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Early Implant Failures in Edentulous Patients: A Multivariable Regression Analysis of 4615 Consecutively Treated Jaws. A Retrospective Study

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Abstract

Purpose: To study the incidence of early implant failures in edentulous jaws and to describe the effects of some patient- and implant-related factors on the risk for early implant failures.
Materials and Methods: The study retrospectively analyzed 4615 edentulous jaws (4067 patients), consecutively treated with dental implants at one referral clinic from 1986 to 2013. Implant failures that occurred from implant surgery up to the first recall examination 1 year after prosthesis insertion were recorded and defined as early implant failures. All removed implants were included as failures. Features of the study group and early implant failure rates were reported. A multivariable logistic regression model was used for analyzing possible associations between clinical factors, and the risk for early implant failures. Implant surfaces were categorized by means of roughness: turned (S_a 0.5-1.0 μm) and moderately rough (S_a 1.0-2.0 μm).
Results: Three hundred twenty-seven patients (344 jaws) were lost to follow-up. Early implant failures occurred in 8.6% of the jaws. In the maxilla there was a significantly higher incidence of early failures compared to the mandible both with turned implants, OR 5.93 (95% CI 4.21; 8.36), and moderately rough implants, OR 2.52 (95% CI 1.19; 5.34). The impact of implant surface roughness was significant in the maxilla with higher incidence of early failures with turned implants, OR 3.51 (95% CI 2.27; 5.42). There was a significant interaction between implant surface and jaw type on early failures ($p = 0.034$). Older age was associated with lower risk for early implant failures, OR 0.9 (95%CI 0.82; 0.99). In total, 63% of the jaws with failure could proceed with the prosthetic treatment without further implant insertions. Twenty-six percent of the early failures occurred after prosthesis insertion and 59% of those could maintain the same prosthesis after implant loss with or without adjustments.
Conclusions: Changing the implant surface from turned to moderately rough decreased the incidence of early implant failures significantly in the maxilla, but not in the mandible. Older age at implant insertion was associated with lower risk for early implant failures in edentulous patients.

Edentulism can cause severe functional, nutritional, and social impairments. Rehabilitation with implant-supported prostheses may restore oral function and improve quality of life.[1-3]

The failure of dental implants at early stages in the healing process can be decisive for the prosthetic treatment of the edentulous patient. Furthermore, the failure of implants shortly after prosthesis insertion can have a major impact on the survival of the implant-supported prosthesis. Additional surgery and the fabrication of new prostheses are both time consuming, and may cause physical and psychological discomfort for the patient. It is therefore important to reduce early implant failure rates to a minimum. Several factors, such as smoking, history of periodontitis, poor bone quality and quantity, different surgical loading conditions, oral hygiene, diabetes, drug abuse, and medication, have been suggested to be associated with early implant failures; however, information related to the understanding of the etiology of implant failures is lacking.[4-6]

Early implant failure is defined as failure to establish osseointegration, referring to the biological process around an implant, predominantly during the early healing phase after

implant surgery.[4,7] Several cut-off points have been suggested to define early implant failures, such as: at abutment surgery (when applying a two-stage protocol), at prosthesis insertion, at first annual check-up, or after various time intervals.[8-10] *Late implant failure* is characterized by bone resorption around an implant with established osseointegration, leading to implant loss.[11,12] Outcomes of implant treatment can be reported in various ways, and on different levels. Using the implant as the statistical unit and reporting on implant level has been common through the years. Additionally, the jaw, the implant surgical intervention, or the patient have been used as the statistical unit. Results reported on implant level often display lower failure rates as compared to reports on surgery or patient level. This is due to the insertion of more than one implant per patient/jaw or surgery.[7,13]

Many studies have indicated that most implant failures occur at an early stage after implant insertion, before osseointegration. Thus, in a major study on implants with turned and moderately rough surfaces, Jemt et al reported that on average, 69% of all jaws with implant failure experienced their first failure within the first year of implant surgery.[7] This figure is consistent with the findings of other reports.[14,15]

Furthermore, Chrcanovic et al reported on 2670 patients provided with 10,096 implants of different types. A total of 139 patients lost 176 implants up to the second-stage surgery.[16] Chrcanovic et al reported an early implant failure rate of 1.74% and 5.21% at implant and patient level, respectively. Earlier studies on insertion of turned implants in the edentulous jaw demonstrated an implant survival rate of 84% to 96% and 92% to 100% during the first year for maxilla and mandible, respectively.[8,17-26]

In a previous publication, significantly higher incidence of early failures was reported for "turned implants" as compared to implants with a moderately rough surface.[7] However, that study included both partially and completely edentulous jaws. The authors suggested that different outcomes might be expected depending on different parameters, such as between patients treated in the partially edentulous mandible compared to the edentulous mandible. Therefore, it could be of interest to perform studies that focus on specific patient groups. Similarly, other studies have reported lower failure rates for implants with moderately rough surfaces (S_a 1.0-2.0 μm) as compared to implants with turned surfaces (S_a 0.5-1.0 μm).[27,28]

Other results on various implant systems with moderately rough surfaces demonstrated an implant survival rate after one year of 95.7% to 100% in the edentulous maxilla, and 96.7% to 100% in the mandible.[29-37] Recently, a meta-analysis[38] reported a 1-year survival rate of 99.5% at implant level and 99.1% at patient level for 12,803 implants/4694 patients, for implants with a moderately rough surface, of the same type that was evaluated in this study.

Although most studies report favorable early results for treatment in the mandible as compared to treatments in the maxilla, inconsistent observations have also been reported. Accordingly, a large-scale clinical study by Alsaadi et al[5] on early implant failures demonstrated comparable survival rates for moderately rough implants compared to turned implants, when placed in the maxilla and mandible. Thus, the pattern of early implant failures in the edentulous jaw seems to be complex and multifactorial, and more research is needed to improve the understanding of factors related to dental implant failures.

The aim of this study was to identify potential risk factors for early implant failures in edentulous jaws, and to report on the incidence of early implant failures in a large population treated at a specialist clinic over 28 years.

Materials and methods

This retrospective study was based on patients consecutively treated with dental implants at one specialist referral clinic (Brånemark Clinic, Public Dental Service, Region Västra Götaland, Gothenburg, Sweden) between January 1, 1986 and December 31, 2013.

Data collection

Data were retrieved from analog and digital registers on performed implant surgeries during the inclusion period.[7] From the total population of treated patients, all patients with edentulous jaws treated with implants were identified, and information on implant failure was collected. Implant failures that occurred from implant surgery up to the first recall examination 1 year after prosthesis insertion were recorded and defined as early implant failures and compiled into the study group.[39]

Furthermore, according to the clinic's routines, all patients had been invited to a follow-up program, including radiographic and clinical examinations, 1 year after prosthesis insertion. Clinical patient records were available for all patients regarding *age* and *gender*, *type of jaw (maxilla/mandible)*, *number of inserted implants*, and *type of inserted implants*.

Exclusion criteria: patients having major bone grafting procedures under general anesthesia at the hospital before implant insertion were excluded from the study. Furthermore, complementary surgeries where additional implants were inserted were excluded. Those could be a result of additional tooth loss in partially edentulous jaws with implants or jaws with preceding implant failure that needed replacement. Hence, only the first implant surgery in each edentulous jaw was included.

Implant surgery

Only turned (S_a 0.5-1.0 μm) Brånemark System® implants (Nobel Biocare AB, Göteborg, Sweden) were used from 1986 to 2000. During the period from 2001 to 2003, implants with moderately rough surfaces (S_a 1.0-2.0 μm) were gradually introduced.[26,30,40] From 2004 only moderately rough implants were inserted, predominantly Brånemark System TiUnite®, but also Lifecore Restore® implants (Lifecore Biomedical Inc., Chaska, MN) and AstraTech Implant System™ implants (OsseoSpeed™; Astra Tech AB, Mölndal, Sweden).[7]

The number of inserted implants per jaw varied depending on the clinic's routines, the amount of available bone volume, and choice of prosthetic treatment. The number of implants inserted in the maxilla varied from 2 to a maximum of 8, and in the mandible the number varied from 2 to 6. The majority of implants were connected with a fixed dental prosthesis or a bar. The original protocol advocated 4 to 8 implants in the maxilla when bone was available for a fixed prosthesis, and

2 to 3 implants in jaws with limited amounts of bone for overdentures. Five or 6 implants were inserted in the mandible as the standard procedure. From 2003, when bone was available, 6 and 4 implants were the routine for the edentulous maxilla and mandible, respectively. A 2-stage surgical protocol was applied as a routine for all patients up to year 2001 (in the maxilla 6-8 months of submerged healing, in the mandible 3-5 months). Thereafter, a 1-stage protocol was introduced and successively used parallel to the 2-stage procedure in the mandible.[41,42] During later years, the 1-stage protocol was the first option in the edentulous mandible with around 6 to 8 weeks of unloaded healing, while the 2-stage protocol was still used as a routine in the maxilla (2-4 months of submerged healing).

Prosthetic treatment

Prosthetic treatment was performed predominantly using screw-retained implant-supported fixed complete dentures designed with metal frameworks supporting prefabricated resin teeth. The frameworks were originally fabricated in cast gold alloy but later in laser-welded, or CAD/CAM-fabricated titanium. Detailed information on prosthesis design was not included in the present analysis due to uncollected data on some patients in the database; however, implant-supported overdentures were used in a limited number of patients, representing less than 5% of the jaws. The overdenture treatment was either the first-choice prosthetic treatment or a second-choice interim solution in patients where the implants needed further evaluation.[43] The overdentures were mainly retained with a metal bar retention. The clinical protocols varied through the years; detailed information on prosthetic and surgical protocols has previously been described by Jemt et al.[42,44]

Definitions

Implant failure was defined as an implant with any problem resulting in removal of the implant at the clinic, such as failure to establish osseointegration, infection, implant mobility, pain, bone loss, or implant fracture.[6,45] Implant failures that occurred from implant insertion up to the first recall examination 1 year after prosthesis insertion were defined as early implant failures. In this study these failures are referred to as *early implant failures*, and the time period is referred to as 1-year follow-up.[7,45] In this study, patients treated with implants with the original turned surface are referred to as "T-group" or as treated with "turned implants." Patients treated with implants with moderately rough surfaces were referred to as "MR-group" or as treated with "moderately rough implants."

Statistical methods

Numbers, means, and percentages were presented as descriptive statistics. All analyses were performed on jaw level. The first event of implant failure for each jaw formed the basis for the calculations. The main data analysis was performed with a multivariable logistic regression built up in steps to evaluate interaction effects using SAS v9.4 software (SAS Institute Inc., Cary, NC).

The starting point for the model selection procedure was a logistic regression model with early implant failure as outcome variable and no explanatory variables. Then, one or more explanatory variables were added stepwise. In the first step the 3 dichotomous variables *gender*, *type of jaw*, and *type of surface* were included. In the following 2 steps *age* and *number of implants* were added, respectively.

After new variables were added, the need for inclusion of interaction effects was evaluated. Interactions between 2 significant main variables would be candidates for inclusion in the main model. The result of this model selection procedure was the main model for analyses.

The Wald chi-square test was employed to evaluate each variable's contribution to the main model. The main model was supplemented with subsequent analyses in subgroups with respect to *type of surface* and *type of jaw*. The model was set to have an acceptable fit if the Hosmer-Lemeshow goodness-of-fit test was not significant, given that a significance of this test would suggest unsuitable choice of model for the analysis.

The results were presented in odds ratio estimates (OR) in addition to 95% confidence intervals (CI). The results are reported in the text in terms of risk by means of OR estimates. A significance level of 0.05 was used throughout the study.

Ethical protection

STROBE Statements were followed in the study design and following report.[46] The study was approved by the Regional Ethical Review Board, Gothenburg, Sweden (Dnr 197-12).

Results

During the inclusion period, 4067 patients consecutively treated in 4899 edentulous jaws were identified, of which 54% were female. Following the application of inclusion/exclusion criteria, 4615 edentulous jaws in 3974 patients with 25,029 implants remained (Fig 1). In total, 641 patients were treated with implants in both maxilla and mandible (16.1%).

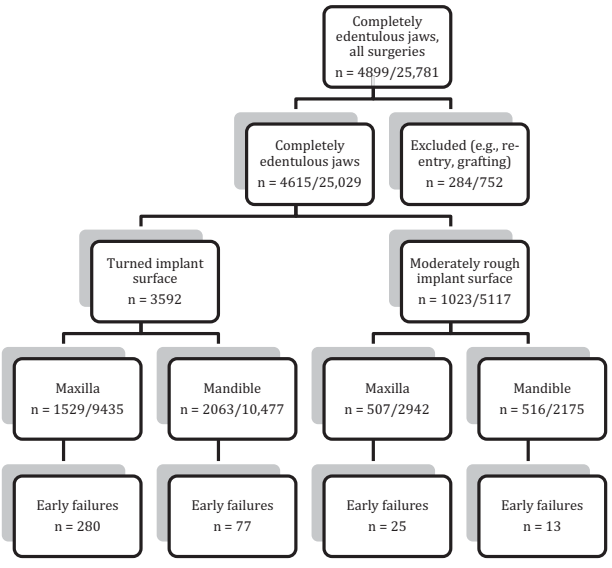

Figure 1 Flow chart of included edentulous jaws 1986 to 2013; n = number of jaws/implants.

Table 1 Comparison of jaws with early implant failures before or after prosthesis insertion (numbers/percentages [n/%])

	Turned surface		Moderately rough surface		
	Maxilla	Mandible	Maxilla	Mandible	Total
Before prosthesis insertion	203 / 73%	57 / 74%	21 / 84%	11 / 85%	292
Prosthesis insertion →1 year	77 / 27%	20 / 26%	4 / 16%	2 / 15%	103
Total n of jaws with early implant failure		357		38	395

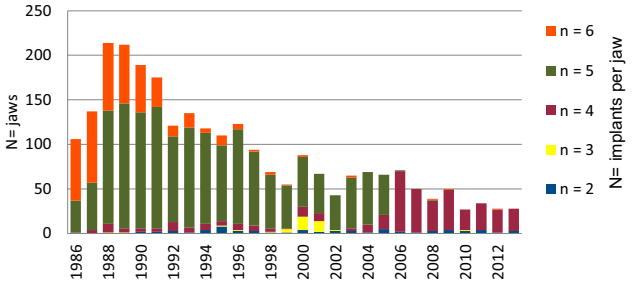

Figure 2 Number of treated mandibles over time, and number of inserted implants per jaw; total n = 2579.

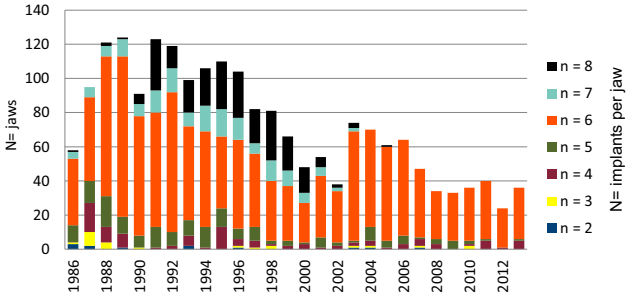

Figure 3 Number of treated maxillae over time, and number of inserted implants per jaw; total n = 2036.

Altogether, 327 patients (344 jaws, 7.5%) were lost to follow-up during the first year after surgery. Sixty-two patients were deceased (64 jaws, 1.4%), and data on follow-up examination were not available for 15 patients. Two hundred fifty patients (265 jaws, 5.7%) were dropouts for unknown reasons to the first follow-up-visit; 11 of those patients were permanently living abroad.

In total, 3592 jaws were provided with turned implants, and 1023 jaws were provided with moderately rough implants (Fig 1). The number of placed implants per jaw varied between 2 to 6 in the mandible and 2 to 8 in the maxilla. The number of placed implants per jaw decreased over time, and a decreasing number of jaws were treated during the inclusion period as well (Figs 2 and 3).

One or several events of implant failures were diagnosed in 395 of 4615 treated jaws up to the first annual examination, corresponding to an overall 1-year failure rate of 8.6%, at jaw level. The distributions of treated jaws and jaws with early failures are shown in Figure 1.

The majority of those failures were observed before loading, that is, before prosthesis insertion (Table 1); however, there were no significant differences between the subgroups in failure before or after prosthesis delivery ($p = 0.41$, mandible; $p = 0.21$, maxilla). In total, 688 implants failed (2.7%, implant

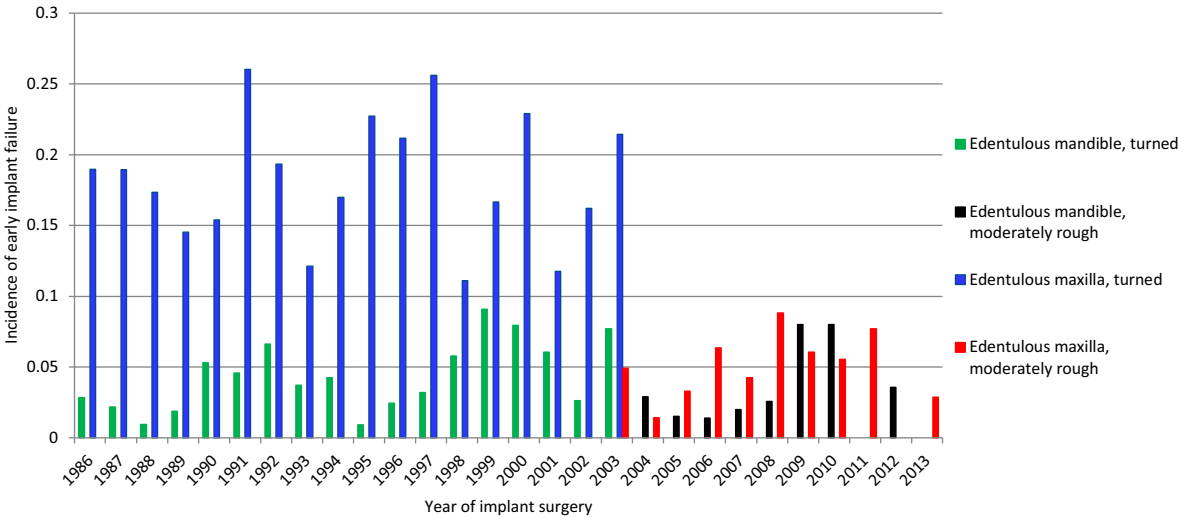

Figure 4 Incidence of early implant failures: incidence per year for edentulous jaws with turned and moderately rough implants, respectively.

Table 2 Prosthetic consequences of first event of early failures, all jaws with early implant failure (n = 395), and subgroup of jaws with early implant failure from prosthesis insertion – 1 year (n = 103)

	Total group of jaws with early implant failure		Jaws with failures from prosthetic loading - 1 year	
	n = 395		n = 103	
Prosthetic consequence after first event of implant failure	Mandible n = 90	Maxilla n = 305	Mandible n = 22	Maxilla n = 81
Unchanged	44	205	11	32
Shortened implant-supported fixed dental prosthesis	13	60	8	33
Overdenture	4	2	0	2
Total failure of implant-supported prosthesis	3	16	0	10
Additional implant surgery and new implant-supported prosthesis	14	6	2	1
Temporary implant-supported fixed dental prosthesis	1	10	0	2
Missing information	11	6	1	1
Total	**90**	**305**	**22**	**81**

level), of which 389 implants (1.6%, implant level) were lost up to prosthesis insertion, in 292 jaws (6.3%, jaw level).

The prosthetic consequences of the implant failures varied. The majority of jaws could continue with unchanged prosthetic rehabilitation, but a few prostheses needed to be shortened. A few patients were provided with an interim prosthesis as a result of the lost implant. In Table 2, the prosthetic consequences after first event of implant failure are shown, both for all failures (n = 395), and for the subgroup that experienced the first failure after prosthesis insertion (n = 103). In the group of 103 jaws the majority could keep their prosthesis with or without minor changes, whereas several jaws needed additional implant insertion to provide the patient with a new functional prosthesis.

Early implant failures occurred in 124 jaws in the patients treated in both maxilla and mandible (altogether 641 patients, 1282 jaws). In 5 patients, early implant failures were registered in both jaws.

Jaws in the T group (turned implants) had a significantly higher overall incidence of early implant failure as compared to jaws in the MR (moderately rough) group ($p < 0.0001$). The overall mean incidence of early failures for the T group was 18.3% for the maxilla and 3.7% for the mandible ($p < 0.0001$). The corresponding overall mean incidence of early implant failures for the MR group was 4.9% for the maxilla and 2.5% for the mandible ($p = 0.047$) (Fig 4).

Overall mean age at implant surgery for treated patients in the T group and MR group was 63.5 (SD 11.1) years, and 67.9 (SD 11.0) years, respectively. For patients with early implant failures, the mean age at implant surgery was 61.7 (SD 10.6) years and 63.6 (SD 13.4) years, respectively.

The multivariable logistic regression analysis demonstrated that all included variables except *gender* contributed to a statistical significance in the main analysis. The ORs for the included variables are presented in Table 3. The highest risk for early implant failures was reported for the T group in the maxilla, OR 5.93 (95% CI 4.21; 8.36) as compared to the mandible. Implants in the MR group inserted in the maxilla also had a significantly higher risk for early implant failures as compared to the mandible, OR 2.52 (95% CI 1.19; 5.34).

There was a significant interaction between type of implant surface and type of jaw ($p = 0.034$) (Table 3). The OR for *type of jaw* depends on *type of surface* and vice versa. Accordingly, in the mandible, *type of surface* had no significant impact on the risk for early implant failures, but in the maxilla, there was a significantly higher risk for the T group as compared to the MR group; OR 3.51 (95% CI 2.27; 5.42).

Older *age* at implant insertion was associated with a lower risk; OR 0.90 (CI 0.82; 0.99, Table 3), for early implant failures. The OR was calculated per age intervals of 10 years, meaning there was a 10% lower risk per 10 years of increased age. In the subsequent analysis of subgroups based on *type of surface*, *age* was significantly related to early implant failures only for patients in the MR group ($p = 0.02$), where older age again was associated with lower risk for early implant failures. In the T group, the variable *age* was not significantly associated with early implant failures ($p = 0.48$, mandible; $p = 0.25$, maxilla).

The number of implants per jaw had a statistically significant impact on early implant failures in edentulous jaws in the main analysis ($p = 0.045$); however, subsequent analyses of the variable *number of implants* in subgroups demonstrated that only in the subgroup 'maxilla, turned implants' was there a statistically significant impact on the probability of early implant failures ($p = 0.0007$). Estimated ORs with 6 implants as baseline are given in Table 4. The results suggest that compared to 6 implants, more (7 or 8) or fewer (3 or 5) implants had an increased risk for early implant failures in the maxilla in the T group. No significant impact of the number of inserted implants could be observed either in the mandible in the T group, or in any jaw in the MR group.

Table 3 Multivariable logistic regression for early implant failures (OR estimates and Wald CIs for included variables; *statistically significant)

Variable	Odds ratio, OR	95% CI	*p*-Value	Comment
Gender			0.67	
Male	1			
Female	0.955	0.77; 1.18		Nonsignificant
Jaw type			<0.0001 *	
Mandible, moderately rough	1			
Mandible, turned	1.49	0.77; 2.89		Nonsignificant difference for the surfaces in the mandible
Maxilla, moderately rough	1			
Maxilla, turned	3.51	2.27; 5.42 *		Significantly higher odds for turned implants in the maxilla
Type of surface			<0.0001 *	
Turned, mandible	1			
Turned, maxilla	5.93	4.21; 8.36 *		Significantly higher odds in maxilla with turned implants
Moderately rough, mandible	1			
Moderately rough, maxilla	2.52	1.19; 5.34 *		Significantly higher odds in maxilla with moderately rough implants
Age, increase by 10	0.9	0.82; 0.99	0.028 *	10% lower odds for every 10 years of increased age.
Number of implants			0.0045 *	Significant impact on the odds for early implant failure
Interaction effect (surface/jaw)			0.034 *	Significant interaction on the odds for early implant failure

Table 4 Subgroup analysis, maxilla treated with turned surface implants, effect of different number of implants on early implant failure (OR estimates and 95% CIs; 6 implants as baseline, OR = 1)

Variable	OR	95% CI	Statistically significant*
Number of implants		$p = 0.0007$	*
6	1		
2	1.52	0.31; 7.43	
3	3.42	1.30; 8.99*	*
4	0.74	0.36; 1.52	
5	1.68	1.09; 2.60*	*
7	2.07	1.39; 3.09*	*
8	1.46	1.02; 2.09*	*

Discussion

Results from this study suggest that the type of implant surface interacts with the type of jaw with respect to the incidence of early implant failures in edentulous jaws. A lower risk for early implant failures can be expected when inserting maxillary implants with moderately rough surfaces as compared to turned surfaces.

When the treatment protocol at the clinic changed from using implants with turned to moderately rough surfaces, the incidence of early implant failures decreased significantly. The moderately rough surface has proven to be effective in different kinds of clinical situations, demonstrating consistent results in the maxilla and mandible on different indications.[38] Studies suggest that the moderately rough surface induces a different biological response, and promotes bone formation around the implant, resulting in a biomechanical bond, leading to a stronger bone/implant interface.[27,47,48] However, in this study, in the mandible there was no statistically significant difference in incidence of early implant failures between implants with turned and moderately rough surfaces. Hence, the benefits of the moderately rough surfaces were mainly present in maxillary bone, as suggested in a previous study partly describing the present material,[7] and also confirmed by other studies.[49,50]

This study covers 28 years of clinical treatment and several treatment protocols have been used. In the beginning of the period the surgical and prosthetic protocols were rather consistent, but with time and increased knowledge as well as introduction of different social insurance systems, the protocols changed.[43,51,52] A transition period occurred around 2000 to 2004, when both turned and moderately rough implants were used. Initially, the moderately rough implants were inserted at 1-stage surgery in the edentulous mandible and as complementary implants in difficult sites in the maxilla; however, later they were used for all indications in both the maxilla and mandible. Enhanced implant survival rates and economic measures led to the current protocol of 6 implants ideally inserted in the edentulous maxilla (Fig 3). This coincided with the use of exclusively moderately rough implants. The results of this study suggest that in the maxilla treated with turned implants, the number of inserted implants significantly affected the incidence of early implant failure, with more failures when inserting 3, 5, 7, or 8 implants as compared to 6. The number of inserted implants did not always correspond to the amount of available bone, but was sometimes a result of treatment planning and safety measures, and this must be considered when interpreting the

results. In early cases, 8 implants were inserted to maintain the possibility of performing a fixed prosthesis, since failures were more common.

Thus, the changes in methodology may have influenced the results, as the protocol of 7 or 8 implants in the maxilla was abandoned almost at the same time as the moderately rough implants were introduced, and it remains unknown what the results would have been with 8 moderately rough implants systematically used in the maxilla.

In the edentulous mandible, the basic standard protocol shifted from 6, via 5, ending up with 4 implants inserted for supporting an implant-supported fixed complete denture. With four implants in the mandible it was possible to avoid insertion in the mandibular symphysis that was reported to have problems with soft tissue retractions and bone loss.[53] This coincided with the use of exclusively moderately rough implants; however, the treatment protocol in the mandible also gradually shifted from a 2-stage to a 1-stage protocol after the moderately rough implants were introduced. There may have been a difference between the T-group and the MR-group if the 2-stage protocol had been used consistently, giving further improved results with MR implants in the mandible as observed in the maxilla.

This study covers treatments during a long period. Thus, changes in the treatment protocols are inevitable. A higher number of edentulous patients were treated in the beginning of the inclusion period of this study as compared to the later part of the study period (Figs 3 and 4). This trend correlates with demographic data in Sweden, with a decreased number of edentulous people as a result of improved dental status in the population due to the dental care system.[54,55]

Annual early implant failure incidence varied widely over time.[7] This was an important finding that demonstrates a stochastic variation over time that can co-vary with factors such as different care providers, patient group variations, changes in treatment protocols, clinical equipment, economic systems in society, and coincidence. This effect may be disregarded in studies covering a shorter period of time, possibly giving an incorrect description of the situation. Furthermore, the factor "time" might also characterize changes and development, exemplified by Antoun et al's study, where implant failures decreased over time as a result of improved surgical experience.[56] However, a long inclusion period also inherently brings time- and procedure-related differences in methodology of treatment, something that may influence the results of the study.

This study was retrospective and can be considered a study of effectiveness of implant treatment in a large group of edentulous patients treated with implants in terms of everyday practice through many years. The risk for selection bias should be minimized according to the clinic's routines to include most patients regardless of any health condition or other circumstances.

A younger age at implant insertion was associated with higher risk of early implant failures. In the subgroup analysis of this study, the effect of age was significant in the MR group only, whereas in the T group no such differences could be detected; however, a statistically significant difference between the two groups could not be observed.

The distribution was previously partly described by Jemt et al, discussing differences in mortality among patients with or without implant failures.[39] In that analysis, younger patients were found to have a higher mortality compared to a reference group in the population, and they had a higher prevalence of early implant failures than older patients. In a large review, Chrcanovic et al concluded that most studies have failed to show any correlation between implant failures and the age of the patient.[4] However, the differences observed in this study would probably be difficult to detect in studies of smaller size.

It has been suggested that becoming edentulous at a younger age may be a risk indicator for general health problems and early implant failures. Jemt et al[57] demonstrated that younger patients (40-49 years) treated with implants in edentulous jaws had a significantly higher mortality compared to a reference population of comparable age in Sweden. The reason why age was significant only in the group of patients treated with moderately rough surface implants in this study can only be speculated; however, it has been discussed that due to improved dental status in the population in general, the possibility exists that the group of younger edentulous patients treated with implants today is different from the group from 1980s, and perhaps these patients represent a less healthy part of the population.[57]

The fact that only edentulous jaws have been used in this study was considered beneficial because the information on the treatment and patient status could be less diversified and more comparable than would be possible with groups of partially edentulous patients with implant treatments that are inherently very different from each other. Moreover, due to the high number of early failures of the turned implants, possibly related to the lack of initial stability of the turned implants, this might have concealed the age factor in that group. It can also be considered that age might be a surrogate endpoint for another patient-related factor that has not been investigated in this study. Thus, the results indicate that the relation between age and risk of implant failures is complex and needs to be further investigated.

A strength of this study was the size of the patient group, including 3974 edentulous patients (4615 edentulous jaws). The overall 1-year failure rate was 8.6% at patient level, and 2.7% at implant level. Three hundred eighty-nine implants were lost up to prosthesis insertion, leading to an early failure rate of 1.6% at implant level, and 6.3% at patient level. In a study by Chrcanovic et al, 2670 patients were analyzed and reported an overall failure rate of 5.2% at patient level up to abutment connection; however, that study included all indications for implant treatment—partially and completely edentulous jaws.[16] Another large-scale study on different implant indications reported an overall failure rate of 4.4% at patient level up to prosthesis insertion.[58] That study also found that the vast majority of all failures during the 9 years of follow-up were recorded up to prosthesis insertion. Furthermore, another large-scale study of edentulous patients reported a patient-level implant failure rate of 9% at 1 year.[19]

A limitation of this study was that a limited number of variables were available for all treated patients at this point, and therefore the analyses were performed on the available data. This is the nature of the retrospective approach; however,

the large number of included patients and observation years strengthens the reliability of the outcome.

Conclusions

The results of this study demonstrated a decreased early implant failure rate in the edentulous jaw consistent with other studies, and also illustrated further how complex the features of early implant failures can be:

1. The overall early implant failure rate was 8.6% of the edentulous jaws.
2. The risk for early implant failures in the edentulous jaw was significantly related to three factors: type of jaw, type of implant surface, and patient's age at implant insertion.
3. The incidence of early implant failures was significantly higher in the maxilla with turned implants compared to moderately rough implants. There was also a reduced failure rate in the mandible with moderately rough implants compared to turned implants; the difference did not reach a significant level.
4. Older age at implant insertion was associated with lower risk for early implant failures.
5. There was a significant interaction effect of jaw and surface on the risk for early implant failures, with the highest risk for implants with turned surface in the edentulous maxilla.
6. After early implant failure, the majority of the jaws could keep their prosthesis or proceed with the prosthetic treatment without further implant insertions. One of four early failures occurred after prosthesis insertion, and the majority of those could maintain the same prosthesis after implant loss with or without adjustments.

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