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ORIGINAL ARTICLE

Radiographic peri-implant bone loss after a function time up to 15 years

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ABSTRACT

Objective: The aim was to assess the degree of radiographic peri-implant bone loss over a follow-up period up to 15 years. In addition, another aim was to identify risk indicators for peri-implant bone loss and for moderate–severe peri-implantitis at patient- and implant level.

Materials and methods: This is a cross-sectional clinical and radiological study of 147 patients with a total of 425 implants in combination with data collected retrospectively for baseline variables. To calculate the peri-implant bone loss (primary outcome variable), the radiographic bone level measurements from baseline were compared to the radiographic bone level measurements at the final radiographic measurement. Multilevel analyses were adopted with peri-implant bone loss and peri-implantitis as outcome variables.

Results: The mean follow-up time was 12.5 years (range 10–15) and the mean age of the patients was 63 years (range 29–83). The mean peri-implant bone loss was 0.94 mm (S.D. 1.3). The prevalence of moderate–severe peri-implantitis at patient level was 17% and 8.9% at implant level. The peri-implant bone loss was significantly more pronounced in healthy implants if moderate–severe peri-implantitis was present in at least one implant within the same patient. The presence of moderate–severe peri-implantitis was significantly associated with general periodontitis Stages III or IV at follow-up and smoking.

Conclusion: The presence of moderate–severe peri-implantitis at patient level was found to be a risk indicator of peri-implant bone loss in healthy implants, while smoking and general periodontitis Stages III and IV were risk indicators of moderate–severe peri-implantitis.

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Cross-sectional study; dental implants; peri-implant bone loss; peri-implantitis; risk indicators

Introduction

Long-term marginal bone stability is a prerequisite to achieve a successful dental implant therapy for the patient. However, marginal peri-implant bone loss may occur both at a primary stage after surgery and at a second stage during implant function. The primary bone loss is regarded as the initial remodelling of the bone after the surgical injury at the implant installation [1]. The level of the crestal bone around healthy implants may vary depending on the initial bone remodelling, and is affected by factors at individual and site level [1]. Bone loss at a second stage, on the other hand, is not regarded as initial. Therefore, pathological reasons should be investigated.

The main reason for bone loss during function is peri-implantitis. Peri-implantitis is 'a plaque-associated pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone' [1]. Strict plaque control is a prerequisite for maintaining peri-implant health in the long run [2]. Depending on the case definition, the overall prevalence of peri-implantitis is estimated to be 14–30% [3]. Often there is a combination of contributing factors that result in a peri-implant disease with progressive bone loss. Patients with a history of severe periodontitis, poor oral hygiene, and a lack of regular maintenance have an increased risk of bone loss due to peri-implantitis [2,4,5]. Another factor that has been linked to bone loss and is a potential risk factor/indicator is submucosal cement excess [6]. However, not all implants with cement excess exhibit peri-implant bone loss, nor do cement-retained restorations, compared to screw-retained, exhibit a higher risk for peri-implantitis [5,7,8]. Iatrogenic factors as malpositioning of implants and the prosthetic superstructure design that do not enable good self-performed oral hygiene and professional maintenance may contribute to the onset and progression of peri-implantitis [9,10]. A number of studies have indicated a link between a higher risk for peri-implantitis in smokers and in patients diagnosed with diabetes, but current evidence is inconclusive whether smoking or diabetes constitute a risk factor/indicator for peri-implantitis [10].

In cross-sectional observational studies with retrospectively collected information on crestal bone levels over time, the analysis demonstrated that progressive bone loss in the absence of clinical signs of inflammation is an exception

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[11–13]. However, not all implants with a small amount of bone loss demonstrate bleeding on probing (BoP) or suppuration [13]. In a recently published study by Cecchinato et al. (2018) [14], the mean additional bone loss after ≥3 years (mean 5.8 years) was 0.4 mm. However, subjects included in the study were periodontally healthy (70%) or had been treated for moderately advanced periodontitis (30%) and all subjects had attended a meticulous and individually designed maintenance care program during the follow-up period [14]. The progression of bone loss due to peri-implantitis is for obvious ethical reasons not feasible to study in randomized controlled trials. Retrospective studies are, therefore, justified for addressing this topic. Available studies suggest an early onset and that the progression of peri-implantitis has a non-linear and accelerating pattern [15,16]. In a retrospective study by Derks et al. [16], 52% of the implants later diagnosed with peri-implantitis demonstrated signs of bone loss (>0.5 mm) already after 2 years of function.

The aim of this study was to assess the degree of radiographical peri-implant bone loss over a long time period up to 15 years. In addition, another aim was to identify risk indicators at patient- and implant level for peri-implant bone loss in healthy implants and for moderate–severe peri-implantitis.

Methods

Ethical statements

The study was conducted in full accordance with the World Medical Association Declaration of Helsinki, approved by the Regional Ethics Board in Stockholm (2013/790-31/2) and registered at ClinicalTrials.gov (OF13122003). Guidelines on 'Strengthening the Reporting of Observational studies in Epidemiology' (STROBE) were followed.

Study design

This is a cross-sectional clinical and radiological study in combination with data collected retrospectively for baseline variables. All patients referred to the Specialist Clinic of Periodontology and Oral Prosthetics (Public Dental Service at Skanstull, Stockholm) where implant therapy was performed during the period 1999–2005 were included in the study group. Dental implant surgical procedures were performed by periodontists, whereas prosthodontists or general dentists performed implant prosthetic treatment. In total, 263 patients were invited to a clinical examination and 163 patients attended (62%) with a total of 470 implants (Figure 1). Sixty patients declined examination and 40 patients failed the appointment. The patients were invited by mail for a free of charge clinical and radiographic examination.

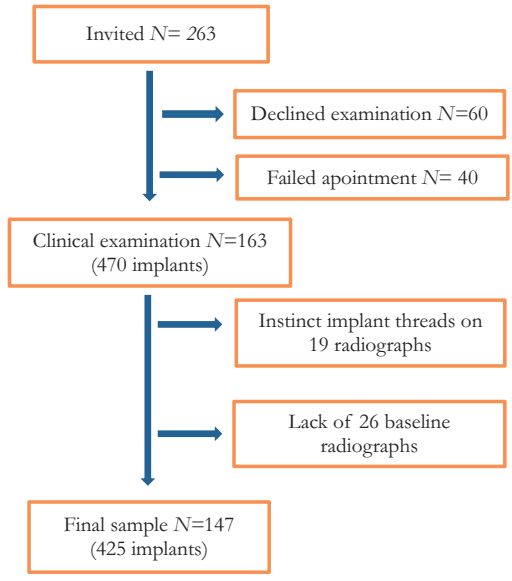

Figure 1. Flow chart.

Variables at baseline

The following variables were registered from the digital dental records by one investigator at baseline: smoking habits (no, yes = daily ≥5 cigarettes/day); history of general periodontitis (≥30% teeth involved) Stages III or IV [17]; prosthetic implant construction; complications during implant surgery (no, yes = rotation/unstable fixture, cervical gap between bone and fixture, or insufficient buccal bone), bone augmentation before/during implant treatment (no, yes); one-stage implant surgery (no, yes); cement-retained construction (no, yes); position of implants (equivalent tooth position); implant length (mm); implant brand.

Registrations of variables at the clinical examination

The clinical examinations were performed by four calibrated periodontists and consisted of full mouth pocket probing depth at teeth and implant sites (PCP15, Hu-Friedy, Chicago, IL), BoP, suppuration and plaque index [18].

The following variables were registered from the follow-up dental visits or the clinical examination: age; sex; smoking habits (no, yes = daily ≥5 cigarettes/day); general health; regular check-ups yearly by periodontist or prosthodontist (no, yes); regular maintenance therapy by the dental hygienist at the specialist clinic at least twice a year (no, yes); number of teeth; number of implants; number of tooth sites bleeding on probing with pocket depth >4 mm and >6 mm; plaque index (<20%, ≥20%; probing bleeding index; periodontal diagnosis; late implant loss (defined as occurring after prosthetic loading); peri-implant mucositis (bleeding/suppuration on pocket probing and radiographic bone loss ≤0.5 mm compared to baseline radiographs); peri-implantitis (bleeding/suppuration on probing, increased pocket depth compared to previous examinations and radiographic bone loss >0.5 mm compared to baseline radiographs. The peri-implantitis was defined as moderate–severe if the

radiographic bone loss was >2 mm compared to baseline radiographs.

Radiographic assessments at baseline and clinical examination

Baseline radiographs were collected from the digital dental records and were classified as baseline radiographs if taken in connection with prosthetic loading or up to 12 months past implant surgery. Radiographic examinations of all dental implants were performed at the clinical investigations.

Marginal alveolar bone level on radiographs at implants and implant length (mm) was assessed by using a software program (ImageJ 1.51d, Wayne Rasband, MD, National Institutes of Health) [19]. For calibration of each radiograph, the manufacturers reported implant inter-thread pitch distance was used before measurements of bone levels, except for Straumann implants (Straumann® Standard implants, Straumann® implant system, Basel, Switzerland) where the length of the implants was used. Reference levels were chosen for the different implant systems and radiographic distance to the crestal bone was measured at the site (mesial or distal site) with the largest crestal bone loss. Reference levels were chosen depending on the reproducibility in the radiographs. The implant shoulder or the level of the first thread was used for Nobel Biocare implants (MkBrånemark System® MkIII or MkIV, Nobel Biocare, Zürich, Switzerland), apical part of the implant shoulder for Astra Tech implants (TiOBlast, Dentsply, IH AB, Mölndal, Sweden) and the implant/abutment connection for Straumann tissue level implants. To calculate the peri-implant bone loss (primary outcome variable), the radiographic bone level measurements from baseline were compared to the radiographic bone level assessments at the final radiographic investigation 10–15 years later. The assessment of radiographic bone levels was performed by two investigators. The inter- and intraexaminer correlations of bone level measurements were estimated by repeating the measurements of 20 radiographs about two months after the first measurements. The intra-examiner and inter-examiner agreements according to measurement error were 0.28 ± 0.18 mm and 0.34 ± 0.27, respectively. Four per cent (19) of the radiographs were excluded due to indistinct threads and 5.6% (26) due to lack of baseline radiographs. The final sample consisted of 147 patients with in total 425 implants (Figure 1).

Statistical methods

A statistical package was used for descriptive statistics and analyses (SPSS 26.0, SPSS Inc., Chicago, IL). Unpaired *t*-test or Chi-square test was used for comparison between two independent groups. The Linear Mixed Model (LMM) procedure was adopted for multilevel analyses with peri-implant bone loss as the outcome variable. Factors with $p \geq .05$ were removed backwards in the final model, which included factors with $p < .05$. The Generalized Estimating Equations (GEE) procedure was adopted for multilevel analyses with peri-implantitis as binary outcome variable. GEE analysis was performed using a covariance matrix used with robust estimator, an unstructured correlation matrix and type III model effects. Factors with $p \geq .05$ were removed backwards in the final model, which included factors with $p < .05$. The inter- and intra-investigator reliability according to assessments of radiographic peri-implant bone loss was estimated by calculating Pearson correlation coefficient. The results were considered statistically significant at $p < .05$.

Results

Description of the patient sample

The subjects who dropped out from the clinical examination ($N = 100$) had fewer teeth and had more frequently history of periodontitis (Table 1). However, these differences were not significant.

The mean follow-up time was 12.5 years (range 10–15). The mean age was 63 years (range 29–83) and 56% were females (Table 2). The relative frequency of smokers decreased from 21% at baseline to 10% at the clinical examination. The presence of cardio-vascular disease was reported by 27% of the subjects. The most frequent prosthetic implant construction was partial prosthesis (62%), while 21% of the constructions were single implants (Table 2). Forty per cent of the subjects had a history of general periodontitis and the majority (60%) had the diagnosis periodontitis stages III or IV at the clinical examination. During the follow-up period, 44% had supportive care regularly at the specialist clinic (Table 2). The prevalence of moderate–severe peri-implantitis at patient level was 17% and 8.9% at implant level (Table 3), while in total 66 implants (15.5%) were affected by mild peri-odontitis (Tables 4 and 5). The distribution differed between implant positions (Table 3). The highest prevalence level of moderate/severe peri-implantitis was found in the

Table 1. Comparisons between clinically examined and non-examined subjects according to background variables at baseline.

Variable	Clinical examination ($N = 163$)	Non-examined subjects ($N = 100$)	*p*
Age (years, mean (SD)	51 (12)[a]	53 (15)	.16
Sex (males/females)	44%/56%[b]	49%/51%	.43
Smokers at baseline	21%[b]	22%	.91
Number of teeth (mean (SD)	20.3 (6.8)[a]	18.4 (8.5)	.06
Number of implants (mean (range))	2.8 (2.2)[a]	3.2 (2.6)	.18
History of general periodontitis	39%[b]	50%	.08

[a]Unpaired *t*-test.
[b]Chi-square test.

Table 2. Description of the patient sample according to anamnestic and clinical variables ($N = 147$).

Baseline variables	Description
Smokers (%)	21
History of general periodontitis Stage III or IV (%)	40
Prosthetic implant construction:	
Single implant (%)	21
Partial implants (%)	62
Full mouth implants (%)	17
Complications registered during implant surgery (%)	8.3
Bone augmentation before/during implant surgery (%)	12
One-stage implant surgery (%)	15
Cement-retained constructions (%)	25
Implant length (mm, mean ± SD)	12.5 ± 2.0
Implant brand (%):	
Astra Tech	76
Nobel Biocare	23
Straumann implant system	0.5
Variables at clinical examination	Description
Age (mean ± SD)	63 ± 12
Males/females (%/%)	44/56
Smokers (%)	10
Cardio-vascular disease (%)	27
Diabetes (%)	8.2
Regular follow-up visits at the specialist clinic (%)	48
Regular maintenance care at the specialist clinic (%)	44
Number of teeth (mean ± SD)	20.6 ± 7.4
Number of dental implants (mean ± SD)	2.9 ± 2.6
Number of tooth sites bleeding on probing with pocket depth >4 mm (mean ± SD)	7.5 ± 7.4
Number of tooth sites bleeding on probing with pocket depth >6 mm (mean ± SD)	2.4 ± 5.0
Plaque index (%) (<20%, ≥20%)	61/39
Probing bleeding index (mean ± SD)	11.1 ± 13.5
Periodontal diagnosis:	
Edentulous (%)	3
Local periodontitis Stages III or IV (%)	37
General periodontitis Stages III or IV (%)	23

Table 3. Peri-implant bone loss (mm) and prevalence of peri-implant mucositis and peri-implantitis at implant level according to region.

Implant position	*N*	Peri-implant bone loss (mm) (mean (SD))	Peri-implant mucositis (%)	Moderate/severe peri-implantitis[a] (%)
Maxillary molar	30	0.99 (1.4)	20.0	10.0
Maxillary premolar	134	0.88 (1.1) [a]	17.2	7.5
Maxillary incisor/canine	119	1.1 (1.6)	20.2	11.8
Mandibular molar	57	0.86 (1.1) [b]	12.3	5.3
Mandibular premolar	59	0.53 (0.60) [c]	20.3	3.4 [d]
Mandibular incisor/canine	26	1.5 (2.0) [abc]	7.7	23.1 [d]
Total	425	0.94 (1.3)	17.4	8.9

[abc] $p < .05$ at pairwise comparison with the Linear Mixed Model (LMM) procedure for multilevel analyses.
[d] $p < .05$ at pairwise comparison with the Generalized Estimating Equations (GEE) procedure for multilevel analyses.

Table 4. Distribution (%) according to peri-implant bone loss ($N = 425$ implants).

Peri-implant bone loss	≤0.5 mm	>0.5 mm	>1 mm	>2 mm	>3 mm	>4 mm
Relative frequency (*N*)	51.0% (217)	49.0% (208)	26.6% (113)	11.6% (49)	6.3% (27)	3.3% (14)

Table 5. Distribution (%) according to peri-implant bone loss at implants with peri-implantitis ($N = 104$ implants).

Peri-implant bone loss	>0.5 mm	>1 mm	>2 mm	>3 mm	>4 mm
Relative frequency (*N*)	24.5% (104)	15.5% (66)	8.9% (38)	5.2% (22)	3.3% (14)

mandibular incisor/canine region (23%, Table 3). Fourteen implants in nine subjects (four males and five females) were lost during the follow-up period.

Radiographic peri-implant bone loss

The frequency distribution for peri-implant bone loss is presented in Tables 4 and 5. The mean peri-implant bone loss after 12.5 years was 0.94 mm (S.D. 1.3, Table 3) and the annual mean peri-implant bone loss was 0.074 mm (S.D. 0.12). The mean peri-implant bone loss differed significantly between implant positions and was 1.5 mm (S.D. 2.0) for implants in the mandibular incisor/canine position compared to 0.53 mm (S.D. 0.60) in the mandibular premolar region (Table 3). Only one patient had Straumann implants and was excluded from the multi-level analyses. The mean peri-implant bone loss did not differ significantly between the other two implant systems ($p = .65$).

Table 6. Factors significantly associated with peri-implant bone loss at healthy sites when adjusted for number of follow-up years. Variables with $p < .05$ are presented in the model[a]. ($N = 247$).

Factor	Estimate	Standard error	*p*
Moderate–severe peri-implantitis at subject level (no = 0, yes = 1)	0.56	0.15	<.001

[a]The Linear Mixed Model (LMM) procedure for multilevel analyses with peri-implant bone loss as the outcome variable. Factors with $p \geq .05$ were removed backwards in the final model.

Table 7. Factors associated with moderate–severe peri-implantitis at patient- and implant levels adjusted for number of follow-up years. Variables with $p < .05$ are presented in the model[a]. $N = 359$.

Independent variable	Odds ratio	95% Confidence interval	*p*
General periodontitis stages III or IV at follow-up			.002
No	1		
Yes	5.9	1.9–19	
Smoker at baseline and follow-up			.014
No	1		
Yes	3.9	1.3–11	

[a]The Generalized Estimating Equations (GEE) procedure for multilevel analyses with peri-implantitis as binary outcome variable. Factors with $p \geq .05$ were removed backwards in the final model.

In the final step of the multi-level analysis, one variable had a significant impact on peri-implant bone loss in healthy implants when adjusted for number of follow-up years and after exclusion of cases with peri-implant mucositis and peri-implantitis at implant level (Table 6). The peri-implant bone loss was significantly more pronounced in healthy implants if moderate–severe peri-implantitis was present in at least one implant within the same patient. Smoking was excluded in the last step since the association was non-significant ($p = .06$). The presence of moderate–severe peri-implantitis was significantly associated with general periodontitis Stages III or IV at follow-up and smoking (Table 7).

Discussion

This clinical study comprises patients from a Specialist Clinic of Periodontology and Oral Prosthetics who received dental implant therapy 10–15 years ago. Forty per cent of the subjects had a history of general periodontitis and 44% had supportive care regularly at the specialist clinic during the follow-up period. Thus, a significant part of the patients are periodontitis-prone individuals, indicating that they are not representative of a general population in Sweden.

The definitions of peri-implantitis vary between studies partly due to the different thresholds for peri-implant bone loss. In the present study, the criteria for the diagnosis peri-implant mucositis and peri-implantitis are in accordance with the Consensus report on peri-implant diseases and conditions of the 2017 World Workshop [1]. The prevalence of moderate/severe peri-implantitis was 17% at patient level in the present study compared to 14.5% up to 37% in other studies with at least 5 years of follow-up [5,7,20–22].

The mean annual peri-implant bone loss was 0.074 mm at implant level. This result is consistent with a previous study on a Swedish general population [5]. Earlier studies have demonstrated a non-linear accelerating bone loss pattern over time for implants affected by peri-implantitis [15,16]. In the present study, the radiographs were evaluated at two occasions (at baseline and the clinical examination). Consequently, the pattern of peri-implant bone loss over time could not be analyzed. The shape of the distribution of peri-implant bone loss resembles the distribution presented in a clinical study over 9 years [5]. However, the total bone loss was greater in the present study which may be explained by a longer mean follow-up time (12 years).

In an earlier longitudinal retrospective study of 376 subjects with a total of 1095 implants including the 147 patients of the present study [23], smoking was found to be a risk indicator for peri-implantitis at implant level in agreement with the present study. However, some studies fail to identify smoking as a risk indicator for peri-implantitis at patient level [10]. In a systematic review by Sgolastra et al. [24], an implant-based meta-analysis based on a limited number of studies found a significant relationship between smoking and an increased risk of peri-implantitis, but the association was non-significant at patient level. However, other studies have reported significantly increased peri-implant bone loss in smokers compared to non-smokers [25]. A recent retrospective cohort study from a private practice with 5- to 10-year follow-up showed that peri-implant bone loss at implant level increased significantly for smokers irrespective of the presence of peri-implantitis [26].

Today, there is evidence that history of periodontitis is a risk indicator of peri-implantitis [1], and significantly associated with greater peri-implant bone loss [25]. In the present study, history of periodontitis was not significantly associated to moderate–severe peri-implantitis. However, individuals with periodontitis Stages III and IV at follow-up had more frequently moderate–severe peri-implantitis, and most of these subjects also had a previous history of periodontitis Stages III and IV.

The peri-implant bone loss was significantly greater in healthy implants if moderate–severe peri-implantitis was present in at least one implant within the same patient. There are several probable explanations for this connection. In patients with ongoing peri-implantitis, there is hypothetically an increased probability that healthy implants have previously suffered from peri-implantitis. Thus, some cases may have been successfully treated surgically for peri-implantitis during the follow-up period. In addition, patients with

peri-implantitis are more likely to have risk factors that can affect bone level in all implants, such as smoking, osteoporosis and a more pathogenic microflora.

The peri-implant bone loss was significantly increased in the lower front region compared to three other regions. This result is in accordance with a study conducted over 12–15 years on mandibular Brånemark implants in 47 subjects, which showed a pronounced peri-implant bone loss in the anterior region [27]. The results were confirmed in a study on 30 of the 47 subjects who were re-evaluated 20 years after implant installation [28]. Another study on a sample of 182 subjects with 419 implants with peri-implantitis-associated bone loss from the Brånemark clinic in Gothenburg, Sweden, showed a significantly higher probability of bone loss in the anterior mandibular region [29].

In the present study, about half of the subjects had supportive dental care regularly at the specialist clinic during the follow-up period. The peri-implant bone loss or presence of peri-implantitis was not correlated with supportive care. This observation was unexpected, since regular maintenance therapy may prevent biological complications after dental implant therapy [30]. The subjects in the study group with regular supportive care were described in an earlier study [23]. These subjects had significantly fewer teeth, more dental implants and a history of being treated for severe periodontitis compared with the subjects without regular supportive care. Thus, we can assume that these subjects were regarded as risk patients with an increased risk for biological complications. Consequently, they were probably advised to stay at the specialist clinic for regular maintenance care after the active treatment period.

This study has some limitations to discuss. The subjects in the study group had more teeth ($p = .06$) and less frequently a history of periodontitis ($p = .08$) compared to those who dropped out. Thus, the sample of the present investigation is not fully representative for the study group, but it is unlikely that this will influence the result. In addition, the retrospective collection of baseline variables may affect the validity of the data. Eight per cent of the radiographs from baseline were missing and instinct implant threads were registered for 19 radiographs. Consequently, a reduced reliability can be expected due to the missing data. The quality of the radiographs may also affect the reliability of the radiographic measurements. The measurement errors due to the angulations of the radiographs may affect the estimated differences between baseline and follow-up radiographs

Conclusion

In this periodontitis-prone population, the mean annual longitudinal peri-implant bone loss was 0.07 mm over 10–15 years. The presence of moderate–severe peri-implantitis at patient level was found to be a risk indicator of peri-implant bone loss in healthy implants, while smoking and general periodontitis Stages III and IV were risk indicators of moderate–severe peri-implantitis. The findings are intriguing; however, more longitudinal studies with large samples from different populations are essential in the future to investigate the importance of these potential risk factors.

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Disclosure statement

The authors report no conflicts of interest and are responsible for the content and writing of the paper.

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Data availability statement

The data that support the findings of this study are available from the corresponding author [L. J.], upon reasonable request.

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