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SYSTEMATIC REVIEW

Implant survival and peri-implant health in prediabetic and healthy patients with adjacent implants over 5 years: A systematic review

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ABSTRACT

Statement of problem. Prediabetes, a metabolic condition occurring before diabetes, involves chronic low-grade inflammation that may impair peri-implant tissue health. Its impact on survival and outcomes of adjacent dental implants remains unexamined.

Purpose. The purpose of this systematic review was to compare implant survival and peri-implant health outcomes between prediabetic and systemically healthy patients with adjacent dental implants over a minimum 5-year follow-up period.

Material and methods. A systematic search was conducted in PubMed, Web of Science, Scopus, LILACS, and Google Scholar from January 2000 to April 2025, with an update in August 2025. Studies including prediabetic and healthy patients with at least two adjacent implants and more than 5 years of follow-up were eligible. Outcomes included implant survival, marginal bone loss, probing depth, bleeding on probing, and inflammatory markers. Risk of bias was assessed using the Newcastle–Ottawa Scale (NOS) for the cohort study and the Appraisal Tool for Cross-Sectional Studies (AXIS) for the cross-sectional study, and data were synthesized narratively due to heterogeneity.

Results. Two studies met inclusion criteria, comprising 139 patients and 336 implants. Implant survival was 100% in both prediabetic and healthy groups ($P>.05$). Peri-implant parameters were worse in prediabetic patients, with higher mean probing depth (3.9 to 4.6 mm versus 2.2 to 3.3 mm; $P<.05$), greater bleeding on probing (24% to 48% versus 18 to 23%; $P<.05$), higher plaque index, increased marginal bone loss (1.6 to 5.3 mm versus 0.8 to 2.3 mm; $P<.05$), and elevated interleukin-6 (IL-6) and tumor necrosis factor-alpha (TNF-α) levels ($P<.05$).

Conclusions. While implant survival remains comparable, patients with prediabetes exhibit poorer peri-implant tissue health. Early glycemic assessment may aid in optimizing implant prognosis. (J Prosthet Dent 2026;135:579.e1-e7)

Dental implants have been widely recognized as a predictable and durable solution for replacing missing teeth, with survival rates exceeding 95% over 10 years in systemically healthy individuals.[1–3] However, systemic metabolic conditions, including diabetes and prediabetes, can adversely affect osseointegration and long-term implant outcomes.[4–6] Prediabetes, a condition characterized by impaired fasting glucose or impaired glucose tolerance has attracted increasing attention because of its rising global prevalence and potential implications for oral health.[7–9] According to the International Diabetes Federation, over 350 million people worldwide have been diagnosed as prediabetic, and this number has been projected to increase significantly in the coming decades.[8]

Although prediabetes does not meet the diagnostic threshold for diabetes mellitus, it has been associated with low-grade systemic inflammation, endothelial dysfunction, and delayed wound healing, all of which may negatively affect the biological environment around dental implants.[10–12] Hyperglycemia-related immune alterations, such as impaired neutrophil function and dysregulated cytokine responses, may further compromise peri-implant host defense and microbial homeostasis.[13,14] Emerging clinical evidence suggests that

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Clinical Implications

Understanding the impact of prediabetes on dental implant outcomes is essential for effective risk assessment and treatment planning, particularly when placing adjacent implants. Even in the absence of overt diabetes, individuals with impaired glucose tolerance may experience compromised peri-implant health. Early identification and monitoring of glycemic status are therefore critical to optimize long-term implant success in partially edentulous patients.

individuals with prediabetes exhibit increased probing depth, bleeding on probing, and marginal bone loss around implants compared to systemically healthy controls.[15–17] Elevated pro-inflammatory cytokines, including interleukin-1β and tumor necrosis factor-alpha, have also been reported in the peri-implant sulcus fluid of patients with prediabetes.[18–20]

While implant outcomes have been extensively studied in patients with overt diabetes,[21] literature exploring the effects of prediabetes remains limited. This is particularly relevant for adjacent dental implants, where biomechanical load distribution and peri-implant tissue interactions are more complex.[22,23] These implants have been commonly placed to support multi-unit fixed partial dentures or complete arch prostheses, and their clinical success can be influenced by occlusal dynamics, prosthesis design, and systemic metabolic status.[24]

To date, only a few longitudinal clinical studies have evaluated peri-implant tissue health and implant survival in patients with prediabetes compared to healthy controls over extended follow-up periods.[25,26] However, the authors are unaware of a systematic review that has consolidated these findings to determine whether prediabetes significantly compromises implant outcomes, particularly in patients with adjacent implants. The research hypothesis was that patients with prediabetes and adjacent dental implants may exhibit reduced implant survival and compromised peri-implant clinical, radiographic, and inflammatory parameters over a 5-year follow-up compared to systemically healthy individuals.

MATERIAL AND METHODS

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.[27,28] The protocol was registered in the PROSPERO database (Registration ID: CRD420251052690).

The inclusion and exclusion criteria were defined according to a population, intervention, comparison, outcome (PICO) framework. The population consisted of adults with prediabetes and systemically healthy individuals receiving adjacent dental implants. The intervention was the placement of adjacent dental implants in patients with prediabetes, while the comparison group included systemically healthy patients. The primary outcomes were implant survival rate and peri-implant health parameters, including marginal bone loss, bleeding on probing, and probing depth, assessed over a minimum follow-up period of 5 years. A focused research question was constructed using the PICO framework: In patients with adjacent dental implants, does a prediabetic condition affect implant survival and peri-implant health outcomes compared to systemically healthy individuals over a 5-year follow-up period?

A comprehensive electronic search was conducted in the PubMed (MEDLINE), Web of Science, Scopus, LILACS, and Google Scholar databases for studies published from January 2000 to April 2025. Search terms included combinations of ("Dental Implants"[MeSH] OR "dental implants") AND ("Prediabetic State"[MeSH] OR prediabetes) AND ("Peri-Implantitis"[MeSH] OR peri-implantitis) AND ("adjacent implants" OR "implant survival") AND ("long-term follow-up" OR "follow-up studies"[MeSH]). Nonpeer-reviewed literature and reference lists of selected articles were also screened. The search was updated in August 2025, when no additional eligible studies were identified.

Studies were included if they were human studies published in English that enrolled participants with prediabetes or systemically healthy individuals receiving at least 2 adjacent dental implants, had a minimum follow-up of 5 years, and reported implant survival or peri-implant health outcomes. Studies were excluded if the follow-up period was less than 5 years, if systemic conditions other than prediabetes were present, or if they were animal studies, case reports, review articles, involved completely edentulous patients, or contained incomplete clinical or radiographic data.

To minimize heterogeneity, only patients with at least 2 adjacent implants were included, as adjacent implants have been reported to influence peri-implant bone and soft tissue behavior through inter-implant spacing, shared prosthetic loading, and localized inflammation.[29] Participants with prediabetes were defined as those with glycated hemoglobin (HbA1c) value between 5.7% and 6.4% or a prior clinical diagnosis of prediabetes, while systemically healthy individuals were defined as those with HbA1c value less than 5.7% and without systemic disease.[30] Participants with compromised periodontal health, bone augmentation procedures, those with a history of chronic smoking, recent use of medications affecting bone or periodontal status (such as steroids, non-steroidal anti-inflammatory drugs

(NSAIDs), antibiotics, or bisphosphonates), or incomplete clinical or radiographic data were excluded.

Two independent reviewers (S.T., A.S.) screened the titles and abstracts, followed by full-text review. Disagreements were resolved through discussion with a third author (A.S.). Data were extracted using a standardized data collection form and included study design, sample size, age, follow-up period, implant survival, probing depth, bleeding on probing, and marginal bone loss (Table 1). Risk of bias was assessed using the Newcastle–Ottawa Scale for the cohort study (Table 2) and an appraisal tool (AXIS) for the cross-sectional study (Table 3).

RESULTS

The initial database search identified 827 articles. After removing 382 duplicates, 445 articles were screened by title and abstract. Of these, 32 full-text articles assessed, 30 were excluded: 10 studies had follow-up periods of less than 5 years, 13 studies did not involve placement of adjacent implants, and 7 studies did not include prediabetic patients (Table 4). Following application of inclusion and exclusion criteria, 2 studies[31,32] were included in the final qualitative synthesis as shown in Figure 1.

The included studies comprised 1 prospective cohort study and 1 cross-sectional study, with a combined sample of 139 participants (69 systemically healthy and 70 with prediabetes) and a total of 336 implants evaluated. Both studies reported 100% implant survival at follow-up.

Alrabiah et al[31] in the prospective cohort study evaluated 39 participants with prediabetes and 40 systemically healthy participants received a total of 158 adjacent implants and were followed for 5 years. While implant survival was equal across groups, peri-implant tissue health was significantly worse in those with prediabetes. Mean ±standard deviation probing depth was 4.6 ±0.2 mm in participants with prediabetes compared with 2.2 ±0.3 mm in the control group (P<.001). Plaque index (46.7% versus 24.4%, P<.001), bleeding on probing (48.2% versus 22.6%, P<.001), and mesial and distal crestal bone loss (5.2 to 5.3 mm versus 2.3 mm, P<.001) were all significantly greater in the prediabetic group.

Alsahhaf et al[32] in the cross-sectional study evaluated 178 implants in 60 participants (30 systemically healthy and 30 with prediabetes) over 12 to 14 years. Again, survival rates were identical, but peri-implant soft and hard tissue parameters were poorer in those with prediabetes. The prediabetic group showed higher plaque index (35.9 to 41.2% versus 21.7 to 29.6%), greater bleeding on probing (24.4 to 35.3% versus 18.4 to

Table 1. Summary of included studies on implant survival and peri-implant health in patients with prediabetes versus systemically healthy patients

Study (Author, Year)	Study Design	Sample Size (Patient With Prediabetes/ Systematically Healthy)	Follow-up Duration	Implants Evaluated	Implant Survival (%)	Mean Marginal Bone Loss (mm ±SD)	Probing Depth (mm ±SD)	Bleeding on Probing (%)	Plaque Index (%)	Inflammatory Markers	Prosthetic Outcome
Alrabiah et al, 2020	Prospective cohort	39/40	5 years	158	100/100	5.2 to 5.3 versus 2.3	4.6 ±0.2 versus 2.2 ±0.3	48.2 versus 22.6	46.7 versus 24.4	↑ IL-6, TNF-α	Single crown: 28.6% complications; Splinted crown: 21.4%
Almoharib et al, 2022	Cross-sectional	30/30	12 to 14 years	178	100/100	1.6 to 1.7 versus 0.8 to 1.0 (mesial), 1.7 to 1.8 versus 0.9 to 1.1 (distal)	3.9 to 4.2 versus 3.1 to 3.3	24.4 to 35.3 versus 18.4 to 21.8	35.9 to 41.2 versus 21.7 to 29.6	↑ IL-6, TNF-α	Single crown: 15.8% complications; Splinted crown: 34.9%

Table 2. Risk of bias assessment of included studies

Study	Study Design	Tool Used	Selection (Max 4☆)	Comparability (Max 2☆)	Outcome (Max 3☆)	Total Score/Max	Risk of Bias
Alrabiah et al, 2020	Prospective Cohort	Newcastle–Ottawa	☆☆☆☆	☆☆	☆☆	8/9	Low

Table 3. AXIS risk of bias assessment for cross-sectional study

No.	Domain/Question	Response
1	Were the aims/objectives of the study clear?	Yes
2	Was the study design appropriate for the stated aims?	Yes
3	Was the sample size justified?	No
4	Was the target population clearly described?	Yes
5	Was the sample frame appropriate?	Yes
6	Were the selection methods described?	Yes
7	Was the measurement of risk factors clearly defined?	Yes
8	Were outcome measures clearly defined?	Yes
9	Were statistical methods described?	Yes
10	Were non-responders accounted for?	No
11	Were limitations discussed?	Yes
12	Were results internally consistent?	Yes
13	Were estimates of random variability provided?	No
14	Were results presented with confidence intervals?	No
15	Were outcome measures valid and reliable?	Yes
16	Was ethical approval reported?	Yes
17	Were conflicts of interest declared?	Yes
18	Was funding source stated?	Yes
19	Were potential sources of bias discussed?	Partial
20	Were conclusions justified by results?	Yes

Overall risk of bias: Moderate.

Table 4. Summary of reasons for exclusion of full-text articles following eligibility assessment in the systematic review

Reason for Exclusion	Number of Studies
Follow-up <5 years	10
No adjacent implant placement,	13
Not involving prediabetes patient	7

21.8%), and deeper probing depths (3.9 to 4.2 mm versus 3.1 to 3.3 mm) were observed in prediabetic participants compared to non-diabetic participants ($P<.05$ for all comparisons). Crestal bone levels were significantly lower in those with prediabetes (mesial: 1.6 to 1.7 mm versus 0.8 to 1.0 mm; distal: 1.7 to 1.8 mm versus 0.9 to 1.1 mm, $P<.05$ for both sites). Biomarker analysis further revealed elevated inflammatory cytokines in prediabetic patients (IL-6: 138 to 154 pg/mL versus 85 to 94 pg/mL; TNF-α: 98 to 115 pg/mL versus 47 to 63 pg/mL, $P<.05$).

With respect to prosthetic outcomes, technical complications were observed more frequently in splinted crowns among participants with prediabetes (34.9%) compared to systemically healthy patients (21.4%) ($P=.002$). Single crown complications were reported in both groups but did not differ significantly. Patient satisfaction remained high overall, with 91% satisfied with esthetics and 79% with function.

The risk of bias for the included studies was assessed using tools appropriate to the study design. The prospective cohort study by Alrabiah et al[31] was evaluated using the Newcastle–Ottawa Scale (NOS) and was found to have a low risk of bias, with a score of 8 out of 9 stars. The cross-sectional study by Alsahhaf et al[32] was assessed using the AXIS tool and had a moderate risk of bias, fulfilling 14 out of 20 criteria. Both studies reported clear objectives and inclusion criteria; however, the cross-sectional design and lack of control for potential confounders in one study may affect the internal validity of its findings. In contrast, the prospective cohort study accounted for potential confounding factors, including age, sex, smoking status, and baseline periodontal health, which may influence implant outcomes. Despite these differences, the overall quality of evidence was considered sufficient for qualitative synthesis. Because only 2 studies with variations in outcome measures were assessed, a meta-analysis was not performed.

DISCUSSION

The research hypothesis that prediabetic status adversely affects implant survival and peri-implant health in patients with adjacent dental implants compared with systemically healthy individuals was partially supported. While implant survival rates remained high in both groups, patients with prediabetes exhibited greater peri-implant soft tissue inflammation and marginal bone loss.[33]

The survival rate of adjacent implants in patients with prediabetes ranged from 94% to 100%, which was comparable with survival rates reported in the general population.[34] Based on this limited evidence, prediabetes does not appear to substantially compromise osseointegration or the mechanical stability of implants in the short to medium term.[35] However, these findings should be interpreted with caution, as the small number of available studies did not allow for definitive conclusions regarding the impact of prediabetes on implant survival. At present, prediabetes cannot be considered an absolute contraindication for implant therapy, although careful patient selection and maintenance remain essential.[36]

Several studies[16,17,19,20,37] have reported statistically significant differences in peri-implant parameters. Increased bleeding on probing, probing depth, and early

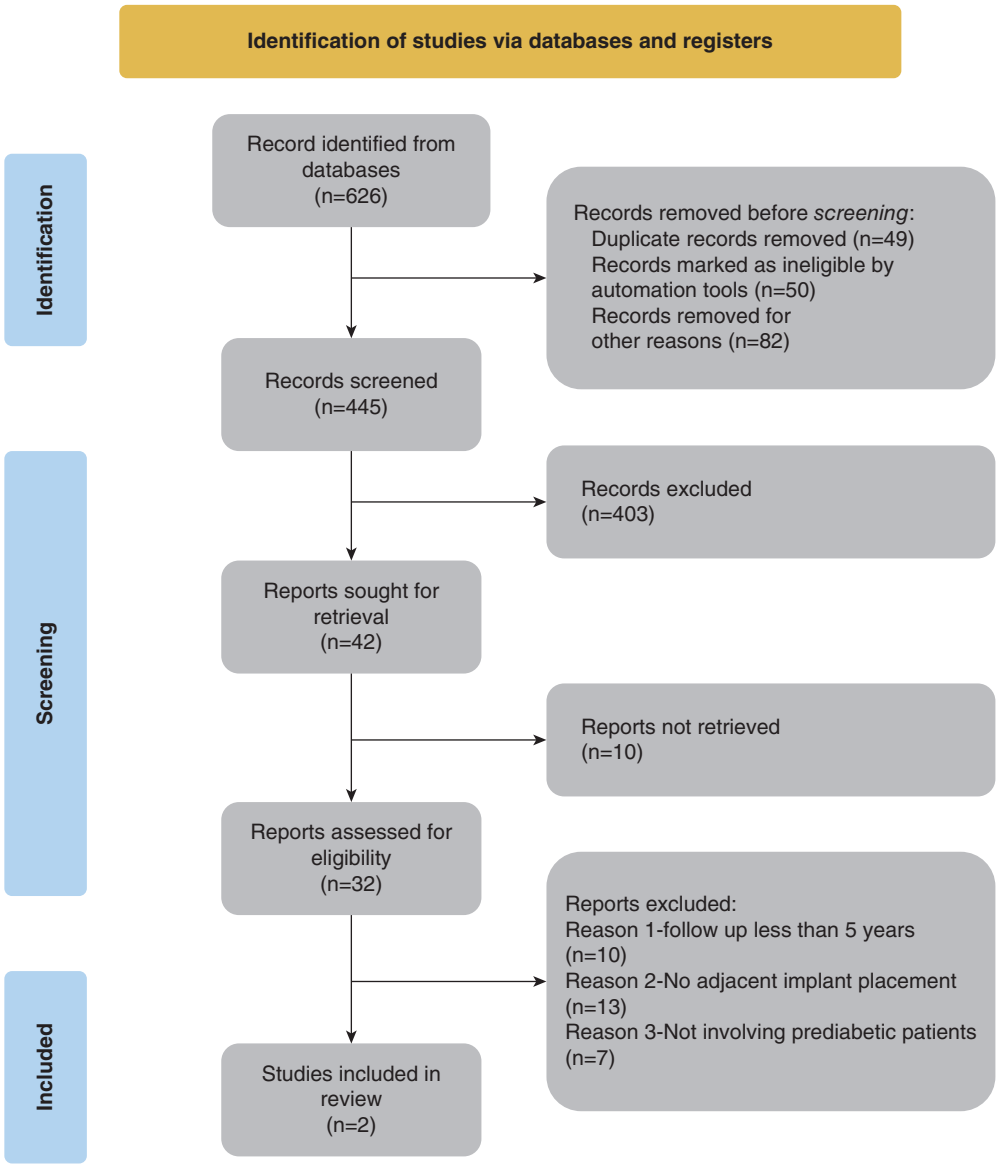

Figure 1. Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) flow diagram detailing disposition of screened, included, and excluded records.

marginal bone loss were more common among patients diagnosed with prediabetes. These findings were consistent with the proposed pathophysiologic mechanisms of hyperglycemia-induced low-grade inflammation and impaired wound healing.[38] Chronic systemic inflammation associated with insulin resistance may contribute to increased susceptibility to peri-implant mucositis and peri-implantitis, even when glycemic levels do not meet the diagnostic threshold for diabetes.[39]

Glycemic control, measured through HbA1c levels, was not uniformly reported across all studies, leading to heterogeneity in defining prediabetic status. Moreover, diagnostic criteria for peri-implantitis varied, further complicating direct comparisons.[40] Despite these limitations, the consistency of trends across the studies reinforced the need for early monitoring and custom maintenance protocols for patients diagnosed with prediabetes receiving implant-supported prostheses.[41]

Adjacent implant placement introduced additional biological and biomechanical challenges. Reduced interimplant distances combined with a systemic pro-inflammatory state may exacerbate bone remodeling and crestal bone loss.[42] Although no significant differences in implant loss were observed, but meticulous treatment planning and individualized recall schedules are still essential to prevent biological complications.

Only 2 studies were included in this review, limiting the strength of the evidence. The evidence regarding peri-implant soft tissue inflammation and marginal bone loss in prediabetic patients remains inconclusive

and should be interpreted with caution. Differences in study design and peri-implant assessment protocols further restrict the generalizability of the results. Well-designed, long-term studies with larger sample sizes are required to confirm these observations and provide more robust clinical guidance.

The findings of this review were clinically significant, as prediabetes is prevalent and often undiagnosed. Given that implant therapy remains suitable in this population, clinicians should screen patients for glycemic status preoperatively and emphasize the importance of metabolic control and oral hygiene.

Limitations of this review included that the 2 studies used different diagnostic criteria for prediabetes and peri-implant disease, creating heterogeneity in data interpretation. Because most studies had follow-up periods shorter than 5 years, only limited long-term evidence was included. HbA1c level and glycemic control were inconsistently reported, limited the ability to stratify outcomes by metabolic control. Variability in study design, implant systems, and peri-implant assessment protocols prevented the performance of a meta-analysis. Finally, limiting the search to English-language publications may have caused publication bias and led to the omission of relevant studies.

Future research should focus on multicenter, prospective longitudinal studies with larger sample sizes and standardized diagnostic criteria for prediabetes and peri-implantitis. Uniform reporting of peri-implant clinical, radiographic, and immunologic parameters is needed. Studies stratifying outcomes by degree of glycemic control could allow more precise risk assessment. Additionally, evaluation of adjunctive therapies such as antimicrobial protocols, probiotics, and host modulation may inform personalized treatment. Given the growing prevalence of prediabetes worldwide, collaboration between dental and medical professionals will be essential to optimize implant outcomes in this population.

CONCLUSIONS

Based on the findings of this systematic review, the following conclusions were drawn:

1. Implant survival rates over a 5-year follow-up period were similar in patients diagnosed with prediabetes and systemically healthy individuals receiving adjacent dental implants.
2. Patients diagnosed with prediabetes demonstrated greater peri-implant marginal bone loss and signs of soft tissue inflammation compared with systemically healthy individuals.
3. Although implant longevity was not compromised, prediabetes was associated with reduced peri-implant tissue health.
4. Early detection and monitoring of glycemic status may improve treatment planning and maintenance protocols for patients receiving multiple implants.

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