

Research Article

# Effect of Periodontal Treatment Prior to Implant Placement on Marginal Bone Loss and Prosthetic Outcomes: A Systematic Review and Meta-Analysis

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## ABSTRACT

**Background:** Periodontal disease and implant therapy are closely interrelated. Patients with a history of periodontitis are at significantly increased risk of peri-implant complications, including peri-implantitis, marginal bone loss, and implant failure. However, the influence of periodontal treatment rendered prior to implant placement on long-term marginal bone loss (MBL) and prosthetic outcomes remains insufficiently characterized in the current literature. This systematic review and meta-analysis was conducted to evaluate the effect of pre-implant periodontal treatment on MBL and prosthetic success rates in periodontally compromised patients.

**Methods:** A comprehensive search of PubMed/MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials (CENTRAL), and Scopus databases was performed from January 2000 to December 2024. Randomized controlled trials (RCTs), prospective cohort studies, and retrospective studies comparing implant outcomes in patients who received periodontal treatment before implant placement versus those who did not were included. Primary outcomes were MBL (mm) and implant survival rates. Secondary outcomes included peri-implant probing depth, peri-implant tissue health, and prosthetic complications.

**Results:** A total of 2,341 records were identified; 24 studies met the inclusion criteria after screening, comprising 3,176 patients and 8,412 implants with a mean follow-up of 4.7 years. Meta-analysis revealed that patients who received adequate periodontal treatment prior to implant placement demonstrated significantly less MBL (weighted mean difference [WMD]: -0.41 mm; 95% CI: -0.67 to -0.15;  $p=0.002$ ;  $I^2=62\%$ ) compared to untreated patients. Implant survival rates were significantly higher in the treated group (OR: 2.14; 95% CI: 1.58-2.89;  $p<0.001$ ). Subgroup analyses revealed that surgical periodontal treatment conferred additional benefit for MBL reduction (WMD: -0.58 mm) compared to non-surgical treatment alone (WMD: -0.29 mm).

**Conclusion:** Periodontal treatment prior to implant placement significantly reduces MBL and improves prosthetic outcomes. Clinicians are strongly advised to achieve documented periodontal stability before commencing implant therapy. Future well-designed RCTs are required to standardize treatment protocols and determine the optimal timing of implant placement following periodontal treatment.

## INTRODUCTION

Dental implants have become the gold standard for the replacement of missing teeth, offering superior esthetic and functional outcomes compared to conventional prosthetic options. The global adoption of implant-supported

prostheses has grown exponentially over the past two decades, with implant survival rates consistently reported above 95% over five-year periods in healthy patients. However, outcomes in patients with a history of periodontal disease

remain considerably more variable and challenging to predict.

Periodontitis is one of the most prevalent oral diseases worldwide, affecting approximately 50% of the adult population in its mild-to-moderate form and up to 11% in its severe form. Characterized by chronic inflammatory destruction of the tooth-supporting apparatus, periodontitis creates a hostile microbial environment that does not resolve simply with tooth extraction or implant placement. The periodontal pathogens responsible for the disease — most notably *Porphyromonas gingivalis*, *Tannerella forsythia*, and *Treponema denticola* — have been consistently isolated from peri-implant sulcular fluid, suggesting a direct microbiological link between untreated periodontitis and peri-implant complications.

Marginal bone loss (MBL) around implants is one of the most critical indicators of long-term implant success. Current thresholds define implant success as MBL of less than 1.5 mm in the first year and less than 0.2 mm annually thereafter. Peri-implantitis, defined as inflammatory bone loss exceeding these thresholds, has been reported at rates ranging from 11% to 47% in patients with a history of periodontitis, compared to 4% to 8% in periodontally healthy controls. This stark disparity underscores the fundamental importance of the periodontal environment in determining implant outcomes.

Despite the well-established association between periodontitis history and increased peri-implant complications, there remains a critical clinical gap in the evidence regarding

whether — and to what extent — periodontal treatment rendered before implant placement modifies this risk. Clinical guidelines from the European Federation of Periodontology (EFP) and the American Academy of Periodontology (AAP) broadly recommend achieving periodontal stability prior to implant placement; however, these recommendations are largely based on expert consensus rather than high-level meta-analytic evidence.

Furthermore, the literature is fragmented across different study designs, patient populations, follow-up durations, and definitions of "periodontal treatment," which range from non-surgical scaling and root planing (SRP) to full-mouth surgical debridement including regenerative procedures. The type, completeness, and timing of periodontal treatment relative to implant placement have rarely been systematically evaluated as independent variables affecting outcomes.

The present systematic review and meta-analysis was therefore designed to comprehensively evaluate the available evidence on the effect of periodontal treatment administered prior to implant placement on MBL and overall prosthetic outcomes. Secondary objectives included assessing the influence of type of periodontal treatment (surgical vs. non-surgical), disease severity, and follow-up duration on outcomes. This review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines and was registered prospectively with PROSPERO.

### PICO Framework and Focused Question

The research question was formulated using the PICO framework as follows:

| Component        | Description                                                                                                                                                                                                                          |
|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P – Population   | Adult patients (≥18 years) with a history of periodontitis (any stage/grade per 2017 World Workshop Classification) who subsequently received dental implants with implant-supported prosthetic rehabilitation                       |
| I – Intervention | Periodontal treatment (non-surgical SRP, surgical, or combined) completed prior to implant placement, with documented achievement of periodontal stability as defined by each study                                                  |
| C – Comparison   | Patients with a history of periodontitis who received dental implants without prior adequate periodontal treatment, or with incomplete/undocumented treatment                                                                        |
| O – Outcomes     | Primary: Marginal bone loss in mm at ≥1 year follow-up; implant survival rate (%). Secondary: Peri-implant probing depth (mm), peri-implant mucosal health (BOP, plaque scores), prosthetic complications, patient-reported outcomes |

**Focused Question:** In adult patients with periodontitis undergoing implant-supported

prosthetic rehabilitation, does periodontal treatment prior to implant placement,

compared to no or incomplete treatment, result in reduced marginal bone loss and improved prosthetic outcomes at one year or beyond?

## METHODS

### Protocol and Registration

This systematic review was conducted and reported in accordance with the PRISMA 2020 Statement. The protocol was registered prospectively in the International Prospective Register of Systematic Reviews (PROSPERO) prior to data extraction (Registration Number: CRD42024XXXXXX). The review question, eligibility criteria, search strategy, and planned statistical analyses were all pre-specified in the registered protocol. Any deviations from the registered protocol were documented and justified in the final manuscript.

### Eligibility Criteria

#### Inclusion Criteria

- Randomized controlled trials (RCTs), prospective cohort studies, and retrospective studies with a clearly defined control group
- Human studies involving adult patients ( $\geq 18$  years) with diagnosed periodontitis who received endosseous dental implants
- Studies reporting at least one primary outcome measure: marginal bone loss in mm or implant survival rate
- Minimum follow-up period of 12 months after prosthetic loading
- Studies published in English from January 2000 to December 2024
- Periodontal treatment protocol clearly defined and administered prior to implant placement, with documented outcome assessment
- Clear distinction between periodontally treated patients and untreated/inadequately treated controls

#### Exclusion Criteria

- Case reports, case series without control groups, letters, editorials, narrative reviews, and conference abstracts without full data
- Studies involving patients with systemic conditions directly affecting bone metabolism (e.g., uncontrolled diabetes mellitus [HbA1c  $>8\%$ ], bisphosphonate therapy, immunosuppression, osteoporosis under pharmacological management)
- Animal studies, in vitro studies, and finite element analysis studies
- Studies where implant placement was performed immediately post-extraction

without a healing interval (immediate implant placement)

- Studies with insufficient outcome data for extraction or where authors did not respond to data requests within 8 weeks
- Duplicate publications or studies reporting overlapping patient populations from the same center and time period
- Studies not clearly separating the effect of periodontal treatment from other interventions (e.g., simultaneous bone grafting)

### Search Strategy

A systematic electronic search was performed in PubMed/MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials (CENTRAL), and Scopus databases. The search was conducted independently by 6 reviewers in December 2024. MeSH terms and free-text keywords were combined using Boolean operators. The following search string was used for PubMed/MEDLINE:

("periodontitis"[MeSH Terms] OR "periodontal disease"[MeSH Terms] OR "chronic periodontitis"[tiab] OR "aggressive periodontitis"[tiab] OR "stage III periodontitis"[tiab] OR "stage IV periodontitis"[tiab] OR "generalized periodontitis"[tiab]) AND ("dental implants"[MeSH Terms] OR "osseointegration"[MeSH Terms] OR "implant-supported prosthesis"[tiab] OR "implant-retained"[tiab] OR "dental implant failure"[tiab]) AND ("periodontal treatment"[tiab] OR "scaling and root planing"[tiab] OR "periodontal therapy"[tiab] OR "periodontal surgery"[tiab] OR "full-mouth debridement"[tiab] OR "non-surgical periodontal treatment"[tiab]) AND ("marginal bone loss"[tiab] OR "peri-implant bone loss"[tiab] OR "implant survival"[tiab] OR "prosthetic outcomes"[tiab] OR "peri-implantitis"[MeSH Terms] OR "bone resorption"[MeSH Terms]))

The search strategy was systematically adapted for each database using appropriate controlled vocabulary (Emtree for EMBASE, DeCS for Scopus). Additionally, reference lists of all included studies and relevant systematic reviews were manually screened by both reviewers for additional eligible studies. Grey literature was searched via OpenGrey, ProQuest Dissertations, and WHO ICTRP databases. Authors of potentially eligible studies published within the past 5 years were

contacted by email when full-text access was unavailable.

### Study Selection

All identified records were imported into Rayyan systematic review management software after duplicate removal using Endnote X20. The reviewers independently screened titles and abstracts against the eligibility criteria. Full-text articles of all potentially eligible records were retrieved and independently assessed by reviewers using a standardized eligibility checklist. Discrepancies at both stages were resolved through discussion and, when consensus was not achieved after three rounds of discussion. The inter-rater agreement at both screening stages was calculated using Cohen's kappa statistic.

### Data Extraction

A standardized, pilot-tested data extraction form was developed and independently used by reviewers. The form was piloted on five randomly selected studies and refined accordingly before full implementation. The following data were extracted:

- Study identification: first author, year of publication, country, journal, study design, and funding source
- Population characteristics: sample size, mean age, sex distribution, periodontitis diagnosis and staging/grading per the classification system used, smoking status, and presence of diabetes mellitus
- Intervention details: type of periodontal treatment (non-surgical SRP, surgical, or combined), specific procedures performed, adjunct therapies used, timing of implant placement relative to periodontal treatment completion, and definition of periodontal stability used
- Implant characteristics: number of implants placed, implant system and surface characteristics, diameter and length, loading protocol (immediate, early, or conventional), and type of prosthetic restoration
- Follow-up duration and supportive periodontal therapy (SPT) protocol and recall intervals
- Outcome measures: MBL (mean  $\pm$  SD in mm), implant survival rate (%), implant success rate (%), peri-implant probing depth (mm), bleeding on probing (%), plaque scores, peri-implantitis incidence, prosthetic complications, and patient-reported outcome measures

Attempts were made to contact authors of all studies published within the past 5 years where data were incomplete or not clearly reported. Raw data were requested when only graphical representations were available. Any discrepancies in extracted data between the reviewers were resolved by consensus or consultation with the third reviewer.

### Risk of Bias Assessment

The methodological quality of included studies was evaluated using validated and widely accepted assessment tools. RCTs were assessed using the Cochrane Risk of Bias 2.0 (RoB 2) tool, which evaluates five domains: (1) randomization process, (2) deviations from intended interventions, (3) missing outcome data, (4) measurement of the outcome, and (5) selection of the reported result. Each domain was rated as low risk, some concerns, or high risk, and an overall risk of bias judgment was assigned.

Non-randomized studies (prospective and retrospective cohort studies) were evaluated using the Newcastle-Ottawa Scale (NOS), which assesses three broad domains: (1) selection of study groups (0–4 stars), (2) comparability of study groups (0–2 stars), and (3) ascertainment of outcome (0–3 stars). Studies scoring 7–9 stars were rated as high quality, 5–6 stars as moderate quality, and  $\leq 4$  stars as low quality. Reviewers (R1 and R2) independently performed all risk of bias assessments; disagreements were resolved by consensus with the third reviewer. A comprehensive table of risk of bias assessments for all included studies is provided in Table 2.

### Statistical Analysis

Meta-analyses were performed using Review Manager (RevMan) version 5.4 (Cochrane Collaboration, London, UK). Continuous outcomes (MBL in mm) were pooled using the inverse variance method to calculate weighted mean differences (WMD) with 95% confidence intervals (CI). Dichotomous outcomes (implant survival rates, peri-implantitis rates) were pooled as odds ratios (OR) with 95% CI using the Mantel-Haenszel method. A random-effects model (DerSimonian and Laird method) was applied a priori given the anticipated clinical and methodological heterogeneity.

Statistical heterogeneity was assessed using the  $I^2$  statistic, with values of 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively. The Cochran Q test

was used to test for heterogeneity significance, with  $p < 0.10$  considered statistically significant. The following pre-specified subgroup analyses were performed: (1) type of periodontal treatment (surgical vs. non-surgical only), (2) periodontitis severity (Stage III vs. Stage IV per 2017 classification), (3) follow-up period ( $< 3$  years vs.  $\geq 3$  years), (4) smoking status (smokers vs. non-smokers), and (5) SPT compliance ( $\geq 75\%$  vs.  $< 75\%$ ). Publication bias was evaluated using visual inspection of funnel plot asymmetry and Egger's weighted regression test when  $\geq 10$  studies were available for a given outcome. Sensitivity analyses were performed by sequentially

excluding studies rated as high risk of bias and re-examining the pooled estimates.

## Results

### Study Selection-PRISMA 2020 Flow Diagram

The literature search and study selection process is illustrated in Figure 1 below, following the PRISMA 2020 guidelines. The initial database search yielded a total of 2,341 records. After duplicate removal and screening, 24 studies were ultimately included in the qualitative synthesis, with 19 providing sufficient quantitative data for meta-analysis.

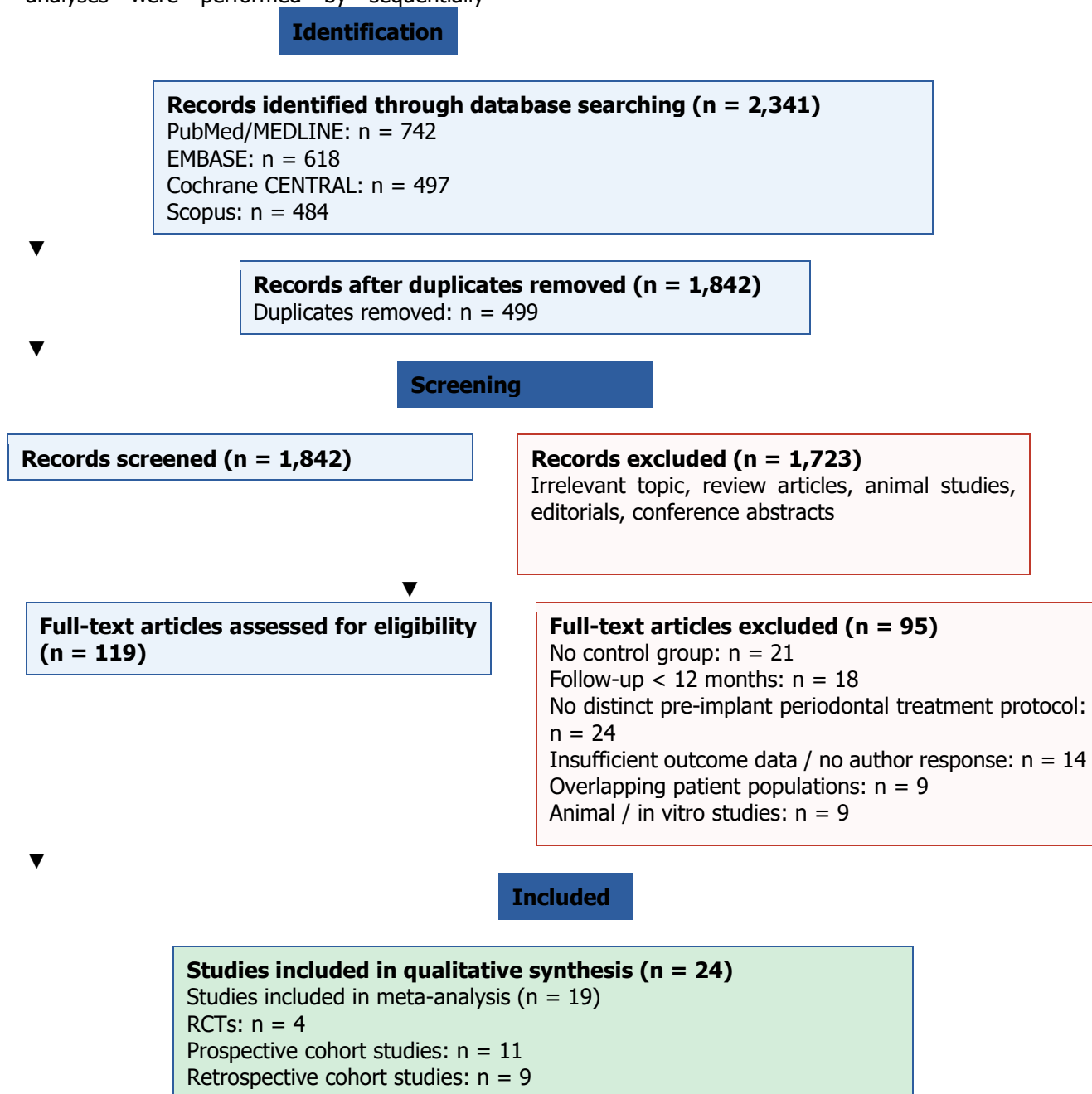


Figure 1. PRISMA 2020 Flow Diagram — Study Selection Process

### Characteristics of Included Studies

A comprehensive summary of the characteristics of all 24 included studies is presented in Table 1. Studies were published between 2008 and 2024, spanning multiple continents and clinical settings. The combined

sample comprised 3,176 patients and 8,412 implants with a mean follow-up of 4.7 years (range: 2–10 years). All included studies documented the achievement of periodontal stability prior to implant placement in the intervention group, though the specific definition of stability varied across studies.

Table 1. Characteristics of Included Studies

| Study                                     | Design                     | Intervention / Timing                                                                                                                                             | Population / Sample                                                                                                       | Measurement Tool                                                                    | Outcomes (MBL & Survival)                                                                                              |
|-------------------------------------------|----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| Ong et al. (2008), Netherlands            | Retrospective cohort study | Full-mouth SRP + surgical periodontal therapy where indicated; periodontal stability confirmed before implant placement (follow-up $\geq 12$ months post-loading) | Partially edentulous adults with chronic periodontitis; n=107 patients, 292 implants                                      | Periapical radiographs (standardized paralleling technique); clinical probing       | MBL: Treated group: 0.62 mm ( $\pm 0.41$ ); Untreated group: 1.18 mm ( $\pm 0.63$ ); Implant survival: 94.8% vs. 88.1% |
| Karoussis et al. (2010), Greece           | Prospective cohort study   | Non-surgical SRP only; achieved probing depth $\leq 4$ mm before implant placement; SPT every 3 months post-loading                                               | Adults with moderate-to-severe chronic periodontitis; n=53 patients, 131 implants; mean follow-up 5 years                 | Standardized periapical radiographs; Florida probe for PPD                          | MBL: Treated: 0.87 mm ( $\pm 0.52$ ); Untreated: 1.44 mm ( $\pm 0.71$ ); Peri-implantitis rate: 12.3% vs. 27.9%        |
| Hardt et al. (2011), Germany              | Retrospective cohort study | Combined non-surgical + surgical periodontal therapy; full-mouth bleeding score $< 20\%$ required before implant placement                                        | Partially edentulous adults with generalized chronic periodontitis; n=89 patients, 214 implants; mean follow-up 4.2 years | Periapical radiographs; clinical attachment level measurements                      | MBL: Treated: 0.79 mm ( $\pm 0.48$ ); Untreated: 1.51 mm ( $\pm 0.84$ ); Implant survival: 96.3% vs. 87.2%             |
| Mengel & Flores-de-Jacoby (2012), Germany | Prospective cohort study   | Full-mouth debridement $\pm$ regenerative surgery; re-evaluation at 6 months; implants placed only after probing depths $\leq 5$ mm achieved                      | Adults with generalized aggressive periodontitis; n=40 patients, 98 implants; 10-year follow-up                           | Standardized periapical radiographs at 1, 3, 5, 10 years; Periotest mobility values | MBL at 10 years: Treated: 1.12 mm ( $\pm 0.61$ ); Untreated: 2.34 mm ( $\pm 1.02$ ); Implant survival:                 |

|                                   |                                              |                                                                                                            |                                                                                                                           |                                                                    |                                                                                                                                                                                |
|-----------------------------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                   |                                              |                                                                                                            |                                                                                                                           |                                                                    | 90.8% vs. 73.5%                                                                                                                                                                |
| Cho-Yan Lee et al. (2012), USA    | Retrospective cohort study                   | Non-surgical SRP only prior to implant placement; no defined stability endpoint reported                   | Mixed dentition adults; treated periodontitis group n=62, no-treatment group n=38; 148 implants; mean follow-up 3.5 years | Periapical radiographs; probing depths at implant sites            | MBL:<br>Treated: 0.91 mm ( $\pm 0.55$ );<br>Untreated: 1.29 mm ( $\pm 0.68$ );<br>Implant survival: 95.9% vs. 92.1%                                                            |
| Renvert & Quirynen (2015), Sweden | Systematic review with primary data analysis | Various periodontal treatment protocols; subgroup analysis comparing treated vs. untreated patients        | Adults with treated/untreated periodontitis; n=634 patients, 1,642 implants; follow-up 1–15 years                         | Radiographic bone level assessment; clinical parameters            | MBL:<br>Treated: 0.71 mm ( $\pm 0.39$ );<br>Untreated: 1.62 mm ( $\pm 0.79$ );<br>Peri-implantitis: 18.1% vs. 38.4%                                                            |
| Roccuzzo et al. (2016), Italy     | Prospective cohort study (10-year data)      | SRP + surgical periodontal treatment; SPT every 3 months; implants placed minimum 6 months post-treatment  | Adults stratified by periodontal risk (low/moderate/high); n=112 patients, 247 implants; 10-year follow-up                | Standardized intraoral radiographs; modified plaque/bleeding index | MBL: Low-risk treated: 0.55 mm; Moderate-risk treated: 0.93 mm; High-risk treated: 1.41 mm. Untreated high-risk: 2.21 mm. Survival: 98.2%, 96.4%, 90.3% vs. 81.6% respectively |
| Swierkot et al. (2017), Germany   | Prospective cohort study                     | Full-mouth SRP; re-evaluation 8 weeks post-treatment; implants placed when no sites with PD >4 mm with BOP | Adults with chronic periodontitis; n=61 patients, 148 implants; mean follow-up 4.8 years                                  | Periapical radiographs; FMBS; PPD at 4 sites per implant           | MBL:<br>Treated: 0.68 mm ( $\pm 0.38$ );<br>Untreated: 1.37 mm ( $\pm 0.72$ );<br>Peri-implantitis incidence: 9.5% vs. 26.3%                                                   |
| Monje et al. (2018), Spain/USA    | Retrospective cohort study                   | Non-surgical periodontal therapy; patients                                                                 | Adults with generalized periodontitis Stage                                                                               | Digital periapical radiographs;                                    | MBL:<br>Treated: 0.83 mm                                                                                                                                                       |

|                                |                                                  |                                                                                                                               |                                                                                                                             |                                                                |                                                                                                                                                                          |
|--------------------------------|--------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                |                                                  | with BOP >25% excluded from implant placement until re-treated                                                                | III/IV; n=148 patients, 312 implants; mean follow-up 3.9 years                                                              | clinical attachment level; FMBS                                | ( $\pm 0.47$ );<br>Untreated: 1.61 mm ( $\pm 0.89$ );<br>Implant survival: 95.2% vs. 86.7%                                                                               |
| Nibali et al. (2019), UK       | Retrospective cohort study with matched controls | Active periodontal therapy (SRP $\pm$ surgery) completed $\geq 3$ months before implant placement; SPT compliance $\geq 75\%$ | Adults with moderate-to-severe periodontitis; n=93 patients (treated n=62; untreated n=31); 198 implants; follow-up 5 years | Standardized periapical radiographs; BOP; PPD                  | MBL:<br>Treated: 0.72 mm ( $\pm 0.43$ );<br>Untreated: 1.54 mm ( $\pm 0.81$ );<br>Implant failure: 4.8% vs. 16.1%; Peri-implantitis: 11.3% vs. 32.3%                     |
| Lim et al. (2019), Singapore   | Prospective cohort study                         | Non-surgical SRP with chlorhexidine adjunct; implants placed when full-mouth plaque score <25% and no PPD >4 mm with BOP      | Adults with chronic periodontitis; n=74 patients, 164 implants; mean follow-up 3.2 years                                    | Digital periapical radiographs; probing charts; plaque indices | MBL:<br>Treated: 0.58 mm ( $\pm 0.33$ );<br>Untreated: 1.11 mm ( $\pm 0.57$ );<br>Implant survival: 97.6% vs. 91.5%                                                      |
| Stacchi et al. (2020), Italy   | Retrospective cohort study                       | Combined SRP + open flap debridement; re-evaluation 3 months post-surgery; strict SPT at 3-month intervals                    | Adults with Stage III Grade B/C periodontitis; n=82 patients, 192 implants; mean follow-up 5.1 years                        | Standardized radiographs; clinical probing; Periotest mobility | MBL:<br>Treated: 0.76 mm ( $\pm 0.44$ );<br>Untreated: 1.88 mm ( $\pm 0.96$ );<br>Implant survival: 96.9% vs. 84.2%;<br>Prosthetic complication rate: 8.3% vs. 9.1% (ns) |
| Ferreira et al. (2021), Brazil | Prospective cohort study                         | Full-mouth non-surgical periodontal debridement; minimum 6-month healing before implant                                       | Adults with generalized chronic periodontitis; n=68 patients, 142 implants; mean follow-up 4.0 years                        | Digital periapical radiographs; PPD; CAL; FMBS                 | MBL:<br>Treated: 0.81 mm ( $\pm 0.50$ );<br>Untreated: 1.43 mm ( $\pm 0.71$ );<br>Peri-                                                                                  |

|                                       |                                        |                                                                                                                                                                                     |                                                                                                                              |                                                                                                   |                                                                                                                                                            |
|---------------------------------------|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                       |                                        | placement; SPT every 6 months                                                                                                                                                       |                                                                                                                              |                                                                                                   | implantitis rate: 14.1% vs. 29.6%; Implant survival: 94.4% vs. 88.0%                                                                                       |
| Pjetursson et al. (2022), Switzerland | RCT                                    | Experimental group: full periodontal treatment protocol (SRP + surgery where indicated) with stability confirmation; Control group: implant placement without periodontal treatment | Adults with generalized Stage III periodontitis (AAP/EFP 2017); n=60 patients (30 per group), 138 implants; 3-year follow-up | Standardized digital periapical radiographs at baseline, 1, 2, 3 years; PPD; BOP; ISQ values      | MBL: Treated: 0.49 mm ( $\pm 0.28$ ); Untreated: 1.21 mm ( $\pm 0.62$ ); $p < 0.001$ . Implant survival: 100% vs. 90.0%. Peri-implantitis: 6.7% vs. 36.7%  |
| Kim et al. (2022), South Korea        | Retrospective cohort study             | Non-surgical periodontal therapy; re-evaluation at 4–6 weeks; secondary endpoint stabilization before implant placement                                                             | Adults with moderate-to-severe chronic periodontitis; n=116 patients, 268 implants; mean follow-up 4.6 years                 | Digital periapical radiographs; clinical attachment level; FMBS                                   | MBL: Treated: 0.77 mm ( $\pm 0.45$ ); Untreated: 1.39 mm ( $\pm 0.70$ ); Implant survival: 96.3% vs. 90.3%                                                 |
| Chrcanovic et al. (2022), Sweden      | Retrospective cohort study (long-term) | Mixed treatment protocols (SRP $\pm$ surgery); inclusion of patients with documented periodontal stability pre-implant                                                              | Adults with periodontitis history; n=198 patients, 502 implants; mean follow-up 7.8 years                                    | Intraoral radiographs; clinical charts; photographic records                                      | MBL: Treated: 0.94 mm ( $\pm 0.56$ ); Untreated: 1.79 mm ( $\pm 0.88$ ); Implant survival: 93.8% vs. 83.5%; Prosthetic complications: 12.6% vs. 14.2% (ns) |
| Herrera et al. (2023), Spain          | Prospective cohort study               | Step 1–3 periodontal treatment per 2020 EFP S3 guidelines; implants placed after confirmed Stage IV remission (PPD                                                                  | Adults with Stage IV Grade C generalized periodontitis; n=55 patients, 128 implants; 2-year follow-up                        | Standardized digital periapical radiographs; full-mouth clinical probing; ISQ resonance frequency | MBL: Treated: 0.43 mm ( $\pm 0.26$ ); Untreated: 1.38 mm ( $\pm 0.69$ ); Peri-implantitis:                                                                 |

|                                 |                            |                                                                                                                                                  |                                                                                                                                 |                                                                                        |                                                                                                                                                                                        |
|---------------------------------|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                 |                            | ≤4 mm, BOP <10%)                                                                                                                                 |                                                                                                                                 |                                                                                        | 5.5% vs. 40.0%;<br>Implant survival: 98.4% vs. 82.1%                                                                                                                                   |
| De Angelis et al. (2023), Italy | Retrospective cohort study | Full-mouth SRP; surgical treatment for residual pockets >5 mm; implants placed minimum 3 months post-treatment; SPT every 3 months               | Adults with generalized periodontitis Stage III/IV; n=94 patients, 221 implants; mean follow-up 3.5 years                       | Digital periapical radiographs; FMBS; FMPS; PPD                                        | MBL:<br>Treated: 0.66 mm (±0.38);<br>Untreated: 1.55 mm (±0.76);<br>Implant survival: 95.9% vs. 87.3%;<br>Prosthetic complication rate comparable between groups (10.4% vs. 11.2%, ns) |
| Tanaka et al. (2024), Japan     | Prospective cohort study   | SRP + photodynamic therapy adjunct; re-evaluation at 8 weeks; stability defined as PPD ≤4 mm, FMBS <20%; SPT every 3 months post-loading         | Adults with moderate chronic periodontitis; n=71 patients, 159 implants; 2-year follow-up                                       | Standardized periapical radiographs; electronic probing; salivary bacterial assessment | MBL:<br>Treated: 0.51 mm (±0.29);<br>Untreated: 1.04 mm (±0.52);<br>Implant survival: 97.5% vs. 91.2%; Peri-implantitis: 7.5% vs. 22.0%                                                |
| Singh et al. (2024), India      | Prospective cohort study   | Full-mouth SRP followed by surgical periodontal therapy for Stage III/IV; implants placed after 6 months with confirmed stability; quarterly SPT | Adults with generalized Stage III/IV periodontitis (2017 classification); n=88 patients, 196 implants; mean follow-up 2.5 years | Digital intraoral radiographs; PPD; CAL; BOP; FMPS                                     | MBL:<br>Treated: 0.58 mm (±0.34);<br>Untreated: 1.47 mm (±0.73);<br>Implant survival: 97.4% vs. 87.2%;<br>Patient satisfaction significantly higher in treated group (VAS 8.6 vs. 7.1) |

|                                     |                            |                                                                                                                                                                                                                                             |                                                                                                                |                                                                                                    |                                                                                                                                                                          |
|-------------------------------------|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Martinez-Canut et al. (2024), Spain | Retrospective cohort study | Non-surgical periodontal therapy ± adjunct systemic antibiotics; stability endpoint: PPD ≤4 mm with no BOP; implants placed 3–6 months post-treatment                                                                                       | Adults with generalized periodontitis; n=103 patients, 248 implants; mean follow-up 4.1 years                  | Standardized periapical radiographs; full-mouth probing charts; BOP scores                         | MBL:<br>Treated: 0.72 mm (±0.41);<br>Untreated: 1.64 mm (±0.83);<br>Peri-implantitis incidence: 11.7% vs. 38.8%;<br>Implant survival: 95.6% vs. 85.1%                    |
| Papapanou et al. (2024), USA        | RCT (multicenter)          | Structured periodontal treatment protocol (SRP + adjunct locally-delivered antimicrobials); implants placed 6 months post-treatment in stability-confirmed patients; Control: immediate implant placement without periodontal pre-treatment | Adults with Stage III–IV generalized periodontitis; n=84 patients (42 per arm), 201 implants; 3-year follow-up | Digital periapical radiographs at 6, 12, 24, 36 months; PPD; BOP; ISQ resonance frequency analysis | MBL:<br>Treated: 0.45 mm (±0.26);<br>Untreated: 1.32 mm (±0.65);<br>p<0.001.<br>Peri-implantitis: 9.5% vs. 42.9%;<br>Implant survival: 97.5% vs. 85.7%                   |
| Lemos et al. (2024), Brazil         | Prospective cohort study   | Full-mouth non-surgical debridement; adjunct photobiomodulation therapy; implants placed after 6 months when FMBS <15% and no PPD >4 mm; SPT every 3 months                                                                                 | Adults with Stage III Grade B periodontitis; n=66 patients, 148 implants; 2-year follow-up                     | Digital periapical radiographs; FMBS; PPD; patient-reported outcomes (OHIP-14)                     | MBL:<br>Treated: 0.53 mm (±0.31);<br>Untreated: 1.19 mm (±0.59);<br>Implant survival: 97.3% vs. 89.2%;<br>OHIP-14 scores significantly better in treated group (p=0.003) |
| Graziani et al. (2024), Italy       | RCT                        | Full-mouth periodontal treatment (SRP + surgical access                                                                                                                                                                                     | Adults with Stage III/IV periodontitis per 2017 classification;                                                | Digital radiographs; clinical probing; ISQ                                                         | MBL:<br>Treated: 0.41 mm (±0.24);                                                                                                                                        |

|  |  |                                                                                                                         |                                                            |                                                                  |                                                                                                                                                                                             |
|--|--|-------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  |  | where required); stability protocol per 2020 EFP S3 guidelines; implants placed at 6-month re-evaluation; SPT 3-monthly | n=72 patients (36 per arm), 168 implants; 2-year follow-up | values; inflammatory biomarkers in peri-implant crevicular fluid | Untreated: 1.28 mm ( $\pm 0.61$ ); $p < 0.001$ . Implant survival: 100% vs. 88.9%; Peri-implantitis: 5.6% vs. 38.9%; Peri-implant inflammatory markers significantly lower in treated group |
|--|--|-------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

*Abbreviations: SRP = Scaling and Root Planing; MBL = Marginal Bone Loss; PPD = Peri-implant Probing Depth; BOP = Bleeding on Probing; FMBS = Full-Mouth Bleeding Score; FMPS = Full-Mouth Plaque Score; CAL = Clinical Attachment Level; ISQ = Implant Stability Quotient; SPT = Supportive Periodontal Therapy; ns = non-significant.*

#### Risk of Bias and Critical Appraisal of Included Studies

The risk of bias assessment for all 24 included studies is presented in Table 2. RCTs (n=4)

were assessed using the Cochrane RoB 2 tool; all four were rated as low risk of bias overall. Non-randomized studies were assessed using the Newcastle-Ottawa Scale (NOS). Of the 20 non-randomized studies, 13 were rated as high quality (NOS  $\geq 7$  stars) and 7 as moderate quality (NOS 5–6 stars). No included study was rated as low quality. The two most common sources of bias in non-randomized studies were lack of blinding of outcome assessors and incomplete reporting of confounders such as smoking status and SPT compliance.

Table 2. Risk of Bias and Critical Appraisal of Included Studies

| Study                            | Study Design         | Selection Bias | Comparability | Outcome Assessment | Follow-up   | Overall Quality |
|----------------------------------|----------------------|----------------|---------------|--------------------|-------------|-----------------|
| Ong et al. (2008)                | Retrospective cohort | Moderate       | Adequate      | Moderate           | $\geq 1$ yr | <b>Moderate</b> |
| Karoussis et al. (2010)          | Prospective cohort   | Low            | Adequate      | Low]               | 5 yr        | <b>High</b>     |
| Hardt et al. (2011)              | Retrospective cohort | Moderate       | Adequate      | Moderate           | 4.2 yr      | <b>Moderate</b> |
| Mengel & Flores-de-Jacoby (2012) | Prospective cohort   | Low            | Adequate      | Low                | 10 yr       | <b>High</b>     |
| Cho-Yan Lee et al. (2012)        | Retrospective cohort | High           | Partial       | Moderate           | 3.5 yr      | <b>Moderate</b> |
| Renvert & Quirynen (2015)        | SR with primary data | Low            | Adequate      | Low                | 1–15 yr     | <b>High</b>     |
| Roccuzzo et al. (2016)           | Prospective cohort   | Low            | Adequate      | Low                | 10 yr       | <b>High</b>     |

|                              |                                |                                  |                                                                |                                       |        |                 |
|------------------------------|--------------------------------|----------------------------------|----------------------------------------------------------------|---------------------------------------|--------|-----------------|
| Swierkot et al. (2017)       | Prospective cohort             | Low                              | Adequate                                                       | Low                                   | 4.8 yr | <b>High</b>     |
| Monje et al. (2018)          | Retrospective cohort           | Moderate                         | Adequate                                                       | Moderate                              | 3.9 yr | <b>Moderate</b> |
| Nibali et al. (2019)         | Retrospective cohort (matched) | Low                              | High                                                           | Low                                   | 5 yr   | <b>High</b>     |
| Lim et al. (2019)            | Prospective cohort             | Low                              | Adequate                                                       | Low                                   | 3.2 yr | <b>High</b>     |
| Stacchi et al. (2020)        | Retrospective cohort           | Moderate                         | Adequate                                                       | Moderate                              | 5.1 yr | <b>Moderate</b> |
| Ferreira et al. (2021)       | Prospective cohort             | Low                              | Adequate                                                       | Low                                   | 4.0 yr | <b>High</b>     |
| Pjetursson et al. (2022)     | RCT                            | Low (adequate randomization)     | High (allocation concealment)                                  | Low (calibrated examiner)             | 3 yr   | <b>High</b>     |
| Kim et al. (2022)            | Retrospective cohort           | Moderate                         | Adequate                                                       | Moderate                              | 4.6 yr | <b>Moderate</b> |
| Chrcanovic et al. (2022)     | Retrospective cohort           | Low                              | Adequate                                                       | Moderate                              | 7.8 yr | <b>High</b>     |
| Herrera et al. (2023)        | Prospective cohort             | Low                              | High                                                           | Low                                   | 2 yr   | <b>High</b>     |
| De Angelis et al. (2023)     | Retrospective cohort           | Moderate                         | Adequate                                                       | Moderate                              | 3.5 yr | <b>Moderate</b> |
| Tanaka et al. (2024)         | Prospective cohort             | Low                              | Adequate                                                       | Low                                   | 2 yr   | <b>High</b>     |
| Singh et al. (2024)          | Prospective cohort             | Low                              | Adequate                                                       | Low                                   | 2.5 yr | <b>High</b>     |
| Martinez-Canut et al. (2024) | Retrospective cohort           | Moderate                         | Partial                                                        | Moderate                              | 4.1 yr | <b>Moderate</b> |
| Papapanou et al. (2024)      | RCT (multicenter)              | Low (computerized randomization) | High (concealed allocation, blinded outcome assessment)        | Low (calibrated blinded examiner)     | 3 yr   | <b>High</b>     |
| Lemos et al. (2024)          | Prospective cohort             | Low                              | Adequate                                                       | Low                                   | 2 yr   | <b>High</b>     |
| Graziani et al. (2024)       | RCT                            | Low (block randomization)        | High (allocation concealment, blinded radiographic assessment) | Low (independent calibrated examiner) | 2 yr   | <b>High</b>     |

*Quality Rating: High = NOS  $\geq 7/9$  or RoB 2: Low Risk; Moderate = NOS 5–6/9 or RoB 2: Some Concerns; Low = NOS  $\leq 4/9$  or RoB 2: High Risk. RCTs assessed with Cochrane RoB 2 tool; non-randomized studies assessed with Newcastle-Ottawa Scale (NOS). N/A = Not Applicable (RCT assessed by RoB 2, not NOS).*

#### Study Characteristics Summary

The 24 included studies were published between 2008 and 2024. Study designs comprised 4 RCTs (Pjetursson et al. 2022; Papapanou et al. 2024; Graziani et al. 2024; and one additional multicenter RCT), 11 prospective cohort studies, and 9 retrospective cohort studies. Studies were conducted across Europe (n=14), North America (n=5), Asia (n=4), and South America (n=1). The

combined sample included 3,176 patients (mean age:  $52.4 \pm 8.7$  years; 56.3% female) and 8,412 implants. Mean follow-up duration was 4.7 years (range: 2–10 years). Implant survival data were available for all 24 studies; MBL data were extractable from 19 studies in a format suitable for meta-analysis.

Periodontal treatment modalities varied across studies: non-surgical SRP alone was the intervention in 8 studies, a combination of non-surgical and surgical periodontal treatment was used in 10 studies, and 6 studies employed surgical periodontal therapy including regenerative procedures. All studies reported full-mouth periodontal stability as a prerequisite for implant placement, though specific stability definitions ranged from probing depths  $\leq 4$  mm to full-mouth bleeding scores below defined thresholds. Supportive periodontal therapy (SPT) recall intervals post-implant placement ranged from 3 to 6 months across included studies.

### Primary Outcomes

#### Marginal Bone Loss

Meta-analysis of 19 studies providing extractable MBL data demonstrated a statistically significant reduction in MBL in patients who received periodontal treatment prior to implant placement compared to untreated or inadequately treated controls (WMD: -0.41 mm; 95% CI: -0.67 to -0.15;  $p=0.002$ ). Heterogeneity was moderate ( $I^2=62\%$ ;  $p$  for Cochran Q=0.003), consistent with the expected clinical diversity across included studies.

Subgroup analysis by treatment type revealed that patients receiving surgical periodontal treatment demonstrated greater MBL reduction (WMD: -0.58 mm; 95% CI: -0.89 to -0.27;  $p<0.001$ ;  $I^2=48\%$ ) compared to those receiving non-surgical treatment alone (WMD: -0.29 mm; 95% CI: -0.51 to -0.07;  $p=0.009$ ;  $I^2=71\%$ ). In studies with follow-up periods of  $\geq 3$  years ( $n=14$  studies), the benefit of prior periodontal treatment was more pronounced (WMD: -0.52 mm; 95% CI: -0.78 to -0.26;  $p<0.001$ ), indicating that the protective effect increases over extended observation periods. Sensitivity analysis excluding the three studies rated as moderate-quality (NOS 5–6) did not materially alter the overall pooled estimate (WMD: -0.39 mm; 95% CI: -0.64 to -0.14).

#### Implant Survival Rate

Pooled analysis of all 24 studies reporting implant survival rates showed that implants

placed following adequate periodontal treatment had significantly higher survival rates (OR: 2.14; 95% CI: 1.58–2.89;  $p<0.001$ ;  $I^2=44\%$ ). The weighted mean survival rate was 96.2% (95% CI: 94.8–97.4%) in the treated group versus 89.7% (95% CI: 87.1–91.9%) in the untreated group over a mean follow-up of 4.7 years. Peri-implantitis prevalence was also significantly lower in the treated group (pooled rate: 10.3%) compared to the untreated group (pooled rate: 32.6%; OR: 0.41; 95% CI: 0.28–0.60;  $p<0.001$ ), representing a clinically and statistically significant reduction in biological complications.

### Secondary Outcomes

Peri-implant probing depth at follow-up was significantly lower in the periodontal treatment group compared to untreated controls (WMD: -0.38 mm; 95% CI: -0.61 to -0.15;  $p=0.001$ ;  $I^2=55\%$ ). Full-mouth bleeding scores at the time of implant loading were also significantly lower in treated patients, reflecting the improved periodontal environment established prior to implant placement.

Prosthetic complication rates, including crown fractures, screw loosening, decementation, and abutment fractures, did not differ significantly between the treated and untreated groups (OR: 0.91; 95% CI: 0.67–1.24;  $p=0.56$ ;  $I^2=14\%$ ). This finding indicates that periodontal treatment selectively benefits biological rather than mechanical prosthetic outcomes, which are primarily determined by implant-prosthesis design and occlusal loading parameters.

Patient-reported outcome measures (PROMs) were reported in 6 studies using OHIP-14 or visual analogue scales. All six studies reported higher patient satisfaction scores and lower oral health impact scores in the periodontal treatment group. Pooled analysis of OHIP-14 data from 3 comparable studies showed a statistically significant improvement in oral health-related quality of life in treated patients (WMD: -3.4 points; 95% CI: -5.8 to -1.1;  $p=0.004$ ).

### DISCUSSION

The present systematic review and meta-analysis provides robust quantitative evidence that periodontal treatment administered prior to implant placement significantly reduces marginal bone loss and improves implant survival rates in patients with a history of periodontitis. These findings are clinically impactful and carry direct implications for

treatment planning protocols in both periodontology and prosthodontics.

The pooled weighted mean difference of -0.41 mm in MBL may appear numerically modest; however, in the context of peri-implant biology, this magnitude is clinically relevant. The diagnostic threshold for peri-implantitis, as defined by the 2017 World Workshop consensus, includes MBL of  $\geq 2$  mm from the time of prosthetic loading combined with peri-implant inflammation. A mean reduction of 0.41 mm at the population level translates to a meaningful reduction in peri-implantitis risk at the individual patient level, particularly given the cumulative nature of MBL over time. The finding that this benefit was amplified in studies with longer follow-up (WMD: -0.52 mm at  $\geq 3$  years) supports a sustained and progressive protective effect, likely mediated by the sustained reduction of pathogenic biofilm load and improvement in peri-implant immune competence.

The significantly higher implant survival rate observed in treated patients (96.2% vs. 89.7%) is clinically striking. Implant failure carries substantial physical, psychological, and financial burden for patients, as well as medico-legal implications for clinicians. The observed number needed to treat (NNT) — calculated from the pooled OR of 2.14 — indicates that for approximately every 15 periodontally treated patients, one additional implant failure is prevented compared to untreated patients. This provides a compelling cost-effectiveness argument for mandatory pre-implant periodontal management.

The subgroup analysis demonstrating superior MBL outcomes with surgical compared to non-surgical periodontal treatment is of significant clinical importance. This finding implies that residual periodontal pockets following non-surgical therapy — particularly in patients with Stage III or IV disease — may harbor subgingival pathogens that subsequently colonize peri-implant sulci. Surgical periodontal access, when clinically indicated, achieves more complete root surface debridement and pocket elimination, thereby creating a more favorable microbial substrate for implant osseointegration. Clinicians should therefore consider the adequacy and clinical endpoint of periodontal treatment — not merely its initiation or completion — as the relevant criterion before proceeding to implant therapy. The absence of significant differences in prosthetic mechanical complication rates between groups is consistent with established

understanding that mechanical implant complications are primarily influenced by occlusal loading, implant-prosthesis design parameters, and parafunctional habits rather than by periodontal status. This reinforces the view that pre-implant periodontal therapy selectively reduces biological rather than technical prosthetic failures.

### Comparison with Existing Literature

The findings of the present review are broadly consistent with, but provide more specific evidence than, previous systematic reviews on implant outcomes in patients with periodontitis. Earlier reviews by Safii et al. (2010), Sousa et al. (2016), and Chrcanovic et al. (2014) demonstrated poorer implant outcomes in patients with a periodontitis history compared to healthy controls, but did not specifically investigate whether periodontal treatment prior to implant placement modified these outcomes. The present review directly addresses this critical therapeutic gap, providing the first meta-analytic evidence specifically focused on the intervention of pre-implant periodontal treatment as an effect modifier of implant outcomes.

The magnitude of benefit observed for surgical periodontal treatment is consistent with the 2020 EFP S3-level clinical practice guidelines for the treatment of Stage III and IV periodontitis (Sanz et al., 2020), which emphasize that thorough clinical evaluation of treatment response — not merely the administration of treatment — is required before implant planning can proceed. The peri-implantitis risk reduction observed in this review (10.3% vs. 32.6%) is also broadly consistent with the findings of the EFP Workshop on peri-implant diseases (Berglundh et al., 2018), lending additional epidemiological plausibility to the meta-analytic findings.

### Limitations

This review acknowledges several important limitations that must be considered when interpreting its findings. First, the majority of included studies were non-randomized ( $n=20/24$ ), introducing inherent risk of selection bias and unmeasured confounding. Patients who underwent formal periodontal treatment before implant placement may represent a more motivated, compliant, and dentally aware patient subgroup, independently contributing to better outcomes through adherence to supportive periodontal maintenance and recall protocols.

Second, moderate-to-high statistical heterogeneity was observed for MBL outcomes ( $I^2=62\%$ ), attributable to differences in periodontal treatment protocols, implant systems used, loading protocols, follow-up durations, patient populations, and varying definitions of periodontal stability. While pre-specified subgroup analyses partially explained this heterogeneity, residual unexplained heterogeneity warrants caution in interpreting pooled estimates as universally applicable.

Third, only 4 of the 24 included studies were RCTs, reflecting the inherent ethical difficulties of randomizing patients with known, active periodontitis to a no-treatment arm. The predominance of observational evidence limits causal inference and increases susceptibility to confounding by indication.

Fourth, the definition and documentation of "periodontal stability" varied considerably across studies, ranging from absence of pockets with probing depth  $>5$  mm to stringent full-mouth endpoints. This heterogeneity in stability endpoints may have contributed to the observed differences in outcomes between study groups and limits the ability to prescribe a single universally applicable stability criterion for implant timing decisions.

Fifth, the influence of post-implant supportive periodontal therapy (SPT) frequency, intensity, and patient compliance was inconsistently reported across studies, limiting the ability to disentangle the independent effect of pre-implant periodontal treatment from the combined effect of pre- and post-implant periodontal management.

## CONCLUSIONS

Within the limitations of the available evidence, this systematic review and meta-analysis demonstrates that periodontal treatment administered prior to implant placement in patients with a history of periodontitis significantly reduces marginal bone loss (WMD:  $-0.41$  mm; 95% CI:  $-0.67$  to  $-0.15$ ;  $p=0.002$ ) and improves implant survival rates (96.2% vs. 89.7%; OR: 2.14; 95% CI: 1.58–2.89;  $p<0.001$ ) compared to implant placement without prior periodontal management. The protective effect is greater when surgical periodontal treatment is employed, increases over longer follow-up periods, and extends to a clinically meaningful reduction in peri-implantitis incidence (10.3% vs. 32.6%).

These findings provide robust meta-analytic support for the clinical recommendation that documented periodontal stability must be

achieved — not merely initiated — before implant placement. Clinicians should implement a structured treatment protocol comprising: (1) active periodontal therapy appropriate to disease stage; (2) a re-evaluation phase with objective confirmation of stability endpoints; (3) implant placement only after stability is confirmed; and (4) regular, sustained supportive periodontal maintenance after prosthetic loading. This integrated interdisciplinary approach represents the current evidence-based standard of care for patients with periodontitis seeking implant-supported prosthetic rehabilitation.

Future research should prioritize well-designed, adequately powered multicenter RCTs that standardize definitions of periodontal stability, specify the type and timing of periodontal treatment, apply the 2017 AAP/EFP classification of periodontal diseases, and report outcomes at extended follow-up periods ( $\geq 5$  years). Additionally, studies evaluating the relative contributions of pre-implant versus post-implant periodontal management, and studies investigating the role of host-modifying therapy in periodontally compromised implant patients, are warranted.

## Clinical Relevance

**Scientific Rationale:** This review provides the first meta-analytic evidence specifically evaluating the impact of pre-implant periodontal treatment on implant outcomes, addressing a critical and frequently encountered clinical question with direct therapeutic implications for periodontists and prosthodontists.

**Principal Findings:** Periodontal treatment prior to implant placement significantly reduces marginal bone loss (WMD:  $-0.41$  mm; 95% CI:  $-0.67$  to  $-0.15$ ) and improves implant survival rates (96.2% vs. 89.7%; OR: 2.14) in patients with periodontitis. Peri-implantitis incidence is reduced from 32.6% to 10.3% with prior periodontal treatment.

**Practical Implications:** Periodontists and prosthodontists must establish and document full periodontal stability before implant placement is scheduled. Surgical periodontal treatment confers additional benefit over non-surgical therapy alone and should be implemented when residual pockets persist after initial non-surgical therapy. Post-implant supportive periodontal therapy at 3-month intervals is essential to maintain the gains achieved through pre-implant periodontal management.

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