

# A retrospective study on clinical and radiological outcomes of oral implants in patients followed up for a minimum of 20 years

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## Abstract

**Background:** Very long-term follow-up of oral implants is seldom reported in the literature.

**Purpose:** To assess oral implant failure rates and marginal bone loss (MBL) of patients followed up for a minimum of 20 years.

**Materials and Methods:** Implants placed in patients followed up for 20+ years were included. Descriptive statistics, survival analyses, generalized estimating equations were performed. Three-hundred implants were randomly selected for MBL.

**Results:** 1,045 implants (227 patients) were included. Implant location, irradiation, and bruxism affected the implant survival rate. Thirty-five percent of the failures occurred within the first year after implantation, and another 26.8% in the second/third year. There was a cumulative survival rate of 87.8% after 36 years of follow-up. In the last radiological follow up, 35 implants (11.7%) had bone gain, and 35 implants (11.7%) presented at least 3 mm of MBL. Twenty-six out of 86 failed implants with available radiograms presented severe MBL in the last radiological register before implant failure.

**Conclusions:** Most of the implant failures occurred at the first few years after implantation, regardless of a very long follow up. MBL can be insignificant in long-term observations, but it may, nevertheless, be the cause of secondary failure of oral implants in some cases.

## KEYWORDS

dental implants, implant failure, long-term follow-up, marginal bone loss, multivariate analysis, risk factors

## 1 | INTRODUCTION

Brånemark discovered the process of osseointegration in the 1960s and placed the first dental implant about 50 years ago.<sup>1</sup> Since then dental implants supported by evidence-based data became an increasingly viable alternative to conventional prosthodontic treatment options. Thousands of clinical studies on dental implants have been carried out and published. Most studies present data on implant and prosthesis survival, as well as on bone response adjacent to the implants. However, many of the studies are on a relatively short- or medium-

term basis.<sup>2</sup> There is an increase in the volume of dental implants being placed and follow up is essential to determine and predict a future clinical course. The patients receiving implants expect to keep them for years ever, and therefore it is more reliable to have a basis for dental implants prognosis with long follow-up studies.

During the first decades of osseointegration, the most commonly used implant in the world was the turned ("machined") Brånemark implant. This implant design showed quite good long-term data with survival rates in the mandible above 90% and in the maxilla above 80% for a follow up time of 5 years or more.<sup>3-5</sup> Having said this, there were

some problems reported in soft maxillary bone<sup>6,7</sup> and the old Brånemark implants showed less good clinical results if loaded prematurely or used in form of short implants.<sup>8</sup> Another problem was reported with Brånemark implants; that of substantial marginal bone loss (MBL) allegedly leading to disease entitled "Peri-implantitis." Roos-Jansåker et al.<sup>9</sup> initially defined disease around oral implants based on bleeding on probing and >1.8 mm of MBL at 9–14 years of follow up; they reported 6.6% of their Brånemark implants with disease. Fransson et al.<sup>10</sup> saw any bone loss after the first year if combined with bleeding on probing and pus to be synonymous to implant disease and reported 12.4% of their 5–20 years followed up Brånemark implants with such problems.

These early reports of disease may not have survived the scrutiny of time,<sup>11</sup> but previous reports have focused on the importance of careful monitoring of implant MBL as one way of documenting their long-term performance.<sup>3,12</sup> The latter authors reported that a successful implant would maximally lose 1 mm of bone during the implant's first year in function and less than 0.2 mm annually thereafter. Implants losing more bone would not be successful, but may certainly survive and function in the bone of the patient.

The purpose of the present study was to assess the dental implant failure rates and MBL of patients followed up for a minimum of 20 years. By selecting such a long follow up time of implants placed at one specialist clinic in Malmö, the included implants are indeed old turned Brånemark ones ( $n = 1,025$ ) and a very small number of turned Astra implants ( $n = 20$ ).

## 2 | MATERIALS AND METHODS

### 2.1 | Materials

This retrospective study was based on all 2,670 patients provided with implants, consecutively treated on a routine basis at one specialist clinic (Clinic for Prosthodontics, Centre of Dental Specialist Care, Malmö, Sweden) during the period from 1980 to 2014. The study protocol was approved by the regional Ethical Committee, Lund, Sweden (Dnr 2014/598; Dnr 2015/72).

### 2.2 | Definitions

An implant was considered a failure if presenting signs and symptoms that led to implant removal. Thus, a failed implant in our study is equal to a lost implant. The failures were classified into two types: (1) implants lost due to lack/loss of osseointegration and (2) fractured implants. Primary failures were those occurring until/at the day of the 2° stage surgery (abutment connection).

For the implants that were lost, we considered as severe MBL at least 1.0 mm of bone loss per year or a minimum bone loss of 1/3 of the implant's full length in the last radiological register before the failure of an implant. That does not mean that, for example, an implant of 15 mm would take an approximate time of 15 years to fail. An implant could have lost a considerable amount of peri-implant bone under a short period of time—loss of 8 mm of vertical bone in 5 years, for

example—that, together with other factors, would condemn the permanence of the implant in the site.

### 2.3 | Inclusion and exclusion criteria

Only implants placed in patients followed up for at least 20 years were included. Patients with all modern types of threaded implants with cylindrical or conical design were included. Zygomatic implants were not included in the study, as well as implants detected in radiographies, but without basic information about them in the patients' files.

A number of 300 implants were randomly selected for MBL. Only implants not lost and with baseline radiographs taken within 12 months after implant placement and with a minimum of 10 years of radiological follow up were considered for MBL. Negative values correspond to bone loss. The marginal bone around the failed implants was also assessed.

### 2.4 | Data collection

The dental records of all patients ever treated with implants in the aforementioned clinic were read in order to collect the data. The data were directly entered into a SPSS file (SPSS software, version 23, SPSS Inc., Chicago, Illinois) as the files were being read. The following data were collected:

- (a) Implant-related factors: implant diameter and length;
- (b) Site-related factors: implant jaw location (maxilla/mandible), anterior or posterior location of the implant (sites from right canine to left canine teeth were considered anterior location), and bone quantity and quality of the implant sites, which were classified at the time of surgery according to the Lekholm and Zarb<sup>13</sup> classification;
- (c) Patient-related factors: patient's sex, age of the patient at the implant insertion surgery, general health, and behavioral history. The presence of a medicament list in the patients' records was also used to correlate the use of certain drugs to specific health conditions. Health factors assessed: diabetes types I or II, hypertension, hypercholesterolemia, hypothyroidism, asthma, chemotherapy, and irradiation of the head-neck region. The patients were also classified according to the intake of the following medication types: antidepressants, immunosuppressives, bisphosphonates, antithrombotic agents (antiplatelet, anticoagulant, thrombolytic drugs), hormone replacement therapy in women, and medicaments to reduce the acid gastric production. Behavioral factors assessed: smoking habits, use of snuff, bruxism;
- (d) Other factors: prescription of antibiotics (the prophylactic antibiotic regimen was usually starting 1–2 hours before surgery and going from 5 to 7 days postoperatively), bone graft procedures, type of implant-supported prosthetic restoration (single crown, partial bridge with 2–6 prosthetic elements, partial bridge with 7–10 prosthetic elements, full-arch, overdenture), number of days until failure, and follow-up time.

As the standard protocol in the clinic, the patients' dental hygiene was followed up by a dental hygienist within 6 months after the final implant-supported/retained restoration. Each patient then attended a dental hygiene recall program based on individual needs.

## 2.5 | Marginal bone level evaluation

Reproducible intraoral radiographs were used. When there were no available digital radiographies from the baseline appointment, the analogue periapical radiographies were scanned at 1,200 dpi (Epson Perfection V800 Photo Color Scanner; Nagano, Japan). Marginal bone level (MBL) was measured after calibration based on the inter-thread distance of the Nobel implants (0.60 mm). Measurements were taken from the implant-abutment junction to the marginal bone level, at both mesial and distal sides of each implant, and then the mean value of these two measurements was considered. MBL was calculated by comparing bone-to-implant contact levels to the radiographic baseline examination. The Image J software (National Institute of Health, Bethesda) was used for all measurements.

## 2.6 | Statistical analyses

The mean, standard deviation (SD), and percentage were calculated for several variables. The Kolmogorov–Smirnov test was performed to evaluate the normal distribution of the variables, and Levene's test evaluated homoscedasticity. Differences between groups were compared with the *t*-test or Mann-Whitney test for continuous variables, depending on the normality. Survival analyses were performed. A life table was presented with cumulative survival rate (CSR), besides Kaplan-Meier analysis. Correlation and linear regression were performed to check the relationship between MBL and time of follow up. An implant-level model was performed in order to assess the effects of the implant-related and local bone factors on the implant failures, also

including health variables. A generalized estimating equations (GEE) method was used to account for the fact that repeated observations (several implants) were available for a single patient. All models were adjusted for clustering of subject and implants in a binary logistic regression model using GEE with a binomial distribution and a logit link function, while assuming an exchangeable working correlation structure. Initially a univariate GEE on each of the variables was performed. In order to verify multicollinearity, a correlation matrix of all of the predictor variables with a significant odds ratio (*P*-value cutoff point of 0.1) identified in the univariate GEE was scanned, to see whether there were some high correlations among the predictors. Collinearity statistics obtaining variance inflation factor and tolerance statistic were also performed to detect more subtle forms of multicollinearity. Then a multivariable model with a forced entry method was used to evaluate the effect of the factors that were univariately significant (*P* < .1) and did not present multicollinearity. A Wald chi-square test was used to analyze the statistical significance of each parameter within the model. The results of the final model were presented as an estimated OR of each significant prognostic variable (*P* < .05). SPSS software version 23 (SPSS Inc., Chicago, Illinois) was used for the statistical analyses.

## 3 | RESULTS

Overall, 642 of 10,096 implants (6.36%) failed. A number of 95 men (405 implants) and 132 women (640 implants) were followed up for at least 20 years and were included for analysis in the present study. The patients were followed-up for a mean  $\pm$  SD of  $291.0 \pm 33.7$  months (min-max, 244.4–437.5). These patients received 1,045 threaded implants with a cylindrical design –1,025 Nobel turned and 20 Astra turned implants. Fifty-eight patients presented 131 implants failures, 116 due to loss/lack of osseointegration and 15 failed fixtures due to implant fracture. The maximum number of implant failures in one

**TABLE 1** Distribution of implants with regard to Lekholm and Zarb (1985) classification<sup>a</sup> of bone quantity and quality. The number between parentheses represents failures

|                                                                      | A     | B       | C       | D       | E      | Total     | % Group <sup>b</sup> | % Failed <sup>c</sup> |
|----------------------------------------------------------------------|-------|---------|---------|---------|--------|-----------|----------------------|-----------------------|
| 1                                                                    | 8     | 10      | 15(2)   | 60(1)   | 16(2)  | 109(5)    | 10.5                 | 4.6                   |
| 2                                                                    | 51(5) | 162(21) | 147(13) | 19      | 19(4)  | 398(43)   | 38.1                 | 10.8                  |
| 3                                                                    | 21    | 158(18) | 185(11) | 46(15)  | 6(2)   | 416(46)   | 39.9                 | 11.1                  |
| 4                                                                    | 2     | 19(6)   | 37(7)   | 35(10)  | 27(14) | 120(37)   | 11.5                 | 30.8                  |
| Total                                                                | 82(5) | 349(45) | 384(33) | 160(26) | 68(22) | 1043(131) | 100                  | 12.6                  |
| % Group <sup>b</sup>                                                 | 7.9   | 33.5    | 36.8    | 15.3    | 6.5    | 100       |                      |                       |
| % Failed <sup>c</sup>                                                | 6.1   | 12.9    | 8.6     | 16.3    | 32.4   | 12.6      |                      |                       |
| Missing information of bone quantity/quality: 2 implants, 0 failures |       |         |         |         |        |           |                      |                       |

<sup>a</sup>According to the Lekholm and Zarb (1985) classification, bone quality is broken down into four groups according to the proportion and structure of compact and trabecular bone tissue: type 1 = large homogenous cortical/compact bone; type 2 = thick layer of compact bone surrounding a dense trabecular bone; type 3 = thin cortical layer surrounding a dense trabecular bone; type 4 = thin cortical layer surrounding a core of low-density trabecular bone. The quantity of jawbone is broken down into five groups (A, B, C, D, and E), based on the residual jaw shape following tooth extraction. Bone classified as 'A' presents the largest amount of bone among all classes, whereas bone classified as 'E' presents the lowest volume of bone.

<sup>b</sup>Percentage of implants in each bone quantity/quality class, considering all implants as 100%.

<sup>c</sup>Percentage of failed implants for each bone quantity/quality class.

TABLE 2 Life table for implant failure

| Interval start time (years) | Number entering interval | Number withdrawing during interval | Number exposed to risk <sup>a</sup> | Number of terminal events (failures) | Proportion terminating | Proportion surviving | Cumulative proportion surviving at end of interval |
|-----------------------------|--------------------------|------------------------------------|-------------------------------------|--------------------------------------|------------------------|----------------------|----------------------------------------------------|
| 0                           | 1037                     | 0                                  | 1037.0                              | 43                                   | .041                   | .959                 | .959                                               |
| 1                           | 994                      | 0                                  | 994.0                               | 17                                   | .017                   | .983                 | .942                                               |
| 2                           | 977                      | 0                                  | 977.0                               | 16                                   | .016                   | .984                 | .927                                               |
| 3                           | 961                      | 0                                  | 961.0                               | 8                                    | .008                   | .992                 | .919                                               |
| 4                           | 953                      | 0                                  | 953.0                               | 3                                    | .003                   | .997                 | .916                                               |
| 5                           | 950                      | 0                                  | 950.0                               | 5                                    | .005                   | .995                 | .911                                               |
| 6                           | 945                      | 0                                  | 945.0                               | 5                                    | .005                   | .995                 | .906                                               |
| 7                           | 940                      | 0                                  | 940.0                               | 2                                    | .002                   | .998                 | .905                                               |
| 8                           | 938                      | 0                                  | 938.0                               | 1                                    | .001                   | .999                 | .904                                               |
| 9                           | 937                      | 0                                  | 937.0                               | 2                                    | .002                   | .998                 | .902                                               |
| 10                          | 935                      | 0                                  | 935.0                               | 4                                    | .004                   | .996                 | .898                                               |
| 11                          | 931                      | 0                                  | 931.0                               | 2                                    | .002                   | .998                 | .896                                               |
| 12                          | 929                      | 0                                  | 929.0                               | 2                                    | .002                   | .998                 | .894                                               |
| 13                          | 927                      | 0                                  | 927.0                               | 2                                    | .002                   | .998                 | .892                                               |
| 14                          | 925                      | 0                                  | 925.0                               | 0                                    | 0.000                  | 1.000                | .892                                               |
| 15                          | 925                      | 0                                  | 925.0                               | 3                                    | .003                   | .997                 | .889                                               |
| 16                          | 922                      | 0                                  | 922.0                               | 4                                    | .004                   | .996                 | .885                                               |
| 17                          | 918                      | 0                                  | 918.0                               | 0                                    | 0.000                  | 1.000                | .885                                               |
| 18                          | 918                      | 0                                  | 918.0                               | 0                                    | 0.000                  | 1.000                | .885                                               |
| 19                          | 918                      | 5                                  | 915.5                               | 1                                    | .001                   | .999                 | .884                                               |
| 20                          | 912                      | 140                                | 842.0                               | 0                                    | 0.000                  | 1.000                | .884                                               |
| 21                          | 772                      | 112                                | 716.0                               | 1                                    | .001                   | .999                 | .883                                               |
| 22                          | 659                      | 137                                | 590.5                               | 0                                    | 0.000                  | 1.000                | .883                                               |
| 23                          | 522                      | 129                                | 457.5                               | 0                                    | 0.000                  | 1.000                | .883                                               |
| 24                          | 393                      | 113                                | 336.5                               | 2                                    | .006                   | .994                 | .878                                               |
| 25                          | 278                      | 84                                 | 236.0                               | 0                                    | 0.000                  | 1.000                | .878                                               |
| 26                          | 194                      | 48                                 | 170.0                               | 0                                    | 0.000                  | 1.000                | .878                                               |
| 27                          | 146                      | 46                                 | 123.0                               | 0                                    | 0.000                  | 1.000                | .878                                               |
| 28                          | 100                      | 59                                 | 70.5                                | 0                                    | 0.000                  | 1.000                | .878                                               |
| 29                          | 41                       | 23                                 | 29.5                                | 0                                    | 0.000                  | 1.000                | .878                                               |
| 30                          | 18                       | 10                                 | 13.0                                | 0                                    | 0.000                  | 1.000                | .878                                               |
| 31                          | 8                        | 0                                  | 8.0                                 | 0                                    | 0.000                  | 1.000                | .878                                               |
| 32                          | 8                        | 3                                  | 6.5                                 | 0                                    | 0.000                  | 1.000                | .878                                               |
| 33                          | 5                        | 0                                  | 5.0                                 | 0                                    | 0.000                  | 1.000                | .878                                               |
| 34                          | 5                        | 0                                  | 5.0                                 | 0                                    | 0.000                  | 1.000                | .878                                               |
| 35                          | 5                        | 5                                  | 2.5                                 | 0                                    | 0.000                  | 1.000                | .878                                               |

<sup>a</sup>The exact date of failure was unknown for 8 implants. Therefore, they were not considered here. If these 8 lost implants were included in the present life table, the CSR would be lower.

patient was nine. Failures were recorded for 130 Nobel implants and 1 Astra implant. The failures happened at a mean  $\pm$  SD of  $54.3 \pm 67.0$  months (min-max, 1.2–294.7) after implant insertion. The exact date of failure of 8 implants was not known; these failures were confirmed when these implants were no longer in place in subsequent radiograms. Nineteen failures happened before the abutment connection. 499 implants were installed in maxillae, of which 92 (18.4%) failed (82 due to loss/lack of osseointegration, 10 fractured implants), and 546 implants were placed in mandibles, of which 39 (7.1%) failed (34 due to loss/lack of osseointegration, 5 fractured implants).

Table 1 shows a comparison of groups according to the distribution of implants with regard to Lekholm and Zarb<sup>13</sup> classification of bone quantity and quality. A greater percentage of failed implants were placed in bone sites having been classified as quantities D and E and bone quality 4. Table 2 shows the life table for implant fracture. Thirty-five percent of the occurrences of failed implants occurred within the first year after implantation. Another 26.8% of the failures occurred in the second and third year after implant insertion. Thus, 59.3% of all failures occurred at the first 3 years after implantation. There was a CSR of 87.8% after 36 years of follow-up. Figure 1 shows the Kaplan-Meier analysis. No censored cases were observed before 20 years of follow-up, as only these cases were included in the present study.

All implants were inserted with open flapped surgery and had a delayed loading. Only 5 implants were inserted in fresh extraction sockets. The abutment connection surgery was performed after a mean  $\pm$  SD healing time of  $167 \pm 56$  days. The mean length of the inserted implants was  $12.4 \pm 2.7$  mm and the mean diameter for was  $3.74 \pm 0.09$  mm.

Seventy-four implants were used for single-crown restorations (3 failed due to loss/lack of osseointegration, 5 fractured implants), 242 implants for fixed partial prostheses of 2–6 prosthetic elements (23 failed due to loss/lack of osseointegration, 4 fractured implants), 25 implants fixed partial prostheses of 7–10 prosthetic elements (7 failed due to loss/lack of osseointegration, no fractured implants), 666

implants for full-arch fixed prostheses (69 failed due to loss/lack of osseointegration, 6 fractured implants), and 33 implants to support overdentures (9 failed due to loss/lack of osseointegration, no fractured implants). There was no information for 5 implants concerning the type of prosthodontic restoration performed.

The univariate GEE model at the implant-level showed that the following predictors had a statistically significant odds ratio at the implant-level (Table 3): location, bone quantity and quality, the intake of antidepressants, irradiation, the intake of medicaments to reduce the acid gastric production, bruxism, and the type of implant-supported prosthetic restoration. The following factors remained statistically significant in the multivariate GEE model (Table 4): location, irradiation, and bruxism.

Of the 4,691 implants that were placed until December 31st 1996, and then could theoretically reach the minimum of 20 years in the year of 2017, 2,762 implants (58.88%) were placed in patients that were deceased by the first day of the year of 2017. Of these 2,762 implants, 2,402 (86.97%) were placed in patients who died before a hypothetical 20-year follow up. Patient referral to other clinics and other reasons accounted for 884 of the unaccounted for implants.

With regard to the MBL around the 300 randomly selected implants, all Nobel turned implants, 1,948 measurements were performed, considering the several radiological follow ups for each implant. This resulted in a mean of 6.5 MBL measurements per implant. Each MBL measurement consisted of a mean value of mesial + distal measurements. A number of 1,032 MBL measurements were performed for the 152 implants in the maxilla and 916 MBL measurements for the 148 implants in the mandible. The baseline radiograms were taken at a mean  $\pm$  SD of  $7.0 \pm 2.4$  months (min-max, 0–12) after implant placement. The implants were radiologically followed up for mean  $\pm$  SD of  $244.8 \pm 54.8$  months (min-max, 127.2–350.2). At the last follow up, there was a mean  $\pm$  SD MBL of  $-1.405 \pm 1.504$  mm (min, max;  $-7.955, 1.442$ ) for all implants ( $n = 300$ ). These values at the last follow up were  $-1.391 \pm 1.691$  mm (min, max;  $-7.955, 1.442$ ) for implants placed in maxillae ( $n = 152$ ), and  $-1.419 \pm 1.289$  mm (min, max;  $-7.128, 0.858$ ) for implants placed in mandibles ( $n = 148$ ). The difference in MBL between implants placed in different jaws was not statistically significant at the last radiological follow-up ( $P = .176$ , Mann-Whitney test). The last radiological follow up was performed at a mean  $\pm$  SD of  $258.9 \pm 54.0$  months (min-max, 123.1–350.2) for implants placed in maxillae and  $229.4 \pm 52.7$  months (min-max, 127.2–336.8) for implants in mandibles. This difference in the mean last follow up between different jaws was statistically significant ( $P < .001$ , Mann-Whitney test).

In the last radiological follow up (Table 5), it was observed that 35 implants (11.7%) had bone gain (min-max 0.010–1.442 mm), 109 implants (36.3%) displayed up to 1 mm of MBL, 84 implants (28%) showed a MBL between 1 and 2 mm, 37 implants (12.3%) a MBL between 2 and 3 mm, and 35 implants (11.7%) with at least 3 mm of MBL, of which 7 implants (2.3%) presented MBL of more than 6 mm. It is important to stress that these 300 implants randomly selected for MBL measurements were among the implants that were not lost.

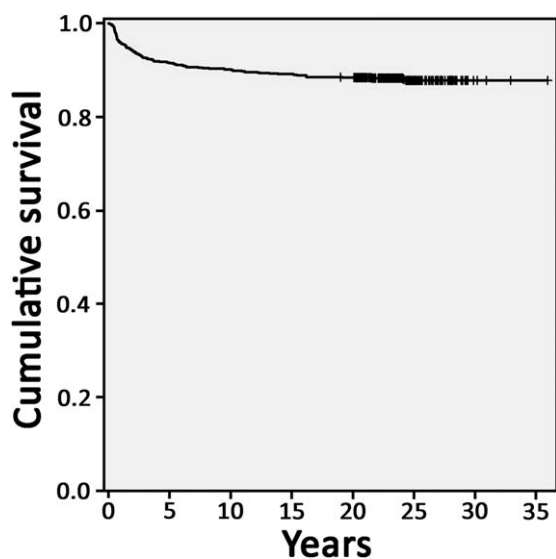


FIGURE 1 Kaplan-Meier curve

**TABLE 3** Risk factor analysis using a univariate generalized estimating equations (GEE) logistic regression model, at the implant-level (OR – odds ratio)

| Factor                           | Failure/<br>survival <sup>a</sup> | OR<br>(95% CI)        | P-value |
|----------------------------------|-----------------------------------|-----------------------|---------|
| <b>IMPLANT-RELATED FACTORS</b>   |                                   |                       |         |
| <i>Implant diameter</i>          |                                   |                       |         |
| Increase by 1                    | –                                 | 1.134 (0.045, 28.288) | .939    |
| <i>Implant length</i>            |                                   |                       |         |
| Increase by 1                    | –                                 | 0.930 (0.835, 1.035)  | .183    |
| <b>SITE-RELATED FACTORS</b>      |                                   |                       |         |
| <i>Location</i>                  |                                   |                       |         |
| Anterior Maxilla                 | 58/280                            | 1                     | ...     |
| Posterior Maxilla                | 34/127                            | 1.546 (0.945, 2.530)  | .083    |
| Anterior Mandible                | 13/283                            | 0.302 (0.141, 0.647)  | .002    |
| Posterior Mandible               | 26/224                            | 0.579 (0.306, 1.096)  | .093    |
| <i>Bone quantity</i>             |                                   |                       |         |
| A                                | 5/77                              | 1                     | ...     |
| B                                | 45/304                            | 1.564 (0.315, 7.758)  | .584    |
| C                                | 33/351                            | 1.743 (0.367, 8.269)  | .484    |
| D                                | 26/134                            | 2.788 (0.567, 13.714) | .207    |
| E                                | 22/46                             | 8.079 (1.624, 40.194) | .011    |
| <i>Bone quality</i>              |                                   |                       |         |
| 1                                | 5/104                             | 1                     | ...     |
| 2                                | 43/355                            | 2.369 (0.556, 10.097) | .244    |
| 3                                | 46/370                            | 1.805 (0.445, 7.319)  | .409    |
| 4                                | 37/83                             | 7.048 (1.690, 29.387) | .007    |
| <b>PATIENT-RELATED FACTORS</b>   |                                   |                       |         |
| <i>Gender</i>                    |                                   |                       |         |
| Male                             | 62/343                            | 1                     | ...     |
| Female                           | 69/571                            | 0.672 (0.359, 1.258)  | .214    |
| <i>Age</i>                       |                                   |                       |         |
| Increase by 1                    | –                                 | 0.998 (0.980, 1.015)  | .781    |
| <i>Diabetes</i>                  |                                   |                       |         |
| No                               | 102/568                           | 1                     | ...     |
| Type I                           | 0/0                               | –                     | ...     |
| Type II                          | 12/64                             | 1.080 (0.393, 2.970)  | .882    |
| <i>High blood pressure</i>       |                                   |                       |         |
| No                               | 83/418                            | 1                     | ...     |
| Yes                              | 31/228                            | 0.734 (0.363, 1.484)  | .390    |
| <i>High cholesterol</i>          |                                   |                       |         |
| No                               | 93/512                            | 1                     | ...     |
| Yes                              | 21/114                            | 1.196 (0.514, 2.780)  | .678    |
| <i>Hypothyroidism</i>            |                                   |                       |         |
| No                               | 109/580                           | 1                     | ...     |
| Yes                              | 5/46                              | 0.605 (0.153, 2.391)  | .474    |
| <i>Asthma</i>                    |                                   |                       |         |
| No                               | 101/577                           | 1                     | ...     |
| Yes                              | 13/61                             | 1.339 (0.452, 3.965)  | .598    |
| <i>Intake of antidepressants</i> |                                   |                       |         |
| No                               | 79/570                            | 1                     | ...     |
| Yes                              | 35/58                             | 3.874 (1.381, 10.866) | .010    |

(Continues)

**TABLE 3** (Continued)

| Factor                             | Failure/<br>survival <sup>a</sup> | OR<br>(95% CI)        | P-value |
|------------------------------------|-----------------------------------|-----------------------|---------|
| <i>Irradiation</i>                 |                                   |                       |         |
| No                                 | 112/625                           | 1                     | ...     |
| Yes                                | 2/3                               | 4.255 (2.996, 6.043)  | <.001   |
| <i>Hormone replacement therapy</i> |                                   |                       |         |
| No                                 | 117/744                           | 1                     | ...     |
| Yes                                | 9/22                              | 2.111 (0.641, 6.956)  | .219    |
| <i>Gastric</i>                     |                                   |                       |         |
| No                                 | 90/556                            | 1                     | ...     |
| Yes                                | 24/62                             | 2.917 (1.161, 7.324)  | .023    |
| <i>Antithrombotics</i>             |                                   |                       |         |
| No                                 | 77/461                            | 1                     | ...     |
| Yes                                | 38/169                            | 1.499 (0.743, 3.025)  | .258    |
| <i>Immunosuppressive</i>           |                                   |                       |         |
| No                                 | 111/612                           | 1                     | ...     |
| Yes                                | 3/10                              | 1.513 (0.277, 8.246)  | .632    |
| <i>Bisphosphonates</i>             |                                   |                       |         |
| No                                 | 113/610                           | 1                     | ...     |
| Yes                                | 1/18                              | 0.283 (0.048, 1.676)  | .164    |
| <i>Smoking</i>                     |                                   |                       |         |
| No                                 | 65/405                            | 1                     | ...     |
| Yes                                | 42/164                            | 1.397 (0.630, 3.096)  | .411    |
| Former smoker                      | 3/11                              | 3.616 (0.618, 21.152) | .154    |
| <i>Cigarettes/day</i>              |                                   |                       |         |
| Increase by 1                      | –                                 | 1.028 (0.983, 1.074)  | .229    |
| <i>Snuff</i>                       |                                   |                       |         |
| No                                 | 106/567                           | 1                     | ...     |
| Yes                                | 4/13                              | 1.356 (0.309, 5.953)  | .687    |
| <i>Bruxism</i>                     |                                   |                       |         |
| No                                 | 79/583                            | 1                     | ...     |
| Yes                                | 37/50                             | 4.414 (1.840, 10.590) | .001    |
| <b>OTHER FACTORS</b>               |                                   |                       |         |
| <i>Antibiotics</i>                 |                                   |                       |         |
| No                                 | 12/87                             | 1                     | ...     |
| Yes                                | 51/358                            | 0.754 (0.298, 1.908)  | .551    |
| <i>Bone grafting</i>               |                                   |                       |         |
| No                                 | 100/864                           | 1                     | ...     |
| Yes                                | 31/50                             | 2.753 (0.753, 10.062) | .126    |
| <i>Prosthetic restoration</i>      |                                   |                       |         |
| Single crown                       | 8/66                              | 1                     | ...     |
| Partial fixed, 2–6 units           | 27/215                            | 1.007 (0.347, 2.921)  | .990    |
| Partial fixed, 7–10 units          | 7/18                              | 2.192 (0.371, 12.966) | .387    |
| Full-arch fixed                    | 75/591                            | 1.033 (0.387, 2.755)  | .948    |
| Overdenture                        | 9/24                              | 4.686 (1.185, 18.528) | .028    |

<sup>a</sup>The information for some conditions is unknown for a variable number of implants.

Figure 2 shows a scatter plot of all 1,948 MBL measurements, showing that there is an estimated trend to loss bone with time, reaching 1.98 mm of bone loss 30 years after implant installation. The linear regression equation ( $y = -0.35 - 0.00453x$ ) estimated a loss of 0.00453 mm of bone for every additional month of follow up. MBL

**TABLE 4** Multivariate generalized estimating equations (GEE) logistic regression model at the implant-level. Only the factors that were considered statistically significant ( $P < .1$ ) in the univariate model and didn't present multicollinearity were included in the multivariate model (OR – odds ratio)

| Factor                           | OR (95% CI)            | P-value |
|----------------------------------|------------------------|---------|
| <i>Location</i>                  |                        |         |
| Anterior Maxilla                 | 1                      | ...     |
| Posterior Maxilla                | 1.388 (0.784, 2.458)   | .260    |
| Anterior Mandible                | 0.264 (0.109, 0.643)   | .003    |
| Posterior Mandible               | 0.488 (0.232, 1.030)   | .060    |
| <i>Bone quantity</i>             |                        |         |
| A                                | 1                      | ...     |
| B                                | 1.455 (0.392, 5.407)   | .575    |
| C                                | 1.078 (0.281, 4.142)   | .913    |
| D                                | 1.828 (0.435, 7.677)   | .410    |
| E                                | 3.412 (0.605, 19.241)  | .164    |
| <i>Bone quality</i>              |                        |         |
| 1                                | 1                      | ...     |
| 2                                | 1.228 (0.318, 4.744)   | .766    |
| 3                                | 0.713 (0.177, 2.878)   | .635    |
| 4                                | 1.335 (0.285, 6.267)   | .714    |
| <i>Intake of antidepressants</i> |                        |         |
| No                               | 1                      | ...     |
| Yes                              | 2.578 (0.813, 8.175)   | .108    |
| <i>Irradiation</i>               |                        |         |
| No                               | 1                      | ...     |
| Yes                              | 13.560 (6.058, 30.354) | <.001   |
| <i>Gastric</i>                   |                        |         |
| No                               | 1                      | ...     |
| Yes                              | 2.097 (0.685, 6.416)   | .194    |
| <i>Bruxism</i>                   |                        |         |
| No                               | 1                      | ...     |
| Yes                              | 2.800 (1.012, 7.748)   | .047    |
| <i>Prosthetic restoration</i>    |                        |         |
| Single crown                     | 1                      | ...     |
| Partial fixed, 2–6 units         | 1.592 (0.448, 5.660)   | .473    |
| Partial fixed, 7–10 units        | 0.520 (0.051, 5.315)   | .582    |
| Full-arch fixed                  | 1.788 (0.456, 7.016)   | .405    |
| Overdenture                      | 1.631 (0.314, 8.467)   | .561    |

was moderately associated to the follow-up time ( $R = -0.358$ ,  $R^2 = 0.128$ ,  $P < .001$ , Pearson correlation).

The marginal bone around the 131 failed implants was also assessed. The radiological follow-up protocol at the clinic did not include the register of a radiogram at the implant placement day, beginning at the abutment connection day only. Thus, it was not able to evaluate the marginal bone condition around some implants, due to lack of radiograms, because they failed before the abutment connection (primary failures). In other cases, some patients received several implants, but the first radiological register of the implants was carried out only after abutment connection. These cases that presented no radiological register of the failed fixtures accounted for 37 implants. Then, of the 131 lost implants, 86 implants had available radiograms: 131 total implants—8 implants with unknown date of failure—37 implants without radiograms = 86 implants with radiograms. Twenty-

**TABLE 5** Marginal bone condition around 300 nonfailed implants at the last radiological follow-up (mean of 244.8 months)

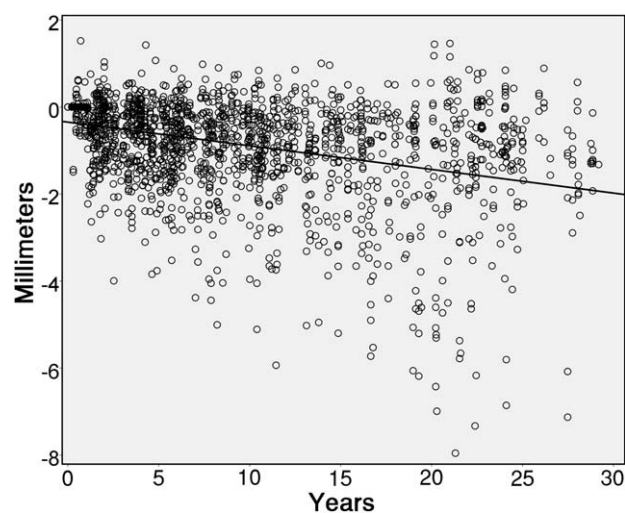
| Marginal bone condition      | Number of implants (%)  |
|------------------------------|-------------------------|
| Bone gain (0.010–1.442 mm)   | 35 (11.7%)              |
| Bone loss up to 1 mm         | 109 (36.3%)             |
| Bone loss between 1 and 2 mm | 84 (28.0%)              |
| Bone loss between 2 and 3 mm | 37 (12.3%)              |
| More than 3 mm of bone loss  | 35 <sup>a</sup> (11.7%) |

<sup>a</sup>Seven (2.3% of the total number of implants) out of these 35 implants presented MBL of more than 6 mm.

six out of these 86 implants with radiograms presented severe MBL. Figure 3 shows radiograms of some examples of implants with advanced MBL found in the present study.

## 4 | DISCUSSION

The results of the present study showed that most of the implant failures occurred at the first few years after implantation, regardless of a very long follow up. The regression analysis performed in this study tried to identify the factors that could possibly be related to implant failure. The univariate regression assessed the relationship between each independent variable and implant failure separately, and the multivariate regression assessed the relationship of the variables that were univariately significant to implant failure, controlling for each other. The negative factors identified by the multivariate GEE model were implant location, irradiation, and bruxism. The improved survival rate of implants placed in the anterior mandible in relation to the anterior maxilla may be related to the usually improved bone quality and greater bone volume found in the anterior mandible, even years after teeth extraction in this region.<sup>14</sup> When it comes to irradiation, it has been shown that it negatively affects the survival of implants,<sup>15</sup> which is



**FIGURE 2** Scatter plot of 1,948 MBL measurements of 300 implants. The line represents the estimated MBL along the years of observation, according to the linear regression

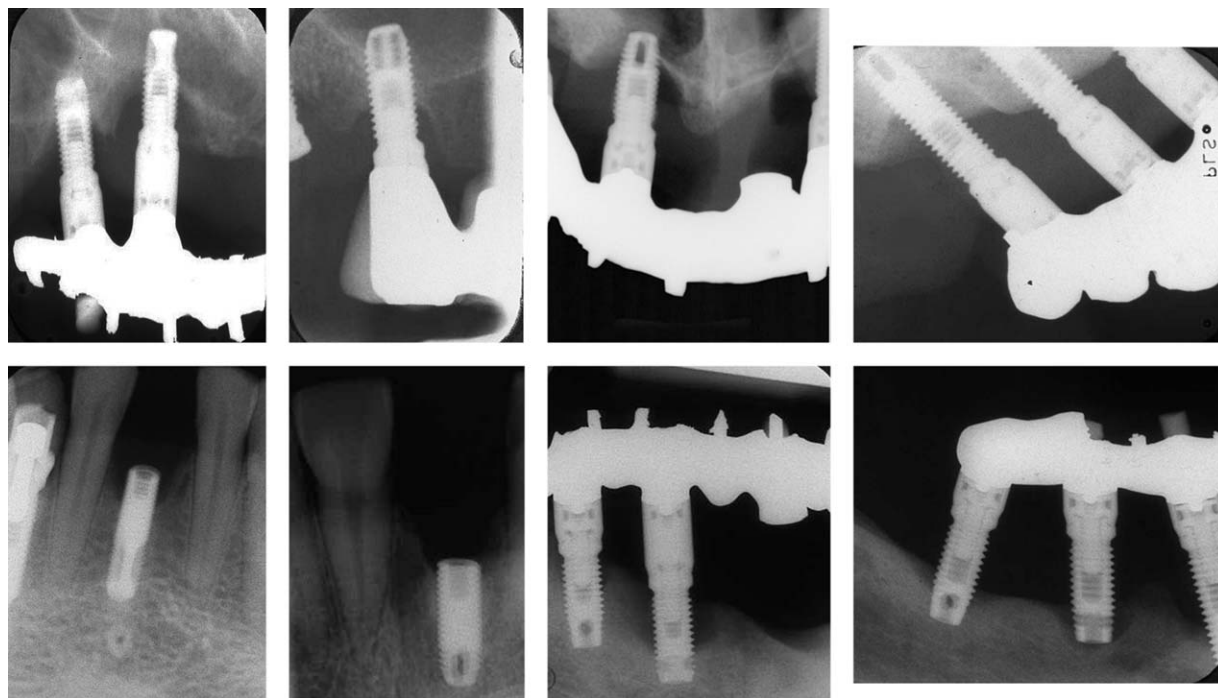


FIGURE 3 Examples of cases of severe MBL around implants that were eventually lost or fractured

mostly related to the deleterious long-term effects of irradiation on the bone vascularization<sup>16</sup> and bone-healing capacity,<sup>17</sup> compromising the implantation site. Concerning the patients' habits, bruxism was shown to significantly affect the implant failure rates negatively, agreeing with the results of the two very recent clinical trials assessing the effect of bruxism on dental implants.<sup>18,19</sup> Bruxism is suggested to generate overload of prosthetic rehabilitations on implants, which could possibly cause implant fracture or peri-implant MBL, ultimately resulting in implant failure.<sup>20</sup> Implant fractures noticed in the present study may further be related to the use of grade 1 titanium which is a less strong material than presently used grade 3–4 titanium.

About 12% of the implants in this study displayed more than 3 mm of MBL. However, this observation must be balanced against the observation that hexed Brånemark implants display an average of 1 mm of MBL already at 1 year of follow up, although the 5 year bone loss figures of the same implants indicated a relative steady state with respect to further bone loss.<sup>4</sup> In contrast, implants with internal couplings instead of hexes only demonstrated an average 5 year bone loss of about 0.2 mm.<sup>4</sup> Furthermore, an average MBL of more than 3 mm need not represent disease or other clinical problems as indicated by Jemt et al.<sup>21</sup> These authors<sup>21</sup> followed up what happened to the implants of the study by Fransson et al.,<sup>22</sup> and reported that 91.3% of the implants saw no significant further bone loss after another 9.1 years (average) of follow up, that is, a total follow-up in the 20 year range. A total of 95.4% of the implants with progressive bone loss were still functioning as part of support for dental bridges at 20+ years of follow-up. Thus, the original bone loss as mentioned in the Fransson et al.<sup>22</sup> paper was not predictive for future ongoing bone loss. Based on these figures, it is obvious that one cannot judge disease on a millimeter report of bone loss. In addition, Coli et al.<sup>23</sup> have recently

questioned the relevance of using probes as criteria for disease around oral implants.

The number of unaccounted for implants was quite high in the present report. However, when patients who died or were just referred to other clinics are concerned, these reasons for drop out are unlikely to skew the present analysis. It must be remembered that the Malmö clinic originally was the only implant active unit in the region, therefore when new clinics started with implants at a later time, it was quite natural that those clinics took over the controls of some patients.

The total failure rate of the Malmö material has been reported to 6.36%. However, this failure rate is presumably greater in reality since some implants controlled at other clinics may have failed too. However, overall oral implants fare quite well, despite some of them seeing MBL of 3 mm or more. Although peri-implantitis was not the topic of the present paper, it is tempting to conclude that the prevalence of peri-implantitis, including ongoing bone loss as a prerequisite, is likely to be rather low.

## 5 | CONCLUSIONS

Most of the implant failures occurred at the first few years after implantation, regardless of a very long follow up. Implants in different jaw locations, irradiation, and bruxism were the factors suggested to affect the long-term survival of implants. MBL can be insignificant in long-term observations, but it may, nevertheless, be the cause of secondary failure of oral implants in some cases.

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## CONFLICT OF INTEREST

There are no conflicts of interest to declare.

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## REFERENCES

- [1] Brånemark PI, Adell R, Breine U, Hansson BO, Lindström J, Ohlsson A. Intra-osseous anchorage of dental prostheses. I. Experimental studies. *Scand J Plast Reconstr Surg*. 1969;3(2):81–100.
- [2] Ekelund JA, Lindquist LW, Carlsson GE, Jemt T. Implant treatment in the edentulous mandible: a prospective study on Branemark system implants over more than 20 years. *Int J Prosthodont*. 2003;16:602–608.
- [3] Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: a review and proposed criteria of success. *Int J Oral Maxillofac Implants*. 1986;1(1):11–25.
- [4] Jimbo R, Albrektsson T. Long-term clinical success of minimally and moderately rough oral implants: a review of 71 studies with 5 years or more of follow-up. *Implant Dent*. 2015;24(1):62–69.
- [5] Lindquist LW, Carlsson GE, Jemt T. Association between marginal bone loss around osseointegrated mandibular implants and smoking habits: a 10-year follow-up study. *J Dent Res*. 1997;76(10):1667–1674.
- [6] Adell R, Lekholm U, Rockler B, Brånemark PI. A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *Int J Oral Surg*. 1981;10(6):387–416.
- [7] Jaffin RA, Berman CL. The excessive loss of Branemark fixtures in type IV bone: a 5-year analysis. *J Periodontol*. 1991;62(1):2–4.
- [8] Brånemark PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg Suppl*. 1977;16:1–132.
- [9] Roos-Jansåker AM, Lindahl C, Renvert H, Renvert S. Nine- to fourteen-year follow-up of implant treatment. Part II: presence of peri-implant lesions. *J Clin Periodontol*. 2006;33(4):290–295.
- [10] Fransson C, Wennström J, Berglundh T. Clinical characteristics at implants with a history of progressive bone loss. *Clin Oral Implants Res*. 2008;19(2):142–147.
- [11] Albrektsson T, Chrcanovic B, Östman PO, Sennerby L. Initial and long-term crestal bone responses to modern dental implants. *Periodontol*. 2017;73(1):41–50.
- [12] Albrektsson T, Zarb GA. Current interpretations of the osseointegrated response: clinical significance. *Int J Prosthodont*. 1993;6:95–105.
- [13] Lekholm U, Zarb GA. Patient selection and preparation. In: Brånemark PI, Zarb GA, Albrektsson T, eds. *Proceedings of the Tissue Integrated Prostheses: Osseointegration in Clinical Dentistry*. Boca Raton: Quintessence Publishing Company; 1985:199–209.
- [14] Glauser R, Ree A, Lundgren A, Gottlow J, Hammerle CHR, Schärer P. Immediate occlusal loading of Branemark implants applied in various jawbone regions: a prospective, 1-year clinical study. *Clin Implant Dent Relat Res*. 2001;3(4):204–213.
- [15] Chrcanovic BR, Albrektsson T, Wennerberg A. Dental implants in irradiated versus nonirradiated patients: a meta-analysis. *Head Neck*. 2016;38(3):448–481.
- [16] Yeric KC, Posch M, Seemann M, et al. Implant survival in mandibles of irradiated oral cancer patients. *Clin Oral Implants Res*. 2006;17(3):337–344.
- [17] Marx RE, Johnson RP. Studies in the radiobiology of osteoradionecrosis and their clinical significance. *Oral Surg Oral Med Oral Pathol*. 1987;64(4):379–390.
- [18] Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. Bruxism and dental implant treatment complications: a retrospective comparative study of 98 bruxer patients and a matched group. *Clin Oral Implants Res*. 2017;28:e1–e9.
- [19] Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. Bruxism and dental implant failures: a multilevel mixed effects parametric survival analysis approach. *J Oral Rehabil*. 2016;43(11):813–823.
- [20] Lobbzoo F, Brouwers JE, Cune MS, Naeije M. Dental implants in patients with bruxing habits. *J Oral Rehabil*. 2006;33(2):152–159.
- [21] Jemt T, Sundén Piker S, Gröndahl K. Changes of marginal bone level in patients with “Progressive Bone Loss” at Branemark System (R) Implants: a radiographic follow-up study over an average of 9 years. *Clin Implant Dent Relat Res*. 2015;17(4):619–628.
- [22] Fransson C, Lekholm U, Jemt T, Berglundh T. Prevalence of subjects with progressive bone loss at implants. *Clin Oral Implants Res*. 2005;16(4):440–446.
- [23] Coli P, Christiaens V, Sennerby L, Bruyn H. Reliability of periodontal diagnostic tools for monitoring peri-implant health and disease. *Periodontol*. 2017;73(1):203–217.

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