

Research Article

Titanium Particles and Foreign Body Reactions in Peri-Implantitis with Implications for Comparison with Peri-Implant Mucositis: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: Titanium particles and corrosion products have been proposed as contributors to peri-implant inflammation. However, detecting titanium does not establish a foreign-body reaction or distinguish peri-implantitis from peri-implant mucositis. This review examined human tissue evidence on titanium detection, particle burden, and associated inflammatory findings, prioritizing direct comparison of these two conditions.

Methods: A structured eligibility framework was applied to reports identified by web, publisher and reference-list searching on 6 October 2026. Human studies assessing titanium in peri-implant biopsies, surgical tissue or exfoliative cytology were eligible. Peri-implantitis was required; healthy implant sites, periodontitis and no-implant controls were accepted as secondary comparators. One reviewer made the original selection decisions. Targeted source verification on 7 October resolved one previously uncertain report. Findings were synthesized narratively because the direct comparison was absent and other outcomes differed in sampling, detection methods and comparator populations. Bibliographic database searching and formal risk-of-bias assessment were not completed.

Results: Of 38 identified reports, nine were retained: six comparative studies and three peri-implantitis-only studies. Twenty-three reports were excluded and six remained awaiting classification. No included study directly compared peri-implantitis with clinically defined peri-implant mucositis. Titanium was detected frequently in peri-implantitis samples, but was also found at reference implant sites. One study reported titanium concentrations of $98.7 \pm 85.6 \mu\text{g/g}$ in peri-implantitis and $1.2 \pm 0.9 \mu\text{g/g}$ in periodontitis controls. A paired implant-site study found no difference in particle density between diseased and reference sites. Another study detected particles in all 39 peri-implantitis specimens without histological evidence of particle-engulfing macrophages or multinucleated giant cells.

Conclusions: The identified evidence supports the presence of titanium in peri-implant tissues but does not establish that titanium is a disease-specific marker or a sufficient cause of peri-implantitis. Differences from mucositis remain unresolved. Incomplete searching, outstanding eligibility decisions and heterogeneous measurements limit the conclusions and preclude a defensible pooled estimate.

Keywords: Titanium, Peri-Implantitis, Peri-Implant Mucositis, Foreign-Body Reaction, Dental Implants, Histopathology, Narrative Synthesis.

INTRODUCTION

Peri-implant mucositis and peri-implantitis represent distinct clinical diagnoses. Mucositis

involves inflammatory changes in the peri-implant mucosa without the progressive supporting bone loss characteristic of peri-

implantitis. Their distinction is important when evaluating a proposed tissue biomarker: an association with inflammation alone cannot establish an association with destructive disease [1].

Titanium-based dental implants can release material during insertion, wear at the implant–abutment interface, corrosion and surface treatment. These pathways create a plausible source of particles or dissolved titanium in surrounding tissues [2]. Human studies have therefore examined whether material release is associated with peri-implant inflammation and whether the tissue response resembles a foreign-body reaction.

Three questions require separate consideration. First, is titanium demonstrably present in the sampled tissue? Second, is its amount or distribution associated with disease status? Third, do histological or immunological findings support a reaction specifically directed at the detected material? Total elemental concentration, microscopically visible particles and particle-associated cellular responses answer different questions and should not be combined without qualification.

Existing reports use diverse specimens and methods, including surgical biopsies, exfoliative cytology, scanning electron microscopy with energy-dispersive X-ray spectroscopy, inductively coupled plasma mass spectrometry and spatial elemental imaging [3–11]. Comparator selection also varies. Periodontitis tissue provides an inflammatory comparison but lacks the same implant exposure; healthy implant tissue is more informative about whether particles discriminate implant disease. Neither comparator substitutes for clinically defined mucositis.

The primary objective was to compare titanium particles and foreign-body reactions in peri-

implantitis and peri-implant mucositis. Secondary objectives were to summarize comparisons with healthy or reference implant tissue, periodontitis and no-implant controls; describe peri-implantitis-only observations; and determine whether quantitative synthesis was justified. Because the identified studies did not address the primary comparison directly, the review emphasizes the distinction between observed titanium exposure and demonstrated disease causation.

METHODS

Review Framework and Reporting

This review used structured eligibility criteria and a narrative synthesis of human observational evidence. Reporting was organized with reference to PRISMA 2020 and applicable principles of synthesis without meta-analysis [12,13]. This does not constitute a claim of complete PRISMA compliance: a reproducible bibliographic database search, separate screening-stage counts and formal study-level risk-of-bias assessments were unavailable. No prospective registration identifier was documented in the review record.

Eligibility Criteria

Eligible participants had dental implants and a soft- or hard-tissue specimen, surgical granulation tissue or exfoliative cytology sample. Peri-implantitis was required, with clinical inflammation and radiographic bone loss forming the intended disease definition. Studies with mucositis as the comparator were prioritized. Studies comparing peri-implantitis with healthy implant tissue, periodontitis or no-implant controls were retained as separate secondary comparisons. Descriptive series were eligible when they comprised at least five human samples.

Table 1 Eligibility Framework

Domain	Criterion
Population	Human patients with dental implants and peri-implant biopsy, surgical tissue, explant-associated tissue or exfoliative cytology.
Disease	Peri-implantitis assessed clinically and radiographically; report-specific diagnostic thresholds were considered where accessible.
Comparators	Primary: peri-implant mucositis. Secondary: healthy or reference implant sites, periodontitis or no-implant controls. Single-group series considered separately.
Outcomes	Titanium presence, concentration, particle burden or morphology; particle-associated histology, giant cells, macrophages and inflammatory markers.
Designs	Comparative observational studies and descriptive series with at least five human samples.
Exclusions	Animal and in-vitro studies, case reports, reviews, non-tissue measurements only, and studies without an eligible peri-implantitis population.

Information Sources and Searching

The original search was conducted on 6 October 2026 through a web search engine and publisher, repository and journal pages. Search terms combined titanium particles, titanium release, peri-implantitis, peri-implant mucositis, biopsy, cytology, histology, immunohistochemistry, macrophage markers, foreign-body reaction and elemental detection methods. Reference lists from the reviews by Suárez-López del Amo et al. and Chen et al. were also examined [2,14]. Six primary reports were identified only through the former review, and all six were excluded.

PubMed, PubMed Central, Wiley and ScienceDirect pages were incompletely accessible during the original search. Bibliographic databases were not searched directly. On 7 October 2026, targeted searches of primary article records and accessible full texts were used to verify citations, selected results and the eligibility of the mucositis pilot study. This verification was not a comprehensive search update and did not add reports to the original set of 38.

A database strategy was proposed in the search record but had not been executed. It combined peri-implant disease terms with titanium, metal particles, debris or foreign-body terms, followed by tissue, cytology, histology or macrophage terms. Because this strategy was not run, database yields, duplicate-removal counts and database-specific coverage cannot be reported. Language and publication-status restrictions were not documented.

Selection and Data Handling

One reviewer made the original eligibility decisions using full texts, abstracts or secondary extractions, depending on access. Reports without sufficient case-definition or sampling information were retained as awaiting classification rather than treated as confirmed exclusions. Targeted verification established that the 2017 mucositis cytology study contained no peri-implantitis group [15]; it was therefore moved from awaiting classification to excluded, consistent with the eligibility criteria. The synthesis retained the nine studies classified as eligible in the original record. Study labels, comparison groups, sample counts, specimen type, titanium detection methods,

histological markers and principal results were tabulated. Sample counts were kept in their original units: participants, biopsies, sites and microscopy subsamples were not assumed to be interchangeable. No aggregate participant total was calculated because denominators differed and cohort independence was not fully established.

Evidence Appraisal and Synthesis

A formal tool-based risk-of-bias assessment was not completed. Instead, the interpretation considered comparator relevance, sampling of advanced lesions, measurement specificity, paired versus independent designs, confounding and uncertainty arising from incomplete source access. These considerations are presented as methodological limitations, not as validated risk-of-bias scores.

Studies were grouped by comparator and by outcome: titanium detection, concentration or particle burden, foreign-body histology, and immune markers. Results were interpreted within those groups rather than by counting statistically significant studies. No pooled proportion or standardized mean difference was calculated. Total titanium measured after digestion may include different physical forms, whereas microscopy-based positivity depends on particle size, sampled fields and detection thresholds. Standardizing these outcomes numerically would not establish that they measure the same construct. Paired implant-site data would also require appropriate within-person variance information.

RESULTS

Study Selection

The original record identified 38 reports: 32 through web and publisher searching and six through reference-list searching. Nine were retained, 22 were originally excluded and seven awaited classification. Following verification of the mucositis-only pilot, the revised disposition was nine retained, 23 excluded and six awaiting classification six included reports contained a comparative human component; three described peri-implantitis samples alone. Figure 1 summarizes this disposition. Separate counts for title screening, abstract screening, retrieval failures and duplicate removal were not recorded.

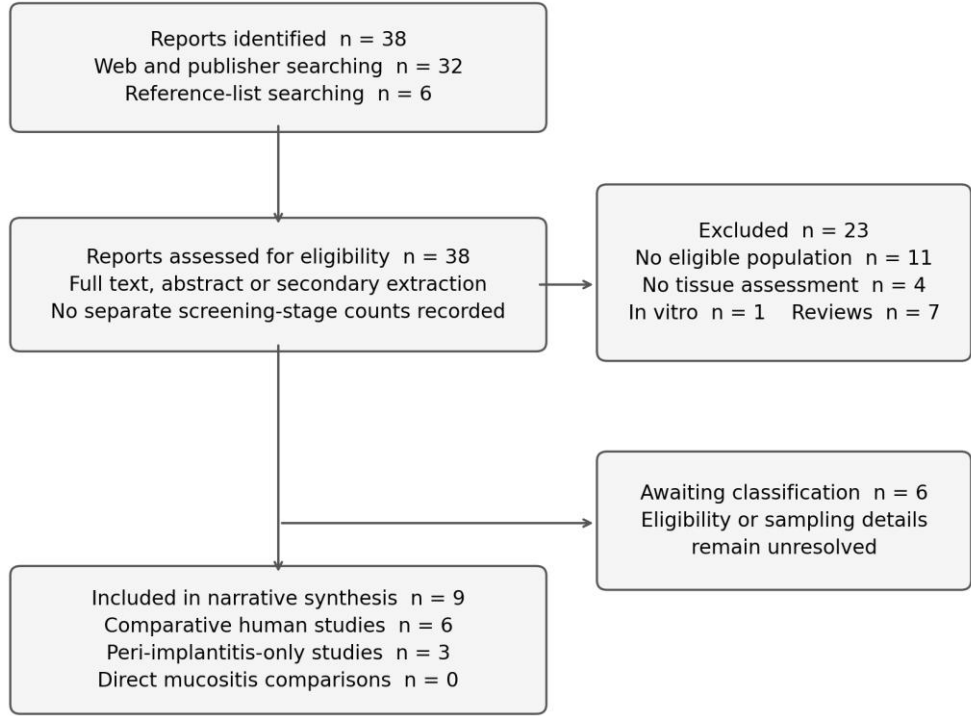


Figure 1 Documented Report Disposition After Targeted Eligibility Verification. The Chart Adapts The Selection Record; It Is Not A Complete PRISMA Database-Search Flow Diagram. Assessment Included Full Texts, Abstracts And Secondary Extractions. The 2017 Mucositis Pilot Was Moved To Exclusions Because It Lacked a Peri-Implantitis Group.

Characteristics of the Included Studies

The nine retained studies were published between 2013 and 2026. Specimens included soft-tissue biopsies, mixed soft- and hard-tissue biopsies, surgically removed granulation tissue

and exfoliative cytology. Detection ranged from total elemental measurement to microscopy and spatial mapping. Tables 2 and 3 summarize comparative and single-group evidence separately [3–11].

Table 2 Comparative Studies of Titanium and Inflammatory Findings

Study	Groups and sampling	Detection	Principal finding
Olmedo 2013 [3]	15 peri-implantitis and 15 implants without peri-implantitis; contralateral gingiva as internal control; exfoliative cytology.	Light microscopy; ICP-MS.	Metal-like particles at both implant groups; higher titanium concentration in peri-implantitis.
Bressan 2019 [6]	160 peri-implantitis and 40 healthy mucosa controls; surgical or explant-associated soft tissue.	ICP-MS; H&E; vascular-marker immunofluorescence.	The selection record reports titanium in diseased samples and no titanium in controls, with inflammatory infiltrates. Control exposure and detection reporting require full-text appraisal.
Pettersson 2019 [7]	13 peri-implantitis and 11 periodontitis patients for elemental analysis; an additional 2 per group for microscopy.	ICP-MS; light microscopy; SEM; TEM.	98.7 ± 85.6 versus 1.2 ± 0.9 µg/g; reported p < 0.001. Element analysis confirmed particulate titanium in peri-implantitis.

Rakic 2022 [9]	39 peri-implantitis and 35 periodontitis samples; surgical granulation tissue.	SEM-EDS; H&E; CD68, IL-6, NF-κB and VEGF.	Titanium in all peri-implantitis specimens; more macrophages and vascularization, but no particle-engulfing macrophages or giant cells.
Dionigi 2025 [10]	18 paired peri-implantitis/reference implant-site samples; 3 periodontitis controls within a 21-patient study.	μ-PIXE; TEM; RNA sequencing; selected IHC.	Similar particle density, number and area at diseased and reference sites; most particles close to the implant interface.
Girón Bastidas 2026 [11]	Human cytology from 5 peri-implantitis sites; tissue comparison with healthy sites, denominator not specified in the accessible extraction.	Microscopy; SEM-EDX; TRPC1 immunofluorescence.	Particles in 4 of 5 cytology samples; greater TRPC1 expression in diseased tissue. Experimental arms are outside this human synthesis.

Abbreviations: ICP-MS, inductively coupled plasma mass spectrometry; SEM-EDS/EDX, scanning electron microscopy with energy-dispersive X-ray analysis; TEM, transmission electron microscopy; μ-PIXE, micro proton-induced X-ray emission; H&E, haematoxylin

and eosin; IHC, immunohistochemistry. Sample descriptions reflect the extraction record and verified article information; absence of a denominator is a reporting limitation, not an assumed zero.

Table 3 Peri-Implantitis-Only Studies

Study	Samples	Assessment	Principal finding
Wilson 2015 [4]	36 soft-tissue biopsies.	H&E; microscopy; SEM-EDS.	Radiopaque foreign bodies in 34/36 biopsies; titanium and cement were prominent materials. This is not a titanium-specific 34/36 detection rate.
Fretwurst 2016 [5]	12 patients: 7 bone and 5 mucosal samples.	Synchrotron X-ray fluorescence; polarized light microscopy; histology.	Titanium and associated iron detected in 9/12 samples. No comparator establishing disease specificity.
Berryman 2020 [8]	10 soft-tissue biopsies.	SEM-EDS; RANKL, TGF-β1 and IL-33 IHC.	Titanium detected in 9/10; greater RANKL expression in titanium-containing areas. Spatial association does not establish causation.

Absence of the Primary Comparison

No retained study directly compared peri-implantitis with a separately defined peri-implant mucositis group. The healthy or mildly inflamed reference sites in Dionigi et al. cannot be relabelled as a mucositis cohort. Their inclusion provides an implant-exposed reference comparison, but does not answer whether titanium distinguishes mucositis from destructive disease [10].

The excluded 2017 pilot examined 40 participants with unloaded implants, divided into mild and moderate-to-severe mucosal inflammation groups. Metal-like particles were observed by light microscopy in 12 of 20 participants in the latter group and none in the

former. There was no peri-implantitis group or elemental confirmation of the visually identified material. These observations provide contextual evidence about mucosal inflammation but cannot estimate the primary disease contrast [15].

Titanium Detection and Burden

Titanium was frequently detected in peri-implantitis specimens, including all 39 samples reported by Rakic et al., nine of 12 in Fretwurst et al., and nine of 10 in Berryman et al. [5,8,9]. These proportions describe selected tissue samples examined with different methods. They do not represent a pooled prevalence in the general implant population.

Wilson et al. identified radiopaque foreign bodies in 34 of 36 biopsies, with titanium and cement among the principal materials [4]. The original review record also noted a secondary extraction reporting titanium in seven biopsies. Because any-foreign-body positivity and titanium-specific positivity are different endpoints, the 34/36 value was not used as a titanium proportion. The unresolved titanium-specific denominator was excluded from quantitative calculations.

The most directly interpretable concentration result was reported by Pettersson et al.: peri-implantitis tissue contained $98.7 \pm 85.6 \mu\text{g/g}$ compared with $1.2 \pm 0.9 \mu\text{g/g}$ in periodontitis tissue [7]. This substantial contrast is informative about titanium exposure at diseased implant sites relative to diseased natural-tooth sites, but cannot isolate the contribution of peri-implant disease from that of having an implant.

Olmedo et al. reported particles in cytology samples around implants with and without peri-implantitis, with greater titanium concentration in the diseased group [3]. By contrast, Dionigi et al. found no material difference in particle density, number or occupied area between paired diseased and reference implant sites [10]. The extraction for Bressan et al. reported a diseased-versus-control difference [6]. Differences in control exposure, sample depth and analytical endpoint prevent treating these reports as estimates of a single common effect.

Foreign-Body Reaction and Inflammatory Markers

Particles coexisting with inflammatory tissue did not consistently show the defining spatial evidence of a reaction directed against those particles. Rakic et al. detected titanium throughout the peri-implantitis specimens but did not identify macrophages or multinucleated giant cells engulfing it. Increased CD68 and VEGF expression compared with periodontitis indicated an altered inflammatory environment, without demonstrating a titanium-specific foreign-body response [9].

Wilson et al. described inflammatory cells around foreign material, but the material included cement as well as titanium [4]. Fretwurst et al. identified metal-associated cellular observations in a small mixed tissue series [5]. Berryman et al. reported greater RANKL expression in titanium-containing regions [8]. These findings support investigation of particle–host interactions, but cannot establish that titanium initiated the lesion.

The human component of Girón Bastidas et al. reported intracellular particles and increased TRPC1 expression [11]. Its experimental components provide mechanistic context, but animal and cell-culture results were not incorporated as human clinical outcomes. Across studies, CD68, vascular markers, osteoclastogenic signals, TRPC1 and transcriptomic findings were not measured or scored consistently enough to pool.

Table 4 Outcome Synthesis and Limits of Inference

Outcome	Evidence	Conclusion supported
Peri-implantitis versus mucositis	No direct eligible comparison.	The primary contrast remains unanswered; absence of evidence does not demonstrate equivalence.
Titanium detection	Frequent positivity in surgical or cytology samples; positivity also reported at reference implant sites.	Titanium occurs in peri-implant tissues; presence alone is not a validated diagnostic marker.
Concentration and burden	Higher concentration in some comparisons; similar density in a paired implant-site comparison.	Findings depend on comparator and measurement; no common pooled effect is justified.
Foreign-body reaction	Inflammatory associations in some reports; no typical particle-directed reaction in Rakic 2022.	A consistent titanium-specific reaction has not been established.
Immune markers	Different IHC, immunofluorescence and transcriptomic endpoints.	Biological associations are descriptive and cannot be translated into a proven causal pathway or treatment target.

Reports Awaiting Classification and Exclusions

Six reports remain outside the synthesis because eligibility could not be resolved. Their

status is summarized in Table 5. A negative eligibility decision based solely on unavailable details would risk excluding relevant evidence. Conversely, treating all failed implants as peri-

Abira Hamid et al / Titanium Particles and Foreign Body Reactions in Peri-Implantitis with Implications for Comparison with Peri-Implant Mucositis: A Systematic Review and Meta-Analysis

implantitis or all metal-like deposits as confirmed titanium would widen the eligibility criteria without justification.

Table 5 Reports Awaiting Classification

Report label in the selection record	Unresolved eligibility issue
Kheder 2023, International Journal of Molecular Sciences 24:11644	Whether failed implants satisfied a clinical and radiographic peri-implantitis definition.
Daubert 2019, JDR Clinical and Translational Research	Whether titanium was assessed in tissue or only in submucosal plaque.
Nelson 2020, Analytical Chemistry 92:14432–14443	Disease definition and number of eligible titanium-implant tissue samples.
Potential role of titanium particles in peri-implantitis, Biomaterials 2026	Clinical-arm sampling, comparator groups and denominators.
Peri-implant mucosal barrier dysfunction in peri-implantitis, Saudi Digital Library thesis	Complete bibliographic identity, disease groups and confirmation of the metal-like particles.
Tawse-Smith 2012, Clinical Advances in Periodontics 2(4)	Whether the report was a case report or an eligible series of at least five samples.

The 23 excluded reports are listed in Table 6. The reasons reflect the eligibility record, which used different levels of source access. Exclusion

of a study from this tissue-based synthesis does not imply that it lacks relevance to implant material biology more generally.

Table 6 Excluded Reports and Recorded Reasons

Report	Recorded reason
Karatas 2020	Histology and inflammatory markers without titanium or foreign-body assessment.
Fretwurst 2020, Clinical Oral Implants Research 31:274–281	Macrophage polarization; titanium not assessed in the accessible abstract.
Fretwurst 2021, Journal of Periodontology	Ceramic-implant tissue rather than eligible titanium assessment.
Safioti 2017	Titanium assessed in submucosal plaque rather than tissue.
Daubert 2023	Treatment trial measuring titanium in plaque rather than tissue.
Halperin-Sternfeld 2016	Implant-related reactive lesions without eligible peri-implantitis.
Olmedo 2003	Failed implants without an eligible peri-implantitis definition.
Olmedo 2010	Two reactive lesions; below series threshold and different disease population.
Olmedo 2012	Healthy cover-screw tissue without peri-implantitis.
Flatebo 2006; Flatebo 2011	Two separate reports of healthy tissue before/after implant placement.
He 2016	Jawbone at implant sites without peri-implantitis classification.
Quantification of titanium and zirconium in oral mucosa around healthy implants 2023	Healthy implant population only.
Suárez-López del Amo 2017	In-vitro study.
Schoon 2020	Hip and knee arthroplasty tissue rather than dental peri-implantitis.
Suárez-López del Amo 2018; Si 2023; Souza 2026; Messous 2021; Mombelli 2018	Five review reports; not primary studies.

Histopathological characterization of peri-implant diseases 2021	Systematic review rather than primary tissue study.
Release of titanium particles after implantoplasty 2025	Integrative systematic review rather than primary study.
Titanium particles in tissues from peri-implant mucositis 2017 [15]	Mucositis-only population; no peri-implantitis group confirmed on full text.

Grouped rows represent separate reports where explicitly stated. The total is 23 reports, including seven reviews. Some exclusions were made from titles, abstracts or secondary extractions and warrant reassessment in a completed database-based review.

Methodological Limitations of the Evidence

The available studies were predominantly observational and frequently sampled lesions requiring surgery or implant removal. Such sampling may overrepresent advanced disease. Non-implant controls introduce exposure differences, while implant-reference controls may differ in local biofilm, implant design or treatment history. Tissue depth and the proximity to the implant affect the opportunity to detect particles. Paired comparisons reduce some person-level differences but require accounting for within-person dependence. Detection methods differed in sensitivity and material specificity. Cytological metal-like appearance alone is less specific than elemental confirmation; ICP-MS quantifies titanium without necessarily establishing particle morphology. Inflammatory markers can reflect the broader lesion environment rather than a direct reaction to titanium. Because full-text access and extraction were incomplete, formal low-, moderate- or high-risk labels and a graded certainty rating were not assigned.

DISCUSSION

Principal Interpretation

This synthesis separates a relatively consistent observation—titanium can be detected in peri-implant tissues—from the more uncertain proposition that it causes destructive peri-implant disease. Detection in peri-implantitis samples is compatible with several explanations: implant-associated exposure, release during disease or prior treatment, amplification of an existing inflammatory response, or a contributory pathogenic role. The available human comparisons do not resolve those alternatives.

The absence of a direct mucositis comparison is central to the original question. Peri-implantitis cannot be positioned as having a greater titanium burden than mucositis on the basis of

healthy or periodontitis controls. Likewise, the mucositis-only pilot cannot be combined indirectly with unrelated peri-implantitis series to infer a disease-stage gradient. Its population, implant loading status and detection method differ from those of the surgical studies [15].

Why Comparator Choice Changes the Interpretation

The concentration contrast in Pettersson et al. demonstrates greater titanium content in diseased implant tissue than in periodontitis tissue [7]. However, the control tissue did not share implant exposure. A disease-specific inference is therefore weaker than the numerical contrast alone suggests. This distinction also applies whenever healthy mucosal controls are taken from sites without an equivalent implant exposure history.

The paired reference comparison in Dionigi et al. addresses part of this problem by comparing implant sites within individuals [10]. Similar particle densities argue against a simple explanation in which particle abundance necessarily distinguishes peri-implantitis from reference conditions. This result does not exclude effects of particle chemistry, location, susceptibility or interactions with microbes, but those possibilities require direct testing rather than assumption.

Foreign-Body Response and Biological Plausibility

The term foreign-body reaction should be reserved for an adequately characterized tissue response, not inferred automatically from implant material or macrophage-marker expression. Particle-engulfing cells, giant-cell formation and a spatially related response provide more specific evidence than diffuse inflammation. The negative particle-directed histology in Rakic et al. is therefore important even though titanium was detected in every diseased specimen [9].

Conversely, inflammatory infiltrates around mixed foreign material, localized RANKL expression and altered cellular markers are reasons to investigate material–host interactions further [4,8,11]. They remain

associations. Cross-sectional observations cannot establish whether titanium release preceded inflammation, followed it, or interacted with another cause. The findings are compatible with biological involvement in some circumstances but do not justify replacing the established biofilm-associated disease model with a titanium-only explanation [1].

Implications for Clinical Practice

Titanium detection in a tissue sample should not by itself determine diagnosis, prognosis or implant removal. Clinical and radiographic assessment remains necessary to distinguish mucositis from peri-implantitis [1]. The studies reviewed do not validate a titanium concentration threshold, a routine biopsy-based test or a particle-directed treatment. Similarly, they do not demonstrate that choosing a different implant material or altering an established therapy improves patient outcomes.

Careful management of biofilm and other clinically established contributors remains consistent with current disease definitions. When foreign material is found during pathological assessment, interpretation should consider material identity, implant and restoration history, residual cement, sampling technique and the surrounding tissue response. Specific claims about the benefit or harm of implantoplasty require separate treatment evidence rather than extrapolation from untreated or explanted tissue.

Research Priorities

The most informative study would compare clearly defined peri-implantitis, mucositis and healthy implant sites using the same sampling and elemental methods. Participant-level factors, implant composition and surface, time in function, plaque burden, restoration retention and previous instrumentation should be documented. Analysis should distinguish total titanium from confirmed particles and relate material findings to spatial histology. Within-person comparisons should preserve their paired structure.

Prospective observations are needed to examine whether material release predicts progression from mucositis to peri-implantitis. Standardized reporting of sample denominators, particle size, concentration units, detection thresholds and blinded pathological assessment would improve comparability. A future meta-analysis should combine only studies measuring compatible outcomes within clinically relevant comparator

strata, rather than use standardization to obscure differences in what was measured.

Review Limitations

The major limitation is incomplete evidence identification. Web and publisher searching with reference-list checking does not provide the reproducibility or coverage of a completed multi-database search. Single-reviewer decisions increase the possibility of selection errors, and abstract- or secondary-based judgments may change after full-text review. Six unresolved reports could alter the eligible evidence base. The selection chart cannot supply screening or duplicate-removal information that was never recorded.

Extraction was not independently verified across all outcomes, and full-text quantitative data were insufficient for a pooled analysis. Source disagreements concerning Wilson et al. and an unspecified human tissue denominator in Girón Bastidas et al. remain material constraints [4,11]. Formal risk-of-bias assessment, outcome-specific certainty grading and assessment of reporting bias were not completed. These limitations concern the review process in addition to the heterogeneity of the primary studies.

The review is therefore a preliminary structured synthesis rather than a completed, exhaustive systematic review. Its conclusions should be confined to the identified evidence. No direct mucositis comparison was found within that evidence; this statement should not be interpreted as proof that no such study exists anywhere in the literature.

Conclusion

Titanium is frequently detectable in human peri-implant tissues, including peri-implantitis lesions and reference implant sites. Comparative findings are inconsistent across concentration and particle-density measures, and detection does not consistently coincide with a particle-directed foreign-body reaction. The identified evidence does not establish titanium as a disease-specific marker or sufficient cause of peri-implantitis. A direct comparison with peri-implant mucositis remains unanswered, and comprehensive searching, full-text eligibility resolution and formal appraisal are required before stronger conclusions or quantitative synthesis are justified.

Declarations

Ethics and Consent

This review used published aggregate evidence and involved no recruitment or collection of new identifiable participant data. It makes no claim to a separate institutional ethics approval. Ethical approvals and consent for the primary studies remain the responsibility of their original investigators.

Data Availability

The study-level information used in the narrative synthesis and the report-disposition decisions are presented in the manuscript tables. No individual participant data were obtained or generated.

Authorship and Disclosures

Institutional affiliations, corresponding-author contact details, individual author contributions, funding information and competing-interest declarations were not documented in the review record.

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