BULLETIN OF STOMATOLOGY AND MAXILLOFACIAL SURGERY
Volume 21, Issue 7

DOI: 10.58240/1829006X-2025.7-401

ORIGINAL RESEARCH

CRUCIAL FACTORS INVOLVED IN IMPLANT FAILURE AND PERI-IMPLANT PATHOLOGY IN SYSTEMICALLY COMPROMISED PATIENTS

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Received: *Jun 15, 2025;* ***Accepted:*** *Jul. 30, 2025;* ***Published:*** *Aug. 21,2025*

ABSTRACT

Background: Systemically compromised patients exhibit elevated risks of dental implant failure and peri-implant pathology due to impaired healing and immune responses. Identifying modifiable risk factors is critical for optimizing clinical outcomes.
Objective: To determine crucial factors associated with implant failure and peri-implant pathology in systemically compromised patients.
Methods: A retrospective cohort study was conducted with 300 systemically compromised patients (512 implants) followed for 3.5 ± 1.2 years. Data included systemic conditions (diabetes, osteoporosis, immunosuppression), implant characteristics, smoking status, oral hygiene indices, and clinical outcomes. Logistic regression identified risk factors.
Key Findings: Implant failure occurred in 12.7% of cases. Uncontrolled diabetes (HbA1c >7%) increased failure risk (OR = 3.5, 95% CI: 2.1–5.8, $p < 0.001$), as did smoking (OR = 2.8, 95% CI: 1.5–5.2, *p* = 0.002) and poor oral hygiene (plaque index >30%; OR = 2.1, 95% CI: 1.2–3.7, $p = 0.01$). Peri-implantitis affected 18.3% of implants, strongly associated with diabetes ($p = 0.003$) and smoking ($p = 0.005$).
Conclusion: Uncontrolled diabetes, smoking, and poor oral hygiene are pivotal risk factors. Strict glycemic control, smoking cessation, and enhanced hygiene protocols are essential for implant success in this population.

Keywords: risks of dental implant failure, peri-implant pathology

INTRODUCTION

Dental implantology has revolutionized edentulism management, yet systemically compromised patients face heightened risks of implant failure and peri-implant diseases[1].

Conditions such as diabetes mellitus, osteoporosis, and immunosuppressive therapies disrupt bone metabolism, angiogenesis, and immune surveillance, compromising osseointegration and peri-implant tissue integrity [2]. Recent epidemiological data indicate a 2–4× higher implant failure rate in diabetic patients compared to healthy counterparts, with peri-implantitis prevalence exceeding 20% in immunocompromised cohorts [3].

The significance of this issue is amplified by the rising global burden of systemic diseases; over 537 million adults have diabetes, and age-related osteoporosis affects 200 million individuals worldwide [4]. Despite advances in implant surfaces and surgical techniques, studies report inconsistent outcomes in systemically compromised populations, partly due to heterogeneous methodologies and inadequate control of confounding variables [5]. While diabetes and smoking are established risk factors, the interplay between systemic conditions, local factors (e.g., oral hygiene), and implant-specific variables remains poorly elucidated [6].

A critical research gap exists in comprehensive, multivariate analyses that simultaneously evaluate systemic, behavioral, and implant-related determinants of failure. Most studies focus on single conditions (e.g., diabetes), neglecting synergistic effects of comorbidities [7]. Furthermore, limited data address peri-implant pathology progression in high-risk groups, hindering evidence-based preventive strategies [8].

This study aimed to identify crucial factors associated with implant failure and peri-implant pathology in systemically compromised patients, integrating systemic, behavioral, and clinical variables to inform targeted interventions.

MATERIALS AND METHODS

Sample Size: 300 patients with systemic conditions who received ≥1 dental implant were included. Power analysis ($\alpha = 0.05$, $\beta = 0.2$) determined this sample could detect a minimum odds ratio (OR) of 2.0 for failure predictors.

Inclusion Criteria:

- Adults (≥18 years) with ≥1 systemic condition: diabetes (types 1/2), osteoporosis, autoimmune disorders (e.g., rheumatoid
- arthritis), or immunosuppressive therapy (e.g., corticosteroids, post-transplant drugs).
- Implants placed ≥12 months prior to data extraction.
- Complete records of systemic status, implant details, and follow-up examinations.

Exclusion Criteria:

- Healthy patients without systemic diseases.
- Implants with <12 months follow-up.
- Incomplete data on key variables (e.g., HbA1c, smoking status).

Data Collection:

- **Systemic Variables:** Disease type, duration, control status (e.g., HbA1c for diabetes; bone mineral density for osteoporosis), and medications.
- **Implant Variables:** Position (maxillary/mandibular, anterior/posterior), dimensions (length, diameter), surface type (rough/smooth), and loading protocol (immediate/delayed).
- **Behavioral Factors:** Smoking status (current/former/never; pack-years), alcohol consumption (units/week).
- **Clinical Parameters:** Plaque index (PI), bleeding on probing (BoP), probing depth (PD), and radiographic bone loss (RBL) at baseline and annual recalls.

Outcome Definitions:

- **Implant Failure:** Mobility, removal due to infection/pain, or RBL >50% of implant length [9].
- **Peri-implant Mucositis:** BoP + without RBL.
- **Peri-implantitis:** BoP + with RBL ≥2 mm and/or PD ≥6 mm [10].

Statistical Analysis:

Descriptive statistics (mean ± SD, percentages) summarized baseline data. Chi-square tests compared categorical variables; independent *t*-tests assessed continuous variables. Logistic regression modeled associations between predictors and outcomes, adjusting for confounders (age, sex, implant location). Significance: $p < 0.05$ (SPSS v28.0).

RESULTS

Cohort Characteristics:

300 patients (mean age 62.5 ± 10.3 years; 55% female) received 512 implants. Systemic conditions included diabetes (45%), osteoporosis (20%), autoimmune disorders (15%), and immunosuppressive therapy (10%). Mean follow-up was 3.5 ± 1.2 years.

Implant Failure:

Failure occurred in 65 implants (12.7%), with mean time

to failure of 1.8 ± 1.1 years. Univariate analysis identified diabetes ($p < 0.001$), smoking (*p* = 0.002), and poor oral hygiene (PI >30%; $p = 0.01$) as significant predictors.

Multivariate logistic regression confirmed:

- Uncontrolled diabetes (HbA1c >7%): OR = 3.5 (95% CI: 2.1–5.8, $p < 0.001$).
- Smoking: OR = 2.8 (95% CI: 1.5–5.2, $p = 0.002$).
- Poor oral hygiene: OR = 2.1 (95% CI: 1.2–3.7, $p = 0.01$).

Peri-implant Pathology:

Peri-implant mucositis affected 22.5% of implants; peri-implantitis occurred in 18.3%. Peri-implantitis was significantly associated with diabetes ($p = 0.003$), smoking ($p = 0.005$), and posterior implant location ($p = 0.02$).

Table 1. Demographic and Clinical Characteristics of the Cohort

Variable	Category	n (%) or Mean ± SD
Total Patients		300
Total Implants		512
Age (years)		62.5 ± 10.3
Gender	Female	165 (55.0%)
	Male	135 (45.0%)
Systemic Conditions	Diabetes (Total)	135 (45.0%)
	- Controlled (HbA1c ≤7%)	78 (57.8% of diabetics)
	- Uncontrolled (HbA1c >7%)	57 (42.2% of diabetics)
	Osteoporosis	60 (20.0%)
	Autoimmune Disorders	45 (15.0%)
	Immunosuppressive Therapy	30 (10.0%)
Smoking Status	Current Smoker	90 (30.0%)
	Former Smoker	75 (25.0%)
	Never Smoker	135 (45.0%)
Alcohol Consumption	≥1 unit/week	120 (40.0%)
	<1 unit/week	180 (60.0%)
Implant Position	Maxillary	238 (46.5%)
	Mandibular	274 (53.5%)
	Anterior	153 (29.9%)
	Posterior	359 (70.1%)
Implant Surface	Rough	384 (75.0%)
	Smooth	128 (25.0%)
Loading Protocol	Immediate	205 (40.0%)
	Delayed	307 (60.0%)
Follow-up (years)		3.5 ± 1.2

Table 2. Multivariate Logistic Regression for Implant Failure Predictors

Variable	Category	Odds Ratio (OR)	95% CI	p-value
Diabetes Status	Uncontrolled (HbA1c >7%)	3.5	2.1–5.8	<0.001
	Controlled (HbA1c ≤7%)	1.2	0.6–2.4	0.62
	Reference (No diabetes)	1.0	—	—
Smoking Status	Current Smoker	2.8	1.5–5.2	0.002
	Former Smoker	1.3	0.7–2.5	0.41
	Reference (Never Smoker)	1.0	—	—
Oral Hygiene (Plaque Index)	>30% (Poor)	2.1	1.2–3.7	0.01
	≤30% (Good)	1.0	—	—
Implant Location	Posterior	1.6	0.9–2.8	0.11
	Reference (Anterior)	1.0	—	—
Age	Per 10-year increase	1.1	0.9–1.4	0.35

Table 3. Factors Associated with Peri-implantitis

Variable	Category	Odds Ratio (OR)	95% CI	p-value
Diabetes Status	Uncontrolled (HbA1c >7%)	3.2	1.9–5.4	0.003
	Controlled (HbA1c ≤7%)	1.4	0.8–2.5	0.25
	Reference (No diabetes)	1.0	—	—
Smoking Status	Current Smoker	2.5	1.3–4.8	0.005
	Former Smoker	1.2	0.6–2.3	0.61
	Reference (Never Smoker)	1.0	—	—
Implant Location	Posterior	1.9	1.1–3.3	0.02
	Reference (Anterior)	1.0	—	—
Oral Hygiene (Plaque Index)	>30% (Poor)	2.3	1.3–4.1	0.004
	≤30% (Good)	1.0	—	—
Implant Surface	Rough	1.7	0.9–3.2	0.09
	Reference (Smooth)	1.0	—	—

Table 1 summarizes baseline data, highlighting the prevalence of systemic conditions (e.g., 45% diabetes, 30% current smokers) and implant distribution (70.1% posterior).
Table 2 confirms uncontrolled diabetes (OR = 3.5), current smoking (OR = 2.8), and poor hygiene (OR = 2.1) as significant predictors of implant failure ($p < 0.05$).
Table 3 identifies uncontrolled diabetes (OR = 3.2), current smoking (OR = 2.5), poor hygiene (OR = 2.3), and posterior location (OR = 1.9) as risk factors for peri-implantitis ($p < 0.05$).

DISCUSSION

This study identifies uncontrolled diabetes, smoking, and poor oral hygiene as critical, modifiable risk factors for implant failure and peri-implant pathology in systemically compromised patients. The 12.7% failure rate aligns with meta-analyses reporting 8–15% failure in diabetic cohorts [11], but exceeds rates in healthy populations (3–5%) [12], underscoring the vulnerability of this group.

Uncontrolled diabetes (HbA1c >7%) tripled failure risk, consistent with Monje et al. [13], who linked hyperglycemia to impaired osteoblast function and collagen degradation. Our data extend these findings by demonstrating that glycemic control (vs. diabetes presence alone) is the pivotal determinant, emphasizing the need for preoperative HbA1c optimization [14].

Smoking emerged as a potent independent risk factor (OR = 2.8), corroborating Chrcanovic et al. [15], who attributed nicotine-induced vasoconstriction and immune suppression to compromised osseointegration. Notably, current smokers exhibited higher peri-implantitis rates than former smokers, suggesting that cessation may mitigate risk [16].

Poor oral hygiene (PI >30%) doubled failure risk, highlighting the synergy between systemic compromise and local biofilm accumulation. This mirrors Schwarz et al. [17], who identified plaque as the primary etiological factor in peri-implantitis, even in systemically healthy patients. Our results reinforce that rigorous hygiene protocols are non-negotiable in high-risk cohorts [18].

Peri-implantitis prevalence (18.3%) exceeded rates in non-compromised patients (10%) [19], with diabetes and smoking as key drivers. This aligns with Derks et al. [20], who reported accelerated bone loss in diabetic patients due to dysregulated inflammatory responses. The association with posterior implants may reflect biomechanical stress and accessibility challenges for hygiene [21].

Limitations: Retrospective design risks selection bias; unmeasured confounders (e.g., genetic factors) may exist. Single-center data limit generalizability. Prospective studies with standardized systemic assessments are warranted.

Clinical Implications: Interdisciplinary collaboration is essential—endocrinologists for glycemic control, physicians for smoking cessation, and hygienists for personalized maintenance. Preoperative systemic optimization and lifelong supportive care are paramount [22].

CONCLUSION

This study demonstrates that uncontrolled diabetes, smoking, and poor oral hygiene are crucial factors driving implant failure and peri-implant pathology in systemically compromised patients. Addressing these modifiable risks through glycemic control, smoking cessation, and enhanced hygiene protocols can significantly improve outcomes. These findings underscore the need for integrated, patient-specific management strategies to optimize implant success in vulnerable populations.

DECLARATIONS

Funding

The work was not funded.

Ethical Approval

"Not applicable"

Consent for publication

"Not applicable"

Ethical approval

None

Competing interest

The authors declare that there are no competing interest.

Acknowledgements

None

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