture and short implants. Patient-related factors include age, poor bone quality, oral proton pump inhibitor use, smoking, and bruxism. In the present study, we believe that bone quality was not the only reason for the high rate of early failure of maxillary implants. Since immediate loading was performed, it is thought that the effects of opposing teeth and bruxism may have also been involved.

## Factors related to survival rate
### Implant-related factors
In the present study, there was no significant difference in the survival rate between axial and tilted implants in either the maxilla or the mandible. A recent systematic review [17] reported no significant difference in the survival rate and marginal bone loss between axial and tilted implants placed during treatment using the All-on-four concept. One advantage of tilted placement is that

it enables the placement of a longer implant compared to placement in the axial direction. As a result, the contact area between the implant and the bone increases, and the possibility of obtaining better primary stability increases [22]. Zampelis et al. [24] performed finite-element analysis on the difference in the stress applied to the bone around the implant site when the implant was placed in the axial direction, when the implant was placed tilted, and with or without a cantilever. They reported no difference in stress between axial and tilted implants, and the difference was dependent on the presence or absence of the cantilever. It is biomechanically advantageous to shorten the distance of the cantilever via tilted implantation. Therefore, there is no difference in the amount of marginal bone resorption and the survival rate of the implant between the angled placement using this technique and the placement along the tooth axis. Furthermore, since the cantilever can be shortened by embedding in the centrifugal slope, it is considered to be a superior method in terms of mechanics.

Regarding the effects of length and primary stability, the consensus statement [25] on fixed prosthetic treatment with implants in edentulous maxillary patients recommends the placement of at least four implants. Furthermore, to perform immediate loading, it is recommended to place an implant with a length of $\geq 10$ mm and obtain primary stability of $\geq 30$ Ncm. In the present study, in all cases (34 cases) in which an implant with a length of $\geq 10$ mm could not be placed, additional implants were placed nearby. Regarding primary stability, the All-on-four concept consensus statement [26] recommends achieving a primary stability of $\geq 35$ Ncm. Further reports [27, 28] recommend the acquisition of primary stability of 35 Ncm when performing immediate loading. In the present study, additional implantation was performed, where it is possible (57 cases = 78.1%) for cases (73 cases) in which primary stability of $\geq 35$ Ncm could not be achieved. In the present study, there was no significant difference in survival rate due to implant length or primary stability. However, one reason for this was likely that the load could be distributed by performing additional insertions near implants that did not meet the criteria. There was no significant difference in the length of the implant and the survival rate, but the survival rate was low for implants < 10 mm in both the maxilla and mandible. Indeed, the OR indicated a 1.97-fold increased risk of failure for implants < 10 mm in length. In addition to situations in which implants with a length of < 10 mm must be placed due to problems with residual bone height, if sufficient contact area with the bone cannot be obtained, such as when the thread is exposed in the extraction socket, additional implantation should be performed nearby. That is, it is important to attempt to disperse the load by doing so. With respect to primary stability, in maxillary cases treated with the All-on-four concept, there was no difference in the survival rate of implants with primary stability > 30 or < 30 Ncm, even without additional placement [29]. It is also reported that linked implants can be loaded immediately even if the primary stability value is < 20 Ncm [30]. Thus, it is necessary to further examine the criteria for primary stability values that permit immediate loading.

### Patient-related factors

In the present study, we investigated the survival rate of implants in relation to the presence or absence of systemic disease. We did not observe any significant differences in survival rate between the presence or absence of systemic diseases for either the maxilla or the mandible. However, due to the small number of patients with each disease, it is not possible to draw conclusions from these results alone. There are several reports that patients with poorly controlled diabetes mellitus [10, 11] and cardiovascular disease [10, 12, 13] have a high risk of developing peri-implantitis and failure. Furthermore, it has been reported that patients receiving bisphosphonates for osteoporosis are at risk of implant failure [14]; thus, this is an issue for future investigation.

In the present study, a significant decrease in implant survival rate was observed in smokers in both the maxilla and mandible in univariate analysis. Similarly, there are several reports that smoking reduces the survival rate of implants [18, 31–33], and Maló et al. [33] reported that the survival rate of implants placed in smokers continued to decline after 5 and 10 years. Long-term follow-up and smoking cessation guidance are considered necessary for smokers undergoing implant treatment.

In the present study, there were no significant differences in implant survival by sex in both the maxilla and mandible. However, Malo et al. reported an association between male sex and decreased implant survival and increased marginal bone loss in the maxilla [3] and an association between male sex and increased mechanical complications, such as superstructure and screw fracture in the mandible [4], suggesting that more careful follow-up is considered necessary.

This was a limited-scope study that did not examine factors, such as the causes of tooth loss, the condition of opposing teeth (edentulous or dentulous), the presence or absence of bruxism, or multiple comparisons of risk factors. In particular, there are several studies indicating that bruxism is an important patient-related risk factor. De Angelis et al. [34] compared four localized risk factors—bruxism, smoking, bone augmentation, and lateral load on the implant body—and reported that bruxism was the greatest risk factor. Thus, because bruxism is

considered to be a very important factor, we would like to accumulate further data on this and examine its effects in the future.

## Conclusion

We treated the maxillae and mandibles of patients based on the All-on-four concept and studied patients who had undergone treatment ≥ 3 years prior. We obtained the following results:

1. While the implant survival rate after ≥ 3 years was generally high for both the maxilla and mandible, the maxilla had a significantly lower survival rate at the implant level.
2. The survival rates of maxillary implants within 24 months of implantation were significantly low at both the patient and implant levels.
3. The various risk factors influencing the survival rate were examined, with the maxilla of the 'treatment area' being the most influential factor.

**Abbreviations**
OR    Odds ratio
SD    Standard deviation

**Availability of data and materials**
All data generated or analysed during this study are included in this published article.

## Declarations

**Ethics approval and consent to participate**
This study protocol was approved by the Ethics Committee of Showa University. All participants provided informed consent verbally. Study information was disseminated to participants both verbally and in written form.

**Consent for publication**
Not applicable.

**Competing interests**
YS and PM received previous educational fees from Nobel Biocare Services AG. Other authors have no conflict of interest to declare.

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