The original concept for osseointegrated implants was to provide edentulous patients with stable support for prostheses to restore both oral function and quality of life.1–6 The clinical evidence for this treatment was first established by the original Brånemark team, who reported encouraging retro-prospective data on implant and prosthesis survival for 10 to up to 20 years.1,7,8 In the late 1970s, the first prospective study on osseointegrated implants was designed to further evaluate function of osseointegrated implants in the edentulous jaw, showing favorable clinical results.9–13 These early results were thereafter confirmed by other clinical teams also showing similar function of the treatment protocol.14–19 Thereafter, early results were followed by numerous other prospective and retrospective short- and long-term clinical studies on the treatment of the edentulous jaw.20,21 However, Kwon et al,21 presenting a meta-analysis on implant function in the edentulous jaw on short-term (5 to 10 years) and long-term (more than 10 years) perspectives, reported problems identifying studies with a follow-up period exceeding 10 years. They considered these long-term follow-up studies to be “scarce” in the literature.21 Of the 18 studies included in their report, only 3 covered data on 15 years or more, and no patients were followed up for more than 23 years.21 Accordingly, there seems to be a need for more follow-up studies on edentulous implant patients exceeding at least a 10-year follow-up.

The aim of the present study was to report clinical data on implant failures in a large number of edentulous patients consecutively treated in routine practice at one referral clinic over a 30-year period of time. Available data were analyzed in a multivariate logistic regression model to identify possible factors of significance for overall implant failures.

Purpose: To report retro-prospective data on the prevalence of overall implant failure in a large number of edentulous patients treated at one referral clinic over a 30-year period and to analyze possible associations between implant failure and basic clinical variables. Materials and Methods: Altogether, 24,781 implants were consecutively placed in 4,585 edentulous arches between 1986 and 2015. All implant failures identified at the clinic during follow-up were consecutively recorded, and a multivariate logistic regression analysis was performed to identify possible associations between implant failure and different clinical factors. Results: Altogether, 1,333, 688, and 249 treated arches were followed up for 15, 20, and 25 years, respectively. Cumulative survival rates (CSR) for the treated arches were 86.2% and 83.8% after 15 and 25 years, respectively. Most patients lost only one implant each (58%). Loss of all implants was reported in 68 arches, with total failure rates of 1.9% and 2.2% after 15 and 25 years, respectively. The strongest associations with increased risk for implant failure were maxilla (hazard ratio [HR] 4.76; 95% confidence interval [CI] 3.70 to 6.25) and implant surface (HR 2.38; 95% CI 1.59 to 3.57). Age at surgery, implant surgeon, calendar year of surgery, and time of follow-up also showed significant associations with risk of implant failure (P < .05). A completely steady-state level in implant survival was not observed, but few implants were lost up to the last years of follow-up. Conclusion: There is a higher risk for implant failure in the maxilla compared to the mandible. Risk is reduced when using implants with a moderately rough surface. The highest risk for failure was observed during the first year. This was followed by a reduced failure rate, which never reached a steady-state level. Int J Prosthodont 2018;31:425–435. doi: 10.11607/ijp.5875
Materials and Methods

The present retro-prospective register study covered all patients consecutively treated with dental implants in the edentulous jaw from January 1986 to December 2015 at one referral clinic (Brånemark Clinic, Public Dental Care, Region of Västra Götaland, Sweden). Based on previous early Brånemark group studies, basic clinical parameters were recorded in special logbooks from the start of the clinic in 1986 (prospective), aiming to allow retrospective follow-up studies on selected patients at a later stage (retrospective). A systematic follow-up program to invite patients to participate after treatment was also designed at this time. The follow-up in the current study covers clinical recalls up to May 2017, which allows for at least 1 year of follow-up in included patients. Patients that had become edentulous after tooth extraction but that had previously been treated with implants in the partially edentulous jaw; patients with re-entry surgery in the edentulous jaw due to implant failure; nonresidence edentulous patients living abroad; and patients provided with major bone grafts under general anesthesia at the hospital were excluded from the study group. The study was approved by the Regional Ethical Review Board, Gothenburg, Sweden (#197-12).

All patients had been referred to the clinic for implant surgery, and the majority were also restored with the final prosthesis at the referral clinic. Implants were placed by 23 dentists at the clinic during the inclusion period.

Between 1986 and 2002, nearly all patients were provided with implants using a turned surface with an external hexagonal head (Nobel Biocare). Surgery was performed according to an original two-stage implant surgical protocol in both arches. During this period, all patients were given at least one dose of antibiotics in association with the surgery. After surgery, a majority of the patients were also provided with a fixed prosthesis in the referral clinic. Basic protocol during the entire study period (1986 to 2015) was to connect the prostheses to the abutments. Prostheses were designed as fixed, screw-retained restorations with a metal framework either in cast gold alloy or fabricated in titanium and either using a laser-welding technique or, later, a computer-aided design/computer-assisted manufacture (CAD/CAM) protocol. The metal frameworks supported on average 10 (maxilla) to 12 (mandible) artificial denture teeth, cured to the metal frameworks by means of acrylic resin. The frameworks were provided with one or two bicuspid cantilevers distal to the terminal implant on a routine basis. Occasionally, patients were also treated with a removable overdenture, in most situations supported by two to four implants and provided with a clasp metal bar for retention.

Implant surgery from 2003 to 2015 was performed according to a basic protocol using either a one-stage (mandible) or two-stage (maxilla) surgical procedure placing implants with a moderately rough surface. When it was indicated due to poor patient health, severe loading situation, or compromised available bone volume/bone quality, some patients treated in the mandible received implants according to a two-stage protocol. Occasionally, an immediate implant placement protocol was used in direct association with tooth removal. During this period, all patients received antibiotics on a routine basis at surgery except for those selected by random in 2014 and 2015, who were excluded from this routine and treated without antibiotics at surgery. Immediate grafting procedures using either autologous or nonautologous bone grafts (predominantly Geistlich Bio-Oss, Geistlich Pharma) were occasionally performed in selected patients.

The final prosthetic treatment in this group was performed by 1 of 16 different dentists (15 prostodontists) at the referral clinic or by the referring dentist, of whom almost all were general dentists.

After treatment, all patients were invited to participate in a follow-up program at the referral clinic, where intraoral periapical radiographs were taken on a routine basis at prosthesis placement and then at the time of the first annual recall after prosthesis placement. A clinical and radiographic examination was thereafter scheduled after 5 years in function and then every 5 years of follow-up. When indicated, radiographs were taken at longer or shorter time intervals.

Data on patients, operations, and implants at implant surgery were retrieved from surgical logbooks for the entire period of inclusion (Table 1). Recorded events (dichotomous) in the present study were related to all failed implants that had been identified and removed at the clinic after implant surgery; during the entire period of follow-up (overall implant failure); early (up to 1 year after implant surgery); or late (> 1 year after implant surgery). Accordingly, time of failure was related to implant surgery as the baseline.

Statistical Analyses

Descriptive statistics are presented as numbers, frequencies, percentages, means, and standard deviations (SDs). Cumulative survival rates (CSRs) for treated arches without failures were calculated according to general principles, as described by Kaplan and Meijer.

Statistical analyses were performed in accordance with earlier studies by the same biostatistician.
regarding the event implant failure in relation to available factors, as given in Table 1. Statistics were based on the first event of an implant failure in the treated arch. The statistical analysis was performed by first analyzing the available factors using a univariate Poisson regression analysis. Thereafter, identified significant factors were analyzed together in a final multivariate logistic regression analysis using a forward protocol; ie, including the significant factors one by one until no further contribution was observed. The multivariate analysis was first performed using treated arch, followed by an analysis at the patient level. When testing on the patient level, every second maxilla or mandible was excluded at random from the analysis for patients treated in both arches. Confidence intervals (95% CIs) were calculated for hazard ratio (HR) values. P values below 5% were considered statistically significant (P < .05).

Since the above presented statistical methods only analyze linear relationships, nonlinear associations between implant failure and time after surgery, as well as relationship to number of implants, were studied by means of a spline logistic regression model.

Calculations of CSR according to Kaplan and Meijer lack the means to compensate for dependent observations and are questionable for use for survival rates based on all implants (implant level) that are not independent statistical observations (ie, when many implants are placed in the same arch). Still, some few descriptive results at the implant level are reported in the present study to allow for comparison to other studies based on implant-level statistics. However, these results should be judged with caution due to the limitations in the handling of statistical data not based on independent observations.

Results

Overall Patient Databases

In total, 9,343 individual patients were consecutively treated with 41,876 dental implants during 11,994 implant operations between January 1986 and December 2015 at the present referral clinic. The mean age at implant surgery was 56.5 years (SD 18.65) for this group.

After exclusion of all partially edentulous patients and the edentulous patients accounted for in Materials and Methods, the total group (patients from 1986 to 2015) was comprised of 4,049 edentulous patients (43.3% of the original population) who were provided with 24,781 implants placed in 4,585 edentulous arches (Table 2, Figs 1 and 2). Altogether, 536 of the patients had been treated in both arches (13.2%). A total of 2,455 operations were performed in female patients (53.4%), and the overall mean age at implant surgery was 64.5 years (SD 11.44), ranging from 16.9 to 100.2 years.

Patients Lost to Follow-up

All patients were invited for follow-up at the referral clinic after implant surgery up to May 2017. Recorded mean follow-up time from surgery to last examination at the referral clinic was 10.8 years (SD 7.53). The longest follow-up time for a patient in this group was 31.1 years. Altogether, 1,939 patients (2,166 treated edentulous arches) were deceased during follow-up (48.0%), of whom 227 were treated in both arches (11.7%). In total, 49, 287, 752, 1,364, 1,846, and 2,100 treated arches were lost due to deceased patients at 1, 5, 10, 15, 20, and 25 years after implant surgery, respectively. The remaining missing patients were lost due to: scheduled for a later time of examination at the referral clinic; compromised health; did not want to come for examination; were followed up by other dentists; and/or moved from the region. Based on a digital file system, the overall mean time of follow-up for all patients—including visits at other clinics in the Public Dental Care system of the region—was 14.7 years (SD 7.94) at the termination of the study.

### Table 1

<table>
<thead>
<tr>
<th>Variables</th>
<th>Univariate regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at surgery (cut-offs: 75/80 y)</td>
<td>&lt; .05/NS</td>
</tr>
<tr>
<td>Age at surgery (HR)</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>Treated in both arches (yes/no)</td>
<td>NS</td>
</tr>
<tr>
<td>Gender (male/female)</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>Surgical period/implant surface&lt;sup&gt;b&lt;/sup&gt; (1986–2002/2003–2015)</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>Arch (maxilla/mandible)</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>No. of implants (HR)</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>Overdenture (maxilla)</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>Time of follow-up after surgery</td>
<td>&lt; .05</td>
</tr>
<tr>
<td>Surgeon (one surgeon vs all other)</td>
<td>&lt; .05&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Surgery immediate/one-/two-stage</td>
<td>&lt; .05&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Calendar year of surgery (1986 to 2015)</td>
<td>&lt; .05</td>
</tr>
</tbody>
</table>

HR = hazard ratio.
<sup>a</sup>1986 to 2002 and 2003 to 2015, respectively.
<sup>b</sup>1986 to 2002 with turned implants; 2003 to 2015 with moderately rough surface implants.
<sup>c</sup>Four surgeons with increased risk and one surgeon with decreased risk.
<sup>d</sup>One-stage surgery decreased risk, but only when performed in mandibular arches with implants with a moderately rough surface.
The number of implants placed in edentulous patients between 1986 and 2015 ranged from 2 to 8 per jaw (mean 5.4 [SD 1.07]).

During the first period of inclusion (1986 to 2002), 3,111 patients were provided with 19,338 Brånemark System implants (Nobel Biocare), mostly with a turned implant surface and an external hex, in 3,493 edentulous arches (Table 2). In this subgroup, 28 arches (0.8%) were provided with one or more implants with moderately rough surfaces (n = 76 implants [0.4%]). Altogether, 9,121 implants were placed in 1,479 maxillary arches, and 10,217 implants were placed in 2,014 mandibular arches (Table 2). All implants in the maxilla were placed according to a two-stage surgical procedure (100%), but 58 operations were performed as one-stage operations in the mandible (2.9%). Thirty-eight of these operations were handled as an immediate/early loading protocol, and the remaining 20 as a delayed loading protocol, waiting for prosthesis placement 2 to 4 months after implant/abutment surgery.

During the second period of inclusion (2003 to 2015), 936 patients were provided with 5,443 implants with a moderately rough implant surface in 1,092 edentulous arches (Table 2). In total, 3,210 implants were placed in the maxilla and 2,233 implants in the mandible. Most of the implants (n = 5,207) were Brånemark System implants (Nobel Biocare) provided with a TiUnite surface and an external hex (Nobel Biocare), but Astra Tech Implant System implants (Dentsply Implants; OsseoSpeed; 18 edentulous arches/91 implants) and Lifecore...
Restore implants (Lifecore Biomedical; Resorbable Blast Media [RBM] surface; 37 edentulous arches/145 implants) were also placed in some patients (5.9%). All but 15 operations (2.7%) during this period were performed according to a two-stage surgical procedure in the maxilla. In the mandible, a one-stage protocol was routine, but 141 two-stage operations (26.2%) were performed as well. In 59 of all implant operations, the implants were immediately placed after tooth extraction (40 operations in the mandible), and immediate local bone grafts were performed in 78 arches (55 operations with nonautologous grating material), most often performed in maxillary (n = 73; 93.6%). Altogether, 112 arches were provided with removable overdentures, of which 78 were placed in the mandible. Prosthetic treatment was performed in the referring clinic by general dentists in 92 of the treated arches (2.0%).

Implant Failures: Descriptive Overview

In total, 565 patients (576 treated edentulous arches) were recorded with implant failures (1,194 implants) from implant surgery to the termination of the study (Tables 3 and 4; Fig 3). No more than three events of implant failure were reported in any treated arch. Of 803 reported events of implant failures, 344 were observed during the first year (43%), 131 during the second year (16%), and 147 for the 3 following years up to 5 years after implant surgery (18%). The remaining 181 events were observed after 5 years in function. The last reported first and second events of a failure were recorded after 24.7 years and 26.2 years after implant surgery, respectively. A total of 391 arches (68%) were recorded with implant failures up to the first annual examination, while 309 were recorded up to 1 year after implant surgery (Table 3).

Table 3 Overall Number of Followed-up Edentulous Arches, Percentage of All Arches Treated During the Study Period, and Number of Implant Failures in Treated Arches

<table>
<thead>
<tr>
<th>Years of follow-up</th>
<th>Followed-up arches</th>
<th>No. of arches with failures (events)</th>
<th>CSR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total no.</td>
<td>% of total</td>
<td>First event</td>
</tr>
<tr>
<td>Inclusion</td>
<td>4,585</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>0–1</td>
<td>4,279</td>
<td>93.3</td>
<td>309</td>
</tr>
<tr>
<td>&gt; 1–5</td>
<td>3,388</td>
<td>77.3</td>
<td>160</td>
</tr>
<tr>
<td>&gt; 5–10</td>
<td>2,206</td>
<td>55.2</td>
<td>62</td>
</tr>
<tr>
<td>&gt; 10–15</td>
<td>1,333</td>
<td>39.0</td>
<td>23</td>
</tr>
<tr>
<td>&gt; 15–20</td>
<td>689</td>
<td>25.2</td>
<td>16</td>
</tr>
<tr>
<td>&gt; 20–25</td>
<td>249</td>
<td>15.5</td>
<td>6</td>
</tr>
<tr>
<td>&gt; 25–30</td>
<td>11</td>
<td>7.1</td>
<td>0</td>
</tr>
</tbody>
</table>

aCumulative survival rate (CSR) calculated for arches without any failures (first event) and arches without complete failure of all implants (total failures).

bThe CSR is based on few arches; therefore, caution is recommended when interpreting the results.
A total of 804 implants were lost at the first event (576 arches), another 279 at a second event (164 arches), and 110 at a third event (63 arches). Those treated arches with a first implant failure presented a higher risk for a second and third failure during follow-up (Fig 4). Altogether, 333 arches presented one implant failure (58%), 92 lost a total of two implants (16%), and 68 lost all implants (12%) during follow-up. Overall, the CSRs for arches without any failures and for arches with all failures, as well as an estimated CSR for implants, are presented in Fig 5.

The highest risk for first implant failures in the patient group was during the first year after implant surgery (Figs 3 to 5). The risk for a first failure was thereafter reduced by time and reached a low level after the first 2 to 3 years in function (Figs 3 to 5). Even though the risk for an implant failure decreased over time (Fig 4), a steady state in implant survival was not established during long-term follow-up (Fig 5).

Analysis of Risk Factors

The first univariate Poisson regression analysis of the total group of patients revealed 10 significant (P < .05) variables associated with an overall risk for implant failure (Table 1).

In the multivariate logistic regression analysis, seven variables related to the patient remained significant for overall implant failures (Table 6). Two of the significant variables showed a more obvious association with increased risk for implant failure than the others; for instance, treatment in the edentulous maxilla with a fixed prosthesis showed an overall increased risk for failure of 376% compared to treatment in the mandible (HR 4.76; Table 6). The second major risk factor was implant surface, where use of implants with a turned surface (1986 to 2002) increased the overall risk for an implant failure by 138% (HR 2.38; Table 6). A similar pattern was also observed for early and late implant failures (Table 6), where treatment with an overdenture in the maxilla showed the highest risk for implant failure during the early period after implant surgery (Table 6; up to 1 year).
Fig 5 Overall cumulative survival rates (CSRs) for treated edentulous arches without any reported implant failure (black), with no complete failures of implants (gray), and with implant survival (dotted gray) over the 30-year study period. Note that the y axis is truncated and the CSRs for implants have been calculated by using estimations described by Kaplan and Meijer,28 which do not compensate for statistically dependent observations when including several implants in the same arch. Therefore, caution is recommended when interpretation of the CSR results is based on implant level.

Table 6 Variables Statistically Associated with Increased Risk for Implant Failure in Entire Group of Edentulous Patients

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Age at surgery</td>
<td>0.98 (0.97–0.99)</td>
<td>0.99 (0.98–0.99)</td>
<td>Lower risk for older patients</td>
<td></td>
</tr>
<tr>
<td>Calendar year of surgery</td>
<td>1.03 (1.01–1.06)</td>
<td>1.03 (1.00–1.05)</td>
<td>Later year of inclusion increases risk</td>
<td></td>
</tr>
<tr>
<td>Implant surface</td>
<td>3.45 (1.96–5.88)</td>
<td>1.89 (1.28–2.78)</td>
<td>2.38 (1.61–3.57)</td>
<td>Higher risk for implants with turned surface</td>
</tr>
<tr>
<td>No. of implants (5 vs other)</td>
<td>1.44 (1.04–1.99)</td>
<td>Lower risk with 5 implants compared to other numbers (2 to 4/6 to 8)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overdenture in maxilla</td>
<td>9.83 (2.34–41.3)</td>
<td>Higher risk for overdentures than fixed prostheses in maxilla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgeon #9</td>
<td>1.53 (1.07–2.20)</td>
<td>Higher risk compared to all others</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surgeon #5</td>
<td>0.36 (0.14–0.92)</td>
<td>0.51 (0.27–0.95)</td>
<td>Lower risk compared to all others</td>
<td></td>
</tr>
<tr>
<td>Time since surgery</td>
<td>1.69 (1.12–2.57)</td>
<td>0.86 (0.83–0.88)</td>
<td>0.76 (0.74–0.79)</td>
<td>Increased (early)/reduced risk (late) the longer follow-up in period</td>
</tr>
</tbody>
</table>

*Multivariate logistic regression analysis at patient level.
that most implants are lost during the early period after implant surgery,\textsuperscript{1,7} examination.\textsuperscript{23,24,29–32} However, with the diversified clinical protocols used such as abutment connection, implant loading, prosthesis placement, or loading may result in that no implants at all are at risk for early failures (ie, in an immediate loading protocol) compared to being at risk for several months (ie, in a two-stage surgical protocol with delayed loading).\textsuperscript{24} To avoid this problem with different clinical procedures that have been used in the present study over a 30-year period of time, only one baseline time point has been used: implant surgery. From this time point, 1 year has been calculated to be the cut-off point between early and late failures. This alternative time point reduces the number of reported arches with early failures up to 1 year after surgery by about 15% compared to if a cut-off time point of first annual examination had been used.\textsuperscript{23–25,33} This difference may have an impact on statistical calculations on early and late risk factors, with more implant failures early in the late period when using 1 year after surgery as the cut-off. Still, it can be noticed that the present results for early failures are comparable with the results of an unpublished study on a similar patient group that used first annual examination as the cut-off time point.

A total of 2,206 treated arches were still available for follow-up after 10 years (Table 3). After these first 10 years, the following 20 years of follow-up in the present study can be referred to as the long-term follow-up, according to Kwon et al.\textsuperscript{21} During this late period, a total of 66 events of implant failures (115 implants) were recorded in the present edentulous arches, reducing the CSR of treated arches without failures by 3.6% (Table 3). Thus, compared to the early failure time after implant surgery (Fig 3, Table 5; HR 1.69), the risk for implant failure seems to decrease with time (Table 5; late period HR 0.86/overall HR 0.76), but is still higher for those patients with an earlier failure than for a first failure (Fig 4). Compared to the few

**Discussion**

Many clinical follow-up studies have tried to distinguish between implant failures during the early period of establishing osseointegration and those during the later period when established osseointegration has already taken place.\textsuperscript{23,29–32} This approach is probably based on the observation that most implants are lost during the early period after implant surgery,\textsuperscript{1,7} which is in accordance with the observations in the present study (Fig 3). To separate these two time periods, different cut-off time points have been used that are often related to clinical procedures during implant treatment, such as abutment connection, implant loading, prosthesis placement, baseline radiographic examination, and first radiographic follow-up examination.\textsuperscript{23,24,29–32} However, with the diversified clinical protocols used today, these clinically related cut-offs introduce problems when comparing different studies in which cut-offs such as abutment connection, prosthesis placement, or loading may result in that no implants at all are at risk for early failures (ie, in an immediate loading protocol) compared to being
studies available on edentulous patients followed up for 20 years,13,21,34,35 the present results on failures are close to or slightly higher than those reported earlier, and a completely steady-state level on implant failures cannot be observed here (Fig 5).

In one of the most recent major studies on treatment of edentulous patients, Niedermaier et al36 reported a steady-state implant survival rate of 97.0% from the third to the seventh year. No failures were reported in the group of 482 originally treated edentulous arches provided with 2,081 immediately loaded implants after the third year. This could suggest a steady-state survival rate in a larger group of patients from the third year, which is not in accordance with the present study.36 However, there seems to be a reduction of numbers of patients followed up over time, which introduces an obvious problem for interpreting survival over long-term time periods. In the present study, the average annual incidence of implant failure per patient over a 5-year period can be calculated to be 0.38 new patients per year after the first 5 years of function (Table 3). With such a low incidence of expected failure rates, it may be difficult to identify the few late failures in a small group of patients. Thus, the presumed steady-state level in small groups may not be expected in larger groups of patients. Accordingly, the last implant failure in an earlier intact arch in the present study was recorded after 24.7 years, and the very last failure was observed after 26.2 years, also recorded as a complete failure of all remaining implants in that arch.

In the present study, the risk for implant failure was observed to be higher in maxillary compared to mandibular arches. This indicates that the distribution between treated arches seems to be of significance for implant failures in the edentulous population, with a higher risk for failure when there is a higher proportion of included maxillary arches (Table 6). This relationship between risk for implant failures in the maxilla and in the mandible has been reported earlier for other groups of edentulous patients.7,11,18,21,34 Jemt et al23 showed in a recent large study that there was a clear difference between the risk for early implant failures in maxillary compared to mandibular arches, with a pronounced reduction of risk when changing from implants with a turned to a moderately rough surface in any type of arch. These observations on early failures have been statistically confirmed in a subgroup of edentulous patients from the large original patient group (unpublished study) in accordance with the present study (Table 6). Thus, a significant reduction in early failure rate by using implants with a moderately rough surface was reported, but the observation was only statistically significant for the edentulous maxilla, not for the mandible. These authors did not analyze late implant failures, but the present study indicates that moderately rough surfaces may also have a significant favorable impact on the failure pattern during later periods of follow-up (Table 5).

In the first univariate analysis, five surgeons showed a different risk for implant failures compared to all other surgeons (Table 1). This observation is in accordance with a previous study covering all treated patients at the clinic.37 After the multivariate analysis, two surgeons remained with a statistical association with implant failures: one with an increased risk for failures in the maxilla, and one with decreased risk for failures (Table 6). The increased risk for the first surgeon could be related to starting too early with more difficult edentulous maxillary arches before more experience with less complicated situations had been established. This is an approach which to some extent could be associated with the training protocol for new surgeons in the clinic and with the surgeon’s attitude.37,38 The other surgeon had earlier been shown to select more predictable patients, treating fewer edentulous maxillary arches and using surgical protocols with lower risk.24,25 This surgeon represents a more cautious approach, whereas other surgeons in the clinic have handled the more demanding situations.24,25,37 Thus, attitude and risk-taking seem to be important factors for the complication pattern in a clinic. Recently, Jemt et al39 reported from another patient group an increasing use of nonautologous grafting procedures during the inclusion period combined with an increasing prevalence of peri-implantitis problems during inclusion.39 This change of surgical procedures during long-term inclusion must be considered in the present study, as it is also a clear indication of increased risk for failure by time of inclusion (Fig 6, Table 6). This pattern of increased risk for failures related to calendar year of inclusion could be associated with a changed attitude in the clinic regarding treatment procedures and risk for failures, but could also be associated with the more difficult patients treated and that reasons for tooth extraction and general health of patients may change over time.40 Data have also suggested that especially younger edentulous patients treated in the early period of inclusion may present better general health and have lower long-term mortality compared to patients treated in the later part of the present inclusion period, which may have an impact on implant failures over time.40

Conclusions

Within the limitations of this large, long-term, retrospective effectiveness study, the following conclusions could be made for routine treatment of edentulous arches:
A substantial number of edentulous patients may be deceased during follow-up when covering periods of 20 to 30 years.

Altogether, 1,333, 689, and 249 treated arches were available for follow-up after 15, 20, and 25 years of follow-up, respectively.

CSRs related to arches without failures were calculated to be 86.2%, 84.9%, and 83.8% after 15, 20, and 25 years, respectively. Corresponding implant CSRs were estimated to be 94.3%, 93.9%, and 93.3%.

Highest risk for implant failures was observed for the first 2 years after implant surgery, but a low number of implants were lost throughout the entire follow-up period.

Overall implant failures were significantly associated with placement arch, implant surface, surgeon, age at surgery, time after surgery, and calendar year of surgery. The highest risk was observed for maxillary arch (HR 4.76) and for use of implants with a turned surface (HR 2.38).

Acknowledgments

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References

A Systematic Review and Meta-Analysis of 3-unit Fixed Dental Prostheses: Are the Results of 2 Abutment Implants Comparable to the Results of 2 Abutment Teeth?

The purpose of this systematic review and meta-analysis was to compare the performance of three-unit partial dentures on teeth to the performance on implants and to evaluate survival of the partial dentures, survival of the teeth or implants, condition of the hard and soft tissues surrounding the supports, complications, and patient-reported outcome measures (PROM) after a mean observation period of at least 1 year. A literature search was conducted using a combination of the search terms: fixed partial denture and fixed dental prostheses (FPDs). An electronic search for data published up to January 2017 was undertaken using the MEDLINE, EMBASE, and Cochrane Library databases. Eligibility criteria included clinical human studies—either randomized or not, interventional or observational—that evaluated the results of three-unit FDPs. A total of 1,973 three-unit FDPs were supported by teeth, and 765 were supported by implants. No significant differences were found in the survival of the supporting abutments ($P = .52; 99\%$ vs $98.7\%$ survival per year) or in the survival of the prostheses ($P = .34; 96.4\%$ vs $97.4\%$ survival per year). Both treatments showed an almost equally low complication rate, but there was a low level of reporting of hard and soft tissue conditions and PROM. It was concluded that implant-supported, three-unit FDPs seem to be a reliable treatment with survival rates not significantly different from those of teeth-supported FDPs.