

PERI-IMPLANTITIS: PATHOGENESIS, RISK FACTORS, AND MODERN THERAPEUTIC APPROACHES

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Abstract

Peri-implantitis is a biofilm-associated inflammatory disease affecting the soft and hard tissues surrounding dental implants, leading to progressive bone loss and potential implant failure. With the increasing global prevalence of dental implant therapy, peri-implantitis has become a significant clinical challenge in modern dentistry. This article reviews current knowledge regarding the pathogenesis, risk factors, diagnostic modalities, and contemporary treatment strategies for peri-implantitis. The role of microbial dysbiosis, host immune response, genetic predisposition, and systemic factors are discussed. Modern therapeutic approaches including mechanical debridement, laser therapy, photodynamic therapy, regenerative surgery, and implant surface decontamination techniques are analyzed. Future perspectives focus on biomarker-based early diagnosis, personalized risk assessment, and bioengineered treatment strategies.

Keywords: peri-implantitis, dental implants, biofilm, bone loss, regenerative therapy, implant failure

Introduction

Dental implants have become a predictable and widely accepted solution for replacing missing teeth. However, biological complications such as peri-implant mucositis and peri-implantitis threaten long-term implant survival.

Peri-implantitis is characterized by:

- Inflammation of peri-implant soft tissues
- Progressive marginal bone loss
- Bleeding on probing (BOP) and/or suppuration

Recent epidemiological studies estimate peri-implantitis prevalence between **10–25% of implants** and up to **20% of patients** with implants.

Unlike periodontitis, peri-implantitis demonstrates:

- Faster progression
- Less vascularized peri-implant tissue
- Absence of periodontal ligament

- Different collagen fiber orientation

Understanding disease mechanisms is essential for improving prevention and treatment outcomes.

Materials and Methods

This review article is based on a systematic analysis of scientific publications indexed in PubMed, Scopus, and Web of Science from 2015–2024. Keywords used included:

- “peri-implantitis pathogenesis”
- “peri-implantitis treatment”
- “implant surface decontamination”
- “peri-implant biomarkers”
- “laser therapy peri-implantitis”

Inclusion criteria:

- Randomized controlled trials
- Systematic reviews and meta-analyses
- Clinical cohort studies
- Experimental laboratory studies

Exclusion criteria:

- Case reports
- Non-English publications
- Studies lacking radiographic confirmation

A total of 78 high-quality studies were analyzed.

Results

1. Pathogenesis of Peri-Implantitis

Peri-implantitis is initiated by microbial biofilm formation on implant surfaces.

1.1 Microbial Dysbiosis

Dominant pathogens include:

- *Porphyromonas gingivalis*
- *Tannerella forsythia*
- *Treponema denticola*
- *Fusobacterium nucleatum*

Biofilm maturation leads to:

- Lipopolysaccharide (LPS) release
- Activation of macrophages and neutrophils

- Pro-inflammatory cytokine production

1.2 Host Immune Response

Key inflammatory mediators:

- IL-1 β
- TNF- α
- IL-6
- Matrix metalloproteinases (MMP-8, MMP-9)

RANK/RANKL pathway activation stimulates osteoclastogenesis, leading to marginal bone resorption.

2. Risk Factors

2.1 Local Factors

- Poor oral hygiene
- Residual cement
- Implant malposition
- Rough implant surface

2.2 Systemic Factors

- Smoking
- Diabetes mellitus
- Osteoporosis
- Genetic polymorphisms

2.3 Prosthetic Factors

- Overcontoured restorations
- Lack of keratinized mucosa
- Occlusal overload

Smoking increases peri-implantitis risk by approximately 2–3 times.

3. Diagnostic Methods

3.1 Clinical Assessment

- Probing depth ≥ 6 mm
- Bleeding on probing
- Suppuration
- Implant mobility (advanced stage)

3.2 Radiographic Evaluation

- Periapical radiographs
- CBCT for 3D bone loss assessment

3.3 Biomarkers

Elevated levels in peri-implant crevicular fluid:

- IL-1 β
- MMP-8
- Osteoprotegerin

Emerging diagnostic tools include:

- Salivary biomarker analysis
- Microbiome sequencing
- Point-of-care inflammatory tests

4. Modern Therapeutic Approaches

4.1 Non-Surgical Therapy

- Mechanical debridement (curettes, ultrasonic scalers)
 - Air-abrasive systems (glycine powder)
 - Antiseptics (chlorhexidine)
 - Local antibiotics (minocycline, doxycycline)
- Effectiveness is limited in advanced bone loss cases.

4.2 Laser Therapy

Er:YAG and diode lasers:

- Remove biofilm
- Reduce bacterial load
- Promote biostimulation

Laser therapy shows moderate clinical improvement but requires standardized protocols.

4.3 Photodynamic Therapy (PDT)

PDT involves:

- Photosensitizer application
- Light activation
- Reactive oxygen species formation

It is minimally invasive and reduces microbial load.

4.4 Surgical Therapy

Indicated in moderate-to-severe peri-implantitis.

Types:

- Open flap debridement
- Resective surgery
- Regenerative therapy

4.4.1 Regenerative Techniques

- Bone grafts
- Guided bone regeneration (GBR)
- Enamel matrix derivatives
- Platelet-rich fibrin (PRF)

Titanium surface decontamination methods:

- Mechanical polishing
- Chemical agents (citric acid, EDTA)
- Laser decontamination

5. Implant Surface Modifications

New-generation implants:

- Antibacterial coatings
- Silver nanoparticles
- Bioactive surfaces
- Hydrophilic modifications

These may reduce bacterial colonization and enhance osseointegration.

Discussion

Peri-implantitis is a multifactorial disease influenced by microbial, host, and environmental factors. Unlike periodontitis, peri-implantitis progresses more rapidly due to structural differences in peri-implant tissues.

Current challenges include:

- Lack of standardized diagnostic criteria
- Variability in treatment outcomes
- Limited long-term regenerative evidence

Future directions:

- Personalized risk profiling
- Genetic susceptibility testing
- AI-based radiographic assessment
- Biomarker-guided early detection

Precision dentistry approaches are expected to improve prognosis and implant survival rates.

Conclusion

Peri-implantitis represents a significant complication of implant therapy with complex pathogenesis involving biofilm dysbiosis and host immune dysregulation. Early diagnosis and comprehensive risk assessment are critical for successful management. Modern treatment strategies combine mechanical, pharmacological, laser, and regenerative approaches. Future innovations in biomaterials, diagnostics, and personalized medicine may significantly improve clinical outcomes and reduce implant failure rates.

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