

Review Article

Implant-Associated Lesions in Dentistry: Classification and Histopathological Advances

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ABSTRACT

This review aimed to comprehensively characterize implant-associated lesions and pathological conditions in dentistry, with particular emphasis on their clinical, radiographic, histopathological, and microbiological features, as well as their potential risk factors and underlying mechanisms. PubMed, Scopus, Web of Science, Cochrane Library, and Google Scholar were searched for English-language articles published from 2016 to July 2025 using predefined keywords and Boolean combinations related to dental implants, implant-associated lesions, peri-implant diseases, and pathological conditions. Studies addressing clinical, radiographic, histopathological, or microbiological aspects of implant-associated pathology were eligible. Two reviewers independently screened the retrieved records, assessed potentially eligible full-text articles, and resolved disagreements by consensus or consultation with a third expert. Of the 52 articles identified through the search and screening process, 16 met the predefined eligibility criteria and were included in the qualitative synthesis. Peri-implant mucositis and peri-implantitis represented the most extensively characterized conditions, with peri-implantitis associated with inflammatory tissue destruction and progressive supporting bone loss. Implant periapical lesions showed distinct clinical and radiographic characteristics and were differentiated from conventional peri-implantitis. Reactive lesions, including fibrous hyperplasia and granulomatous lesions, were associated with chronic irritation, inflammatory stimuli, and foreign material. Histopathological evidence also demonstrated titanium-associated tissue reactions, including foreign-body responses and metal-induced inflammation. Systemic, surgical, anatomical, prosthetic, microbial, and biomaterial-related factors were identified as potential modifiers of lesion development and progression. The heterogeneity of the included evidence supported qualitative rather than quantitative synthesis. Implant-associated lesions comprise a heterogeneous group of infectious, inflammatory, reactive, and foreign-body-related pathological conditions with distinct clinical, radiographic, and histopathological characteristics. Early recognition through appropriate clinical and radiographic assessment, supplemented by histopathological and microbiological evaluation when indicated, is important for accurate diagnosis and management. Further well-designed clinical and histopathological studies are needed to strengthen the evidence base and establish more consistent diagnostic and management approaches.

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Introduction

Dental implants have revolutionized the field of restora-

tive dentistry, providing reliable solutions for replacing missing teeth and restoring oral function and aesthetics.

With a steadily rising prevalence of implant therapy in clinical practice, understanding the biological responses to these devices has become a crucial aspect of modern dental care. Despite high success rates, dental implants are not without complications, and a spectrum of lesions and pathological conditions can arise in association with their placement and long-term function [1-3].

Implant-related lesions are defined as pathological changes affecting the peri-implant tissues and the implant site itself. These conditions encompass both infectious and non-infectious etiologies, including peri-implant mucositis, peri-implantitis, mechanical and iatrogenic lesions, as well as a variety of soft and hard tissue pathologies that are unique or more prevalent in the presence of dental implants. Differentiating between physiologic adaptation and true pathology is essential for clinicians to ensure timely diagnosis and intervention [4-6].

The pathogenesis of implant-related pathological conditions is multifactorial. Factors such as microbial colonization, host response, biomechanical overload, systemic health, and surgical technique all play roles in determining an implant's long-term prognosis. Moreover, the disruption of the delicate balance between the host and the foreign body (the implant) can trigger local or systemic complications, further emphasizing the need for ongoing clinical vigilance [7-9].

Recent years have seen an increase in reports of peri-implant diseases, particularly peri-implantitis, a destructive inflammatory disease characterized by the loss of supporting bone. These conditions not only threaten implant survival but can also impact the patient's overall oral and systemic health. With more patients receiving implants globally, the dental community is faced with the challenge of early diagnosis and effective management of these emerging pathological entities [10-11].

In addition to infectious complications, clinicians must be aware of other pathological manifestations around implants, including neoplasms, cysts, foreign body reactions, and drug-related effects. The growing range of reported cases reflects increased recognition, improved diagnostic techniques, and an ever-expanding diversity of patient populations receiving implants. Systematic evaluation and documentation are necessary to further elucidate the prevalence and nature of these lesions [12-14]. Although the literature on implant-associated pathology has expanded considerably, the

available evidence remains fragmented across different pathological entities and methodological domains. Previous reports [5, 15-16] have predominantly focused on individual conditions, particularly peri-implant diseases, reactive lesions, implant periapical lesions, or specific histopathological and biomaterial-related responses. Consequently, the clinical, radiographic, histopathological, and microbiological characteristics of these conditions have not been sufficiently integrated within a single contemporary evidence synthesis. In addition, differences in proposed etiological mechanisms, host-related factors, surgical and prosthetic variables, and tissue responses to implant materials make it difficult to obtain a comprehensive understanding of the spectrum and progression of implant-associated lesions from individual studies alone. Therefore, an updated and systematically conducted comprehensive review is warranted to consolidate the available evidence and identify areas in which the current literature remains limited or inconsistent. Accordingly, this review aimed to comprehensively evaluate implant-associated lesions and pathological conditions in dentistry by synthesizing evidence regarding their clinical presentation, radiographic characteristics, histopathological and microbiological features, proposed pathogenesis, associated risk factors, and reported management considerations. The review further sought to identify patterns and gaps across the available literature and to provide an integrated framework that may support improved recognition, diagnosis, prevention, and management of these conditions in clinical implant dentistry.

Search Strategy

The methodology for this review article was designed to gather relevant literature systematically and comprehensively on implant-related lesions and pathological conditions. A detailed search strategy was implemented across multiple electronic databases, including PubMed, Scopus, Web of Science, Cochrane Library, and Google Scholar. Keywords and Medical Subject Headings (MeSH) terms such as "dental implants," "oral implant," "implant-related lesions," "peri-implant disease," "pathological conditions," "peri-implantitis," and "implant complications" were employed using Boolean operators ("AND" / "OR") to ensure broad yet focused retrieval of studies related to the topic.

Inclusion and Exclusion Criteria

The search included articles published from 2016 up to July 2025 based on the English language restriction. Studies were considered eligible if they addressed clinical, radiographic, histopathological, or microbiological aspects of implant-associated lesions or pathological states. Exclusion criteria comprised studies unrelated to implant pathology (such as purely biomechanical or implant planning studies), animal-only research, systematic reviews, meta-analyses, and articles with insufficient or unclear data on lesions or pathological conditions related to dental implants.

Screening and Qualitative Synthesis

Two independent reviewers screened the titles and abstracts of all retrieved records according to the predefined inclusion and exclusion criteria. Potentially eligible articles were subsequently assessed through full-text review. Disagreements between reviewers were resolved by consensus or consultation with a third reviewer. For each eligible study, data were extracted on study characteristics, population, type of implant-associated lesion, clinical and radiographic findings, histopathological and microbiological features, risk factors, and reported management outcomes. The extracted data were organized according to the main categories of implant-associated pathology and synthesized qualitatively.

Results

A total of 52 articles were identified and screened based on the predefined eligibility criteria. Following full-text assessment and application of the inclusion and exclusion criteria, 16 articles were included in the final qualitative synthesis. The included studies addressed clinical, radiographic, histopathological, and/or microbiological aspects of implant-associated lesions and pathological conditions. The extracted evidence was categorized according to the primary type of lesion, including peri-implant mucositis and peri-implantitis, implant periapical lesions, reactive lesions, titanium-related pathologies, and other miscellaneous lesions. The included literature also provided evidence regarding systemic, surgical, anatomical, prosthetic, microbial, and biomaterial-related factors potentially associated with the development or progression of implant-associated pathology.

Discussion

The present review highlights that implant-associated

lesions represent a heterogeneous spectrum of pathological conditions involving the peri-implant mucosa, peri-implant bone, and adjacent anatomical structures. Although peri-implant mucositis and peri-implantitis constitute the most extensively studied implant-related diseases, the literature also identifies reactive, foreign-body, inflammatory, infectious, and implant periapical lesions as clinically relevant entities. Accordingly, the current evidence supports a broader concept of implant-associated lesions in which clinical presentation alone may not adequately distinguish between different pathological processes. Integration of clinical, radiographic, and histopathological findings is therefore essential for accurate classification and diagnosis.

The search and selection process identified a range of implant-related pathological conditions, with peri-implant diseases, particularly peri-implant mucositis and peri-implantitis, featuring prominently in the literature. Peri-implantitis is described as a plaque-associated pathological condition characterized by progressive bone loss around implants, clinically indicated by bleeding or suppuration on probing, increased pocket depth, and radiographic bone loss [17]. Histologically, peri-implantitis lesions are significantly larger than peri-implant mucositis lesions, with a greater inflammatory cell infiltrate comprising B cells, neutrophils, macrophages, and a higher vascular density. Cytokines involved in osteoclast activity, such as IL-1 alpha, TNF-alpha, and IL-6, are elevated in these lesions, underpinning the destructive process in peri-implantitis [18]. The inflammatory infiltrate extends to the bone crest, and the lesion area is approximately twice the size of similar periodontal lesions, confirming a more aggressive nature of peri-implantitis compared to mucositis or periodontitis around natural teeth [19] (Table 1).

The 2017 World Workshop consensus report by Berglundh *et al.* [20] has been foundational in classifying peri-implant diseases into mucositis and peri-implantitis, distinguishing these entities based on clinical, radiographic, and histopathological criteria. Both Klinge *et al.* [21] and Heitz-Mayfield [22] reinforce these definitions in recent clinical guidelines, emphasizing inflammation, tissue destruction, and the pivotal role of microbiological biofilms in disease progression. Importantly, Chang elaborates on the clinical and radiographic features of implant periapical lesions, highlight-

Table 1: Lesion Type categorization based on the included studies

Lesion Type	Representative Articles & Main Focus	Ref.
Peri-implant Mucositis & Peri-implantitis	Several articles provide foundational and advanced insight into inflammatory peri-implant lesions. Consensus reports and guidelines clearly define the distinction between peri-implant mucositis (reversible inflammation of the mucosa) and peri-implantitis (inflammation with progressive bone loss), highlighting the clinical, radiographic, and etiological criteria for each lesion type. Articles also review surgical and non-surgical treatment approaches, with attention to risk modifiers such as systemic disease.	[20-22, 27]
Implant Periapical Lesions	Distinct from peri-implantitis, implant periapical lesions develop at the apex of dental implants and are characterized by unique etiologies (e.g., surgical trauma, residual infection) and radiographic findings. The literature describes clinical presentations and complications, including sinus involvement, providing case-based and narrative evidence for diagnosis and management.	[3, 25-26]
Reactive Lesions	Implant-associated reactive lesions, such as fibrous hyperplasia and peri-implant granulomas, are described histopathologically to share features with reactive oral pathologies seen elsewhere. Their association with chronic irritation, foreign particles, or inflammatory stimuli is emphasized in both clinical series and case reports.	[23]
Titanium-related Pathologies & Miscellaneous Lesions	A broad spectrum of less common lesions, such as inflammatory cysts, osteomyelitis, neoplasms, and metal-induced tissue reactions, is captured in single-institution retrospective studies. These articles also address the impact of biomaterial surface properties and titanium particle deposition on peri-implant tissue response and lesion formation.	[24, 32]
Peri-implant inflammatory diseases	Characterization of peri-implant mucositis and peri-implantitis as major peri-implant inflammatory diseases, with emphasis on their clinical and disease-defining features, progression toward supporting bone loss, and the potential influence of systemic inflammatory status on susceptibility to peri-implant pathology.	[27]

their distinct etiology from conventional peri-implantitis and underlining the diagnostic importance of imaging modalities.

Reactive lesions in peri-implant tissues, such as hyperplastic growths and granulomas, are increasingly documented. Halperin-Sternfeld *et al.* [17] performed detailed histological and microscopic analysis, revealing that implant-related reactive lesions often share features with reactive oral lesions elsewhere, but may be triggered by titanium particles or chronic low-grade infection. Similarly, Bountaniotis *et al.* [23] report reactive fibrous hyperplasia in the peri-implant mucosa, underscoring the clinical need for biopsy and histopathological examination when unusual tissue responses occur. The more severe spectrum of implant pathology is further illustrated by Paparella *et al.* [24], who conducted a retrospective histopathological survey, demonstrated a variety of titanium-associated tissue reactions, including foreign body giant cell responses and metal-induced inflammation. Frauches *et al.* [25] and Kim *et al.* [26] provide clinical case data, describing the direct extension of implant-associated infections to adjacent anatomical structures such as tooth roots and paranasal sinuses, which can complicate diagnosis and management.

Risk factors and disease modifiers beyond bacterial biofilm have received attention in recent research. Orlandi *et al.* [27] found that patients with systemic inflammation, particularly hypertension, exhibited greater

susceptibility to peri-implantitis, indicating an interplay between local and systemic immune responses. Orishko *et al.* [28] and Kumar *et al.* [29] identify surgical, anatomical, and prosthetic elements that influence the onset and progression of peri-implant pathology, including host factors and techniques employed during implant placement. Other studies [30-31] outline practical considerations for the prevention and management of peri-implant disease, suggesting thorough debridement, patient education, and, when necessary, surgical intervention in the esthetic zone to restore peri-implant health. Rounding out the review, Malheiros *et al.* [32] explore innovations in biomaterial coatings and surface engineering to mitigate polymicrobial colonization and nanotechnological strategies for infectious disease control.

Radiographic examination remains essential for identifying supporting bone loss and evaluating the progression of peri-implant disease. Studies show that initial bone loss may occur as early as between the second and third years of implant function, with the progression being nonlinear and variable among individuals. Retrospective data indicate average bone loss of approximately 1.7 mm after one year, with a significant proportion of implants exhibiting progressive radiographic bone loss exceeding 1–3 mm in successive evaluations [33-34]. Soft tissue biopsies from severe peri-implantitis cases reveal elevated proportions of immune cells indicative of intense immune activation, and the vascular

structure density suggests active inflammation and tissue remodeling. This inflammatory milieu likely contributes to bone resorption and implant failure risk. Furthermore, systemic inflammatory markers such as serum C-reactive protein (CRP) have been investigated as correlated indicators reflecting the systemic impact of localized peri-implant inflammation, highlighting the potential systemic repercussions of peri-implant diseases [27, 35].

The evidence reviewed in this study indicates that the concept of implant-associated lesions should extend beyond a binary distinction between peri-implant mucositis and peri-implantitis. Contemporary classification provides a foundation for categorizing the major peri-implant diseases, whereas histopathological evidence expands this framework by revealing distinct inflammatory, reactive, and foreign-body patterns. The integration of these approaches may improve differential diagnosis, clarify mechanisms of tissue injury, and support more individualized management of implant-associated pathological conditions.

Conclusion

The most recent decade of literature demonstrates an evolving understanding of implant-associated lesions through advances in both classification and histopathological characterization. Contemporary classification approaches distinguish peri-implant health and disease from other implant-associated pathological and reactive lesions based on clinical, radiographic, and biological characteristics, thereby improving diagnostic consistency and facilitating appropriate clinical management. In parallel, histopathological advances have provided greater insight into the cellular and molecular features underlying lesion development, including inflammatory cell infiltration, epithelial and connective-tissue alterations, immune responses, and cytokine-mediated pathways. These findings highlight the complex interplay between biomaterials, microbiota, host responses, and systemic risk factors in the pathogenesis and progression of implant-related lesions. Collectively, current evidence supports the value of integrating standardized classification with histopathological assessment to improve differential diagnosis, clarify disease mechanisms, and guide preventive and therapeutic strategies. Continued interdisciplinary research is needed to refine classi-

fication criteria, establish clinically relevant histopathological markers, and translate emerging biological insights into more precise and individualized approaches to implant dentistry.

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Data availability

All of the data is provided in the article.

Credit Authorship statement

The authors worked equally on this study.

Conflict of Interest

The authors declare they have no financial or non-financial conflicts of interest

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