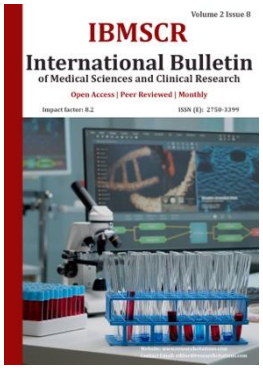

CLINICAL, MEDICAL HISTORY, AND SYSTEMIC FACTORS ASSOCIATED WITH PERI-IMPLANTITIS: A RETROSPECTIVE ANALYTICAL STUDY

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https://doi.org/10.5281/zenodo.22327263

Abstract

Background. Peri-implantitis is among the most significant biological complications of dental implant therapy and is regarded as an inflammatory lesion of the tissues surrounding an implant in function, accompanied by progressive loss of supporting bone [1–4, 8, 12, 13]. Current concepts of its pathogenesis invoke an interplay of microbial, local, and systemic factors, and patient-specific characteristics may considerably modify the probability of the disease [5, 6, 7, 10, 17, 29].

Aim. To identify the clinical and medical history characteristics and systemic conditions associated with peri-implantitis, and to assess their independent contribution to the probability of the disease in a clinical cohort of patients with dental implants.

Methods. A retrospective analytical study of 414 patients with dental implants was performed. According to the recorded clinical outcome, 330 patients were assigned to the group without peri-implantitis and 84 to the peri-implantitis group. Demographic and clinical characteristics, including age and sex, were analyzed. Smoking, diabetes mellitus, bruxism, and a history of periodontal disease were assessed separately; the number of comorbidities and the presence of cardiovascular, renal, endocrine, gastrointestinal, respiratory, and bone-metabolic disease were also recorded. Between-group comparisons used the chi-squared test and non-parametric methods for quantitative variables. Independent associations were assessed by multivariable binary logistic regression, and adjusted odds ratios (aOR) with 95% confidence intervals were calculated.

Results. Peri-implantitis was diagnosed in 84 of 414 patients, accounting for 20.3% of the examined cohort. Patients with peri-implantitis were significantly older than those without the disease: 51.81 ± 8.79 vs 38.07 ± 12.50 years, respectively ($p < 0.001$). Smoking was recorded in 50.0% of patients with peri-implantitis and 29.1% of patients without the disease; the corresponding figures for diabetes mellitus were 69.0% and 9.1%. A history of periodontal disease differed markedly between the groups. In the multivariable model, smoking, diabetes mellitus, osteoporosis, and a more pronounced history of periodontal pathology retained independent associations with peri-implantitis: the aOR was 7.18 (95% CI 2.40–21.51; $p < 0.001$) for diabetes mellitus, 3.48 (95% CI 1.21–10.02; $p = 0.021$) for smoking, and 4.46 (95% CI 1.23–16.20; $p = 0.023$) for osteoporosis. At the most pronounced level of periodontal pathology in the history, the odds ratio was 329.53 (95% CI 51.21–2120.48; $p < 0.001$).

Conclusions. In the cohort studied, peri-implantitis was associated primarily with diabetes mellitus, smoking, osteoporosis, and a history of periodontal disease. The findings support assessing not only the local condition of the implant but also the patient's overall clinical and somatic profile when stratifying the risk of peri-implant disease [16, 23, 28].

Keywords: dental implants; peri-implantitis; risk factors; diabetes mellitus; smoking; periodontitis; comorbidity; logistic regression.

Introduction

Dental implant placement is currently one of the principal methods for the functional and aesthetic rehabilitation of patients with partial or complete tooth loss. High implant survival rates, achieved through advances in surgical, prosthetic, and preventive protocols, have considerably broadened the indications for implant-based rehabilitation [1–3]. At the same time, the growing number of implants in function has been accompanied by an increasing number of patients in whom inflammatory complications of the peri-implant tissues are detected. The clinically most significant of these is peri-implantitis, since its progression may involve destruction of the supporting bone and ultimately jeopardize implant survival [4, 8].

According to the current international consensus, peri-implantitis is a pathological condition associated with inflammation of the peri-implant mucosa and subsequent progressive loss of supporting bone [8, 12, 13]. Unlike peri-implant mucositis, in which the inflammatory response is largely confined to the soft tissues, peri-implantitis is characterized by the combination of inflammatory signs and destructive changes in the bony support [7, 12, 14]. Standardization of the diagnostic criteria is of substantial importance for epidemiological research, since differences in the definition of the disease, in the duration of implant function, and in the bone-loss thresholds applied can considerably alter prevalence estimates [9, 15, 28].

Current epidemiological data indicate considerable variability in the reported frequency of peri-implantitis. In the systematic review by Derks and Tomasi, the patient-level prevalence varied widely, with a pooled estimate of approximately 22%; the frequency of the disease increased with longer implant function time [5, 9]. According to a more recent meta-analysis of 57 studies, peri-implantitis was identified in approximately 19.5% of patients, with an implant-level prevalence of 12.5% [15]. Peri-implantitis should therefore be regarded not as a rare complication but as a clinically significant disease whose prevention requires systematic assessment of risk factors [10, 16, 17].

In recent years, the concept of peri-implantitis risk factors has changed substantially. Whereas attention was initially focused almost exclusively on local plaque accumulation, current models consider the disease as the result of an interplay between microbial challenge and the host immune response, soft-tissue characteristics, systemic diseases, behavioral factors, and previous periodontal status [5, 7, 10, 27, 30]. Nevertheless, the strength of the evidence differs between individual risk factors. According to a recent umbrella review, the most consistent associations with peri-implantitis have been established for a history of periodontitis and smoking, whereas the evidence regarding diabetes mellitus, hyperglycemia, inadequate preventive care, and a narrow band of keratinized mucosa remains less conclusive [10, 17, 27].

A history of periodontal disease occupies a special place among these factors. The biological plausibility of its effect stems not only from the similarity of the inflammatory processes in the periodontium and the peri-implant tissues, but also from the potential

formation of a persistent dysbiotic microbial reservoir that survives tooth loss. Meta-analyses have shown a higher likelihood of peri-implantitis in patients with a history of periodontitis, although the magnitude of the effect depends on the study design and the outcome definition [11, 18–20]. Recent prospective cohort data likewise indicate a higher frequency of peri-implantitis and greater marginal bone loss in periodontally compromised patients [18, 19].

Smoking is another important factor. Its effects may be mediated by an impaired vascular response, altered immune regulation, and poorer control of inflammation. A recent meta-analysis of prospective studies demonstrated an increased risk of peri-implantitis in smokers at both the implant and the patient level [11, 21].

Diabetes mellitus is another potentially significant systemic modifier. Chronic hyperglycemia can affect the inflammatory response, vascular function, and bone remodeling. The findings of individual studies are nevertheless heterogeneous, which calls for the analysis of diabetes in well-characterized clinical cohorts [22].

In the context of population ageing and the growing number of patients with multiple somatic conditions, the study of comorbidity is becoming increasingly important. Patients with dental implants increasingly present with combinations of metabolic, cardiovascular, bone-metabolic, and other chronic diseases. Most studies, however, consider individual factors in isolation, whereas the clinical situation is characterised by their simultaneous presence [1, 29].

Against this background, the aim of the present study was to comprehensively examine the demographic, behavioral, periodontal, and systemic characteristics of patients with dental implants and to determine their independent associations with peri-implantitis.

Study design and study population

The study was designed as a retrospective analytical study based on an electronic clinical database of patients with dental implants. The source database comprised 414 records. The main analytical cohort was formed using the presence of a recorded clinical outcome (Outcome code, the study outcome); records without a documented outcome were excluded from the analysis.

After the application of the selection criteria, 414 patients were included in the final analysis. In 330 of them (79.7%), signs of peri-implantitis were absent, whereas 84 patients (20.3%) were diagnosed with peri-implantitis. The prevalence of peri-implantitis in the study sample was therefore 20.3%.

To assess possible associations with peri-implantitis, age, sex, smoking, diabetes mellitus, bruxism, and the history of periodontal pathology were analyzed. The patients' systemic status was characterized by the number of comorbidities and the presence of cardiovascular diseases, osteoporosis, kidney diseases, other endocrine diseases, gastrointestinal diseases, autoimmune/rheumatological pathology, and respiratory diseases.

Statistical analysis

Quantitative variables were assessed with regard to the nature of their distribution. Data were described using means and standard deviations as well as median values. Between-group differences in quantitative variables were assessed with non-parametric methods; categorical variables were compared using the chi-squared test.

To identify the factors independently associated with peri-implantitis, a multivariable binary logistic regression model was constructed. The model included age, smoking, diabetes mellitus, cardiovascular disease, osteoporosis, and the history of periodontal pathology. For the

latter variable, categorical coding was applied, with levels defined relative to the reference category.

The results of the regression analysis are presented as adjusted odds ratios (aOR) with 95% confidence intervals. The discriminative ability of the model was assessed using ROC analysis and the area under the ROC curve (AUC). A p value < 0.05 was considered statistically significant.

Results

The final analytical sample comprised 414 patients. Peri-implantitis was recorded in 84 patients, corresponding to 20.3%, whereas 330 patients (79.7%) showed no signs of the disease.

Patient age differed substantially between the study groups. In the group without peri-implantitis, the mean age was 38.07 ± 12.50 years, compared with 51.81 ± 8.79 years among patients with peri-implantitis; this difference was statistically significant (p < 0.001).

The sex distribution also differed between the groups: men accounted for 52.4% of the peri-implantitis group versus 33.9% of the group without the disease.

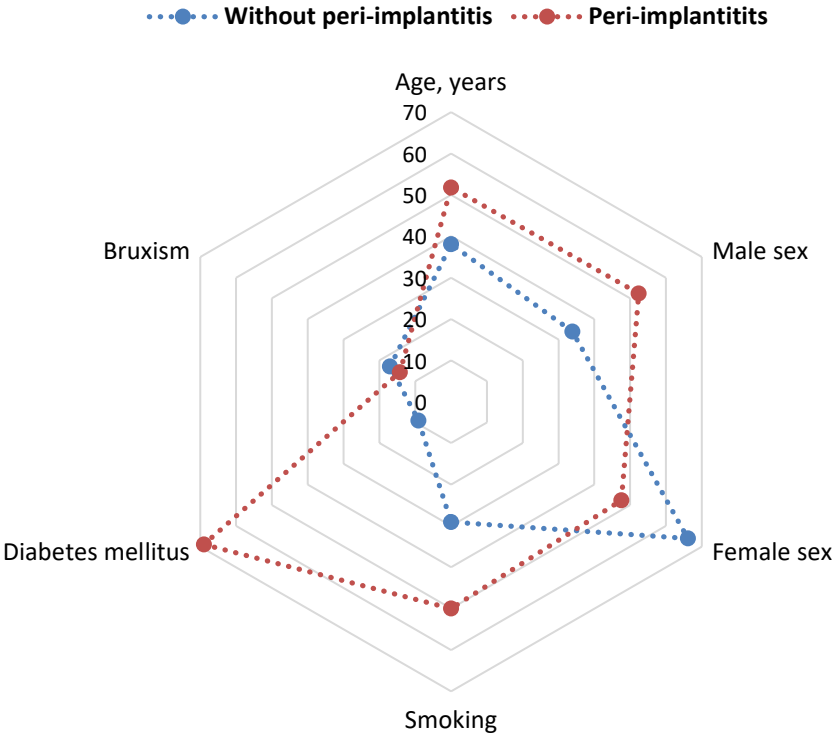

Figure 1. Demographic characteristics of the patients by peri-implantitis status

The most substantial differences were found for smoking and diabetes mellitus. Smoking was recorded in half of the patients with peri-implantitis, whereas in the disease-free group this figure was 29.1%. An even more pronounced difference was observed for diabetes mellitus: 69.0% of the patients with peri-implantitis had diabetes compared with 9.1% of the patients without peri-implantitis.

These pronounced differences persisted in the multivariable analysis, indicating an independent association between these factors and the outcome under study.

The most marked between-group heterogeneity was observed for the history of periodontal disease. In the group without peri-implantitis, 222 patients had no corresponding history, compared with only two patients in the peri-implantitis group. Conversely, the most

pronounced level of periodontal pathology in the history was observed in 68 patients of the peri-implantitis group and in only four patients of the comparison group.

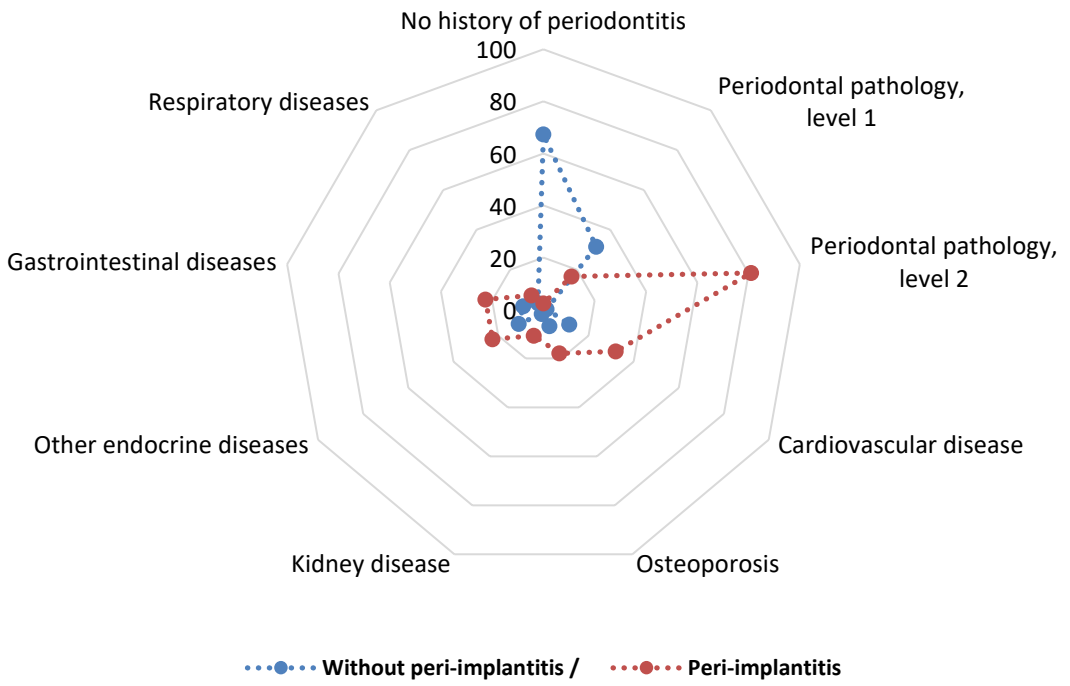

Figure 2. Periodontal history and systemic comorbidity.

After mutual adjustment for the variables under study, smoking, diabetes mellitus, osteoporosis, and the most pronounced level of periodontal pathology in the history retained a statistically significant association with peri-implantitis.

The adjusted odds ratio for smoking was 3.48 (95% CI 1.21–10.02; $p = 0.021$), indicating an approximately threefold increase in the likelihood of peri-implantitis associated with this factor after accounting for the other variables in the model.

For diabetes mellitus, the aOR was 7.18 (95% CI 2.40–21.51; $p < 0.001$). Osteoporosis also retained a statistically significant independent association with the outcome: aOR 4.46 (95% CI 1.23–16.20; $p = 0.023$).

The strongest association was observed for level 2 of periodontal pathology in the history relative to the reference category: aOR 329.53 (95% CI 51.21–2120.48; $p < 0.001$). Such a wide confidence interval reflects the high degree of separation of the groups on this characteristic and, at the same time, points to the need for cautious interpretation of the effect size.

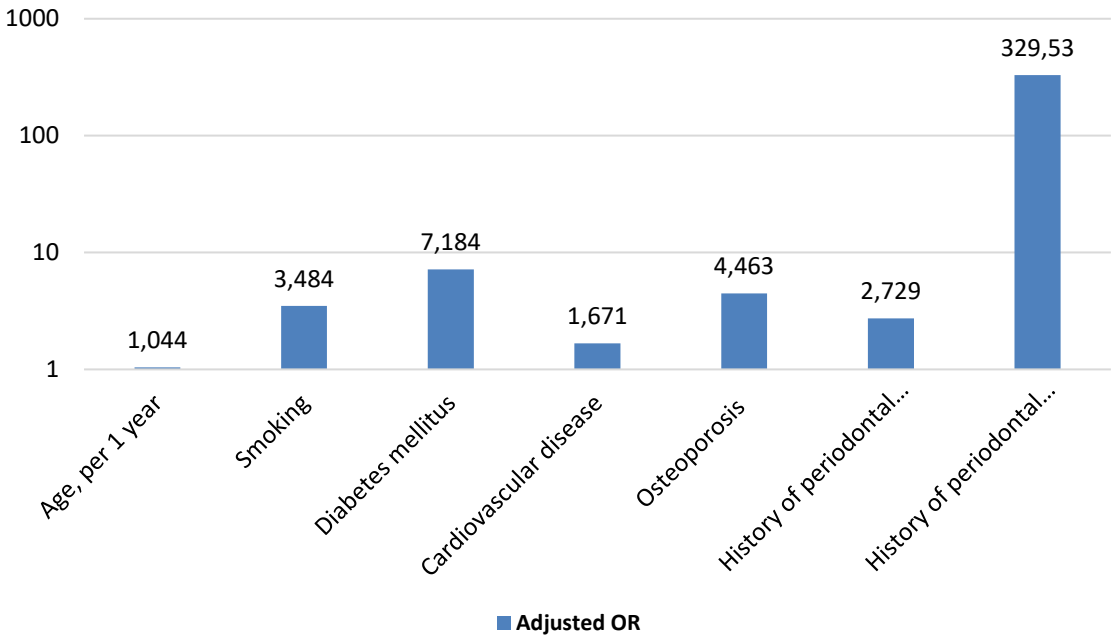

Figure 3. Multivariable logistic regression for factors associated with peri-implantitis (adjusted odds ratios, log scale).

Note. The 95% CI and p values for each predictor were as follows: age, per 1 year – 0.984–1.108, p = 0.152; smoking – 1.211–10.019, p = 0.021; diabetes mellitus – 2.400–21.505, p < 0.001; cardiovascular disease – 0.491–5.695, p = 0.412; osteoporosis – 1.229–16.203, p = 0.023; history of periodontal pathology, level 1 – 0.478–15.569, p = 0.259; history of periodontal pathology, level 2 – 51.210–2120.480, p < 0.001.

The AUC of the multivariable model was 0.981, indicating high discriminative ability of the model in this sample.

Discussion

The findings confirm the multifactorial nature of peri-implantitis and demonstrate that, in the cohort under study, the probability of the disease was associated not only with the local state of the peri-implant tissues but also with the patient's overall profile [10, 16, 29]. The most pronounced associations were established for diabetes mellitus, smoking, osteoporosis, and a history of periodontal pathology.

The prevalence of peri-implantitis in the present sample was 20.3% at the patient level. This figure is close to current estimates obtained in systematic reviews, despite differences between studies in diagnostic criteria and implant function time [9, 15]. The comparability of these figures should be interpreted with the caveat that peri-implantitis prevalence depends heavily on the disease definition used and the observation period [8, 12].

One of the most notable findings of this study was the independent association between diabetes mellitus and peri-implantitis. In the multivariable model, the presence of diabetes was associated with a more than sevenfold increase in the odds of the disease. These results are consistent with the current literature, in which diabetes mellitus and hyperglycemia are regarded as potentially important modifiers of peri-implant inflammation [10, 12]. It should be emphasized, however, that the presence of diabetes does not equate to the degree of metabolic control. HbA1c values are available in the present dataset, but laboratory parameters were deliberately excluded from the present publication. Their analysis in a separate paper will allow

a more detailed assessment of the relationship between the degree of hyperglycaemia and the clinical phenotype of the disease.

Smoking was also associated with an increased likelihood of peri-implantitis after adjustment for other factors. The aOR was 3.48, which agrees with the current meta-analyses indicating a higher risk of peri-implantitis in smokers than in non-smokers [11, 21]. A possible explanation for this association is the effect of tobacco smoke components on microcirculation, immune mechanisms, and tissue repair processes.

The association between osteoporosis and peri-implantitis deserves separate attention. In the present model, osteoporosis was associated with an aOR of 4.46. This result, however, should be interpreted as an association rather than as evidence of a causal effect of the disease on the development of peri-implantitis. The effect of bone-metabolic status on implant outcomes depends on age, pharmacotherapy, disease duration, and other concomitant factors. The interpretation of this finding therefore requires confirmation in larger prospective studies.

The strongest association with peri-implantitis was observed in patients with a history of periodontal disease. This finding is in line with current concepts of peri-implantitis risk factors. According to systematic reviews and meta-analyses, a history of periodontitis is associated with a higher likelihood of developing peri-implantitis [11, 18–20]. In the most recent meta-analysis of prospective cohort studies, patients with a history of periodontitis likewise showed a higher risk of peri-implantitis and more pronounced loss of marginal bone around the implants [18].

At the same time, the OR for the most pronounced category of periodontal history in our model is extremely high. This is probably related to the particular distribution of this characteristic in the study sample: almost all patients in this category belonged to the peri-implantitis group. This value should therefore not be interpreted as a universal population-level risk estimate; rather, it reflects the marked separation of the study groups within this particular clinical database.

Age was statistically significantly higher in the peri-implantitis group in the univariable comparison; however, after adjustment for the other factors, its independent association did not reach statistical significance. This observation has methodological implications: age may act not as an independent factor but as a marker of the accumulation of somatic pathology, longer implant function, and other clinical characteristics [29].

Taken together, the findings support the need to move from a univariable assessment of individual factors to multivariable risk stratification. This approach is consistent with current recommendations, according to which the prevention of peri-implant diseases should begin before implant placement and continue throughout the period of implant function, including regular assessment of the peri-implant tissues and supportive care [16, 23–26].

The limitations of this study include its retrospective design, which restricts the possibility of establishing causal relationships. The single-centre design also limits the direct generalizability of the findings to other patient populations and calls for their confirmation in larger multicenter studies.

The interpretation of the association with active periodontitis requires caution. The high OR and wide confidence interval may be driven by the pronounced imbalance between the groups and the small number of patients with active periodontitis in the control group. This result should therefore be regarded as evidence of a strong association within the cohort under study rather than as a stable risk estimate applicable to the general population.

Conclusion

In this clinical cohort of 414 patients, peri-implantitis was detected in 20.3% of those examined. The disease showed pronounced associations with diabetes mellitus, smoking, osteoporosis, and a history of periodontal pathology. After adjustment for potential confounders, the most robust independent associations persisted for diabetes mellitus, smoking, osteoporosis, and a pronounced history of periodontal pathology.

These findings support the value of comprehensive clinical and somatic stratification of patients before implant placement and during supportive follow-up [16, 24, 25]. A promising direction for further analysis is the integration of clinical characteristics with measures of metabolic control, the immuno-inflammatory response, and the peri-implant microbiota

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