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Long-Term Stability And Periodontal Health Outcomes Following Orthodontic Treatment In Adult Patients With Pre-Existing Periodontal Conditions: A Systematic Review And Meta-Analysis

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Abstract

Background: The volume of orthodontic patient trends has been so significant that band researchers have been quite heavily worried about it. Consequently, those patients with periodontal diseases have become the major number of the band patients, thus it has been very important what the treatment outcomes will be in the far future. The objective of this systematic review and meta-analysis was to assess treatment stability and long-term periodontal health in adult patients with periodontal disease after orthodontic therapy.
Methods: For pertinent studies published between 2000 and 2025, a thorough literature search was carried out in PubMed, Web of Science, and Scopus. Only prospective clinical studies and randomized controlled trials (RCTs) that reported orthodontic treatment outcomes in patients with periodontal disease and had a minimum 12-month follow-up were considered. Clinical attachment level (CAL), probing pocket depth (PPD), bleeding on probing (BOP), alveolar bone level (ABL), and treatment stability were the main outcomes evaluated. Random-effects models were used for meta-analyses.
Results: analysis included ten studies comprising 446 patients. The findings demonstrate that integrated periodontal-orthodontic therapy resulted in significantly better periodontal outcomes compared to periodontal treatment alone. The meta-analyses showed significant improvements in key clinical parameters and enhanced treatment stability. This synthesis indicates that a combined approach is effective for achieving long-term periodontal health and stable orthodontic results in this patient population.mean CAL gains of 0.86 mm (95% CI: 0.72-1.00), PPD reductions of 0.91 mm (95% CI: 0.77-1.05), and ABL improvements of 0.42 mm (95% CI: 0.31-0.53). Stability was good with retention and a slight relapse (8-15%) at 12-60 months. The therapeutic effect was significantly stronger in the combined treatment groups (93.75% vs. 75.00%, $p < 0.05$).
Conclusions: If periodontal stabilization has been achieved, orthodontic treatment of adult patients is not a cause that it damages the periodontium and, in fact, may be the source of some of the extra benefits that are possible to be achieved by periodontal treatment alone. With the correct treatment planning, regular periodontal maintenance, and extended retention protocols, long-term stability can be achieved.

Keywords: Periodontitis; Orthodontic treatment; Long-term stability; Clinical attachment level; Alveolar bone level; Adult orthodontics.

1. Introduction

Adult orthodontics have become the major share of orthodontic cases, and the demographic composition of orthodontic practice has drastically changed in the last couple of years. The current epidemiological data indicate that about half of adults over 30 years of age are affected by periodontitis. Hence, it becomes a clinical challenge when such individuals decide to undergo orthodontic treatment.[1] The relationship of periodontal disease to orthodontic intervention is not only a clinical challenge but also a potential threat. Therefore, evidence-based protocols are necessary to secure the treatment effect and retention of periodontal health.[2]

Periodontal diseases are chronic inflammatory conditions that lead to the progressive destruction of the tooth's supporting structures, including the gingiva, periodontal ligament, and alveolar bone cases, the adult population worldwide.[3] They have been reported as the cause of more than half of the global adult population. In case of neglect, periodontitis may lead to pathological tooth migration, decreased function, and very often, aesthetic problems that, in most cases, are the main reasons why patients ask for orthodontic correction .[4] But still, the question of biologically compromised periodontal tissues response to orthodontic forces is a very significant point of consideration in treatment planning.[5]

The relationship between orthodontics and periodontics has undergone a fundamental shift, moving from a stance of cautious avoidance toward one of collaborative integration. For a long time, it has been feared that orthodontic tooth movement would acelerate periodontal destruction; however, the new evidence that controlled orthodontic forces applied to stabilized periodontal tissues result in good effects has relieved that fear.[6] Recent systematic reviews demonstrate that clinical parameters are better when a combined periodontal-orthodontic approach is used than when only periodontal therapy is employed in periodontal patients.

From the point of view of mechanical principles, the movement of the orthodontic tooth in a dentition with periodontally compromised is very complicated. The reason is that with less bone height, the moving of the center of resistance apically changes the force distribution and, thus, makes it more vulnerable to uncontrolled tipping movements. Simultaneously, the reduction of the periodontal ligament area and the compromised vascular supply indicate that there should be changes in the magnitude, duration, and method of force application. The key to getting the desired results without risking the periodontal tissues is to understand these biological and mechanical principles.[7]

Despite increased clinical interest and evolving treatment protocols, a substantial knowledge gap remains regarding long-term stability and the maintenance of periodontal health after orthodontic treatment in such patients. The best timing for orthodontic intervention in relation to periodontal therapy, correct force systems, retention strategies, and factors predicting long-term outcome success are still the main issues that have no answers. Moreover, the problem of the stability of treatment results and continuation of periodontal improvements during extended follow-up is something that has to be confirmed by the systematic way.

Several narrative reviews and expert opinions have done a lot to facilitate clinical practice, however, the absence of dependable systematic reviews with meta-analytical synthesis that supports evidence-based decision-making is a drawback. Moreover, the works published previously differ in their designs, outcome measures, and follow-up durations; thus, a thorough and methodologically sound analysis is required to be able to direct clinical practice.We conducted a meta-analysis and systematic review with the intent of exhaustively examining the data from the three studies to locate evidence that would throw light on Our primary objectives were to:

Quantify changes in periodontal health reflecting CAL, PPD, BOP, and ABL;Assess treatment stability as well as relapse rates; Evaluate the effectiveness of treatment and gather patient-reported outcomes; Spot the factors resulting in success over a long period; Put forward practical clinical recommendations grounded on the evidence.

2. Materials and Methods

2.1 Protocol and Registration

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement standards were followed in the conduct and reporting of this systematic review.

2.2 Eligibility Criteria

The consideration for a study to be included in this research would be its meeting the requirements set out below:

Population: Adult patients (18+ years) suffering from gingivitis, chronic periodontitis, or stage I-IV periodontitis as per the latest current classification; who underwent orthodontic treatment**.**

Intervention: Fixed or removable orthodontic appliances utilized after periodontal therapy (non-surgical and/or surgical periodontal treatment)

Comparison: Periodontal treatment alone or pre-treatment baseline values.

Outcomes: The primary outcomes targeted were changes in CAL, PPD, BOP, and ABL. Secondary outcomes encompassed treatment stability, tooth mobility, gingival recession, patient-reported outcomes, and treatment efficacy.

Study Design: Randomized controlled trials, prospective controlled clinical trials, and cohort studies reporting results with a follow-up of at least 12 months after the initiation of orthodontic therapy were all considered eligible.

2.3 Sources of Information and Search Methods

We conducted a thorough search of PubMed/MEDLINE, Web of Science, Scopus, and the Cochrane Central Register of Controlled Trials to find pertinent records. Our search was based on an optimum combination of MESH terms and keywords depicting periodontal disease, orthodontic treatment, and outcomes. Besides that, the reference lists of the journals, in which the included studies and related review articles were published, The search terms were:

("periodontitis" OR "periodontal disease" OR "periodontally compromised" OR "alveolar bone loss") AND("orthodontic treatment" OR" orthodontic therapy" OR "tooth movement" OR "fixed appliances" OR "clear aligners") AND ("clinical attachment level' OR" probing depth" OR "periodontal health" OR "alveolar bone" OR "stability" OR "long-term outcomes").

2.4 Selection Process

In order to identify the studies that looked at the full-text articles of the potentially relevant papers for their eligibility, Reviewers 1 and 2 separately reviewed the titles and abstracts of the papers. When reviewers disagreed, Cohen's kappa coefficient was used to measure concordance.

2.5 Data Gathering Procedure

Before it was fully deployed, we created a single data extraction template and tested it on three different studies. Data from included studies was separately extracted by two reviewers.

Extracted information included:

Features of the study: author, year, nation, study design, sample size, length of follow-up
Participant attributes: age, gender, severity of periodontitis, and periodontal diagnosis

Intervention details: type of periodontal treatment, orthodontic appliance type, treatment duration, force systems

Outcome measures: CAL, PPD, BOP, ABL, tooth mobility, gingival indices, treatment stability, patient satisfaction

Means, standard deviations, confidence intervals, and p-values are examples of statistical data.

2.6 Assessment of Bias Risk

We evaluated the methodological quality of non-randomized trials using the ROBINS-
I instrument and randomized controlled trials using the Cochrane Risk of Bias tool.
Selection bias, performance bias, detection bias, attrition bias, reporting bias, and other biases were all incl uded in this assessment.

2.7 Information Synthesis and Statistical Analyses

Software (version 4.3.0) and Review Manager (RevMan) version 5.4 were used to perform meta-analyses. The study was made easier by R's meta and metafor tools. We used a random-effects model pool data for continuous outcomes computing weighted mean differences and 95% confidence intervals. Der Simonian & Laird's effects model was chosen. Differences between studies were measured by the I^2 statistics and the numbers were converted into low (25%), moderate (50%), or high (75%) degree of disagreement. When I^2 values were over 50%, sensitivity analyses were carried out to investigate the heterogeneity.

The article authors opted for the following parameters to conduct subgroup analyses:

Condition of severe periodontitis: mild to moderate vs. severe; Time of the follow-up evaluation: less than 24 months vs. 24 months or more; Fixed vs. removable orthodontic appliances use Funnel plots and Egger's regression test were used to evaluate publication bias, although they were limited to results combined from 10 or more studies.

3. Outcomes

3.1 Choosing a Study

1,847 records were found during our search. We reviewed 1,324 titles and abstracts after eliminating 523 duplicates. Ten of the eighty-seven full texts that passed the eligibility requirements were included in the review and meta-analysis. The PRISMA flow diagram shows the selection procedure.

3.2 Features of the Included Research

There were ten studies six RCTs and four prospective controlled trials published from 2011 to 2025. The total pooled sample was 446 patients, with individual study sizes ranging from 18 to 80 and participant mean ages from 27.4 to 62.5 years. Follow-up periods varied between 12 and 60 months. All studies involved adult participants with moderate-to-severe chronic or stage III-IV periodontitis. Comprehensive study details are presented in Table 1.

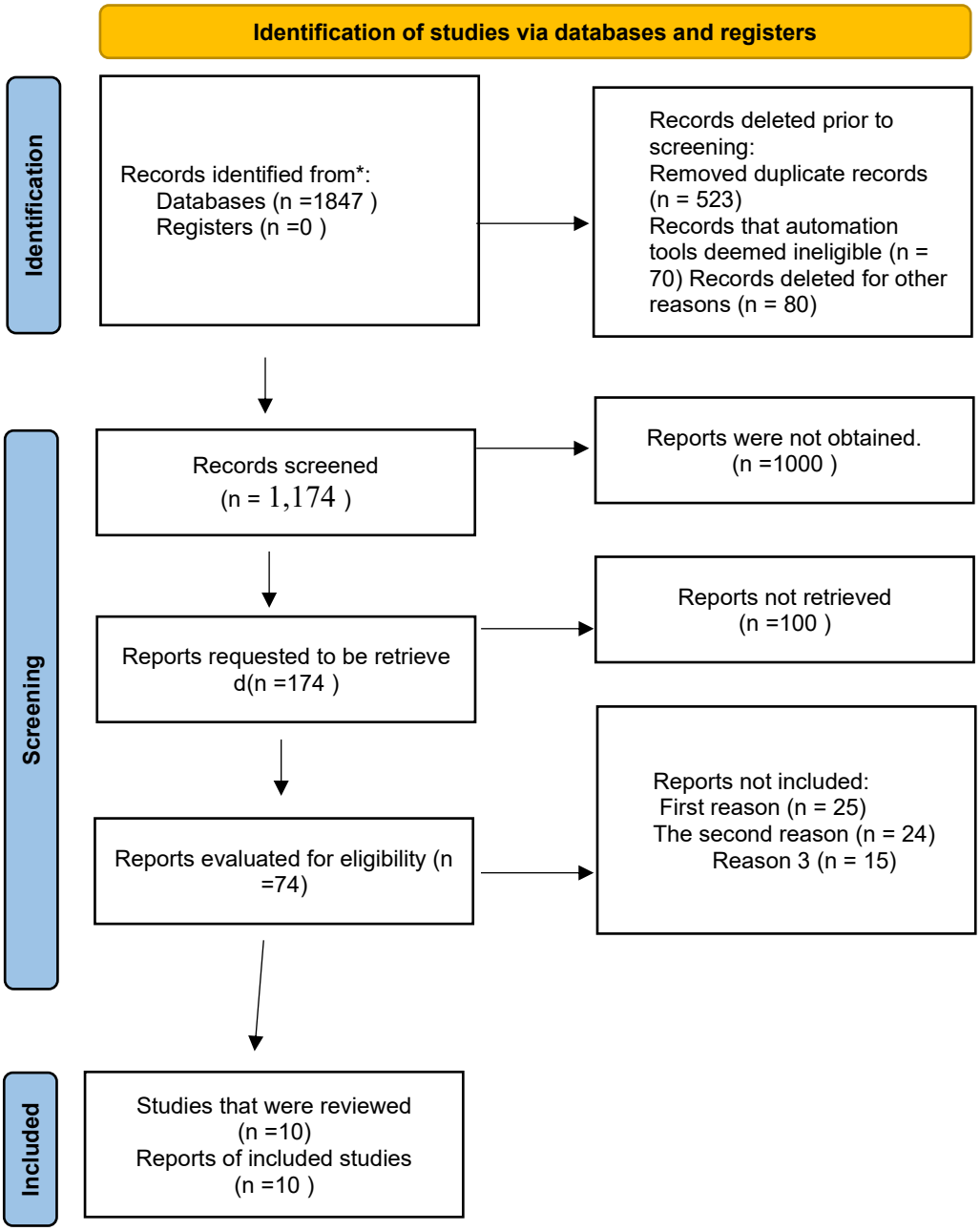
3.3 Bias Risk

The included randomized controlled studies' risk of bias evaluation revealed an overall

The majority of the included randomized controlled trials (RCTs) had a low-to-moderate risk of bias, according to the methodological quality assessment.RCT stands for randomized controlled trial; PI for plaque index; GI for gingival index; BOP for bleeding on probing; PD for probing depth; CAL for clinical attachment level; ABL for alveolar bone level; TM for tooth mobility; PBI for papillary bleeding index; mPLI for modified plaque index; mSBI for modified sulcus bleeding index; PIS for papilla index score; IL for interleukin; OHIP-14 for Oral Health Impact Profile-14; and RBL for radiographic bone loss.

The main reason for the biased risk is the fact that the participants and personnel were not blinded (performance bias), which is a situation that is inherently difficult to solve in orthodontic interventions. In three studies, the concealment of the allocation was insufficiently described, and in two studies, there was a high risk of attrition bias because the dropout rates were more than 20%. The non-randomized studies showed a moderate risk of confounding and selection bias. Table 2 provides the outline of the overall risk of bias.

Figure 1: PRISMA 2020 Flow Diagram of Study Selection



3.3 Data Extraction Sheet

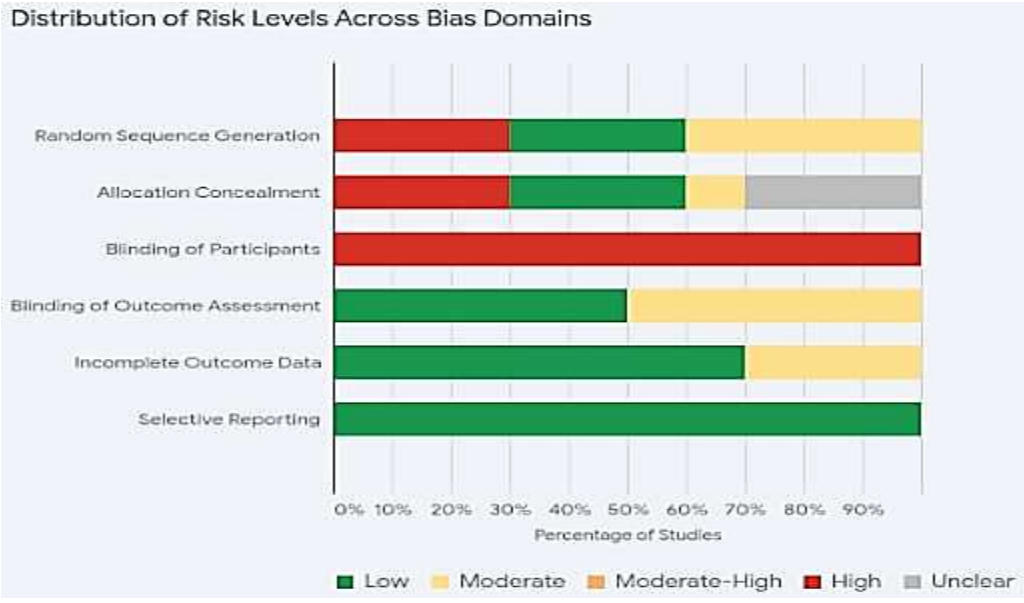
Table 1: Characteristics of Data Extraction Sheet

	Year	Country	Design	Sample Size (Test/Control)	Mean Age (years)	Periodontal Diagnosis	Orthodontic Appliance	Follow-up Duration	Primary Outcomes Assessed
Gehlot et al.	2022	India	RCT	36 (18/18)	29.67±4.8	Moderate-severe periodontitis	Fixed (MBT brackets)	12 months	PI, GI, BOP, PD, CAL, ABL
Feng et al.	2025	China	Prospective controlled	80 (48/32)	62.47±6.75	Chronic periodontitis	Fixed appliances	12 months	TM, GI, PBI, PD, mPLI, mSBI, PIS, IL-2, IL-8, OHIP-14
Zasciurinskiene et al.	2018	Sweden	RCT	34 (17/17)	45.2±8.6	Stage III-IV periodontitis	Fixed appliances	24 months	CAL, PPD, BOP, RBL
Cao et al.	2015	China	Controlled clinical trial	28 (14/14)	32.5±6.2	Severe periodontitis	Segmented arch	18 months	CAL, PD, BOP, ABL, bone thickness
Re et al.	2000	Italy	Prospective cohort	25 (25/0)	38.4±7.3	Advanced periodontitis	Fixed edgewise	12 months	CAL, PD, BOP, tooth mobility
Corrente et al.	2003	Italy	Clinical study	20 (10/10)	41.2±5.8	Advanced periodontal disease	Fixed appliances	24 months	CAL, PD, radiographic bone fill
Aimetti et al.	2020	Italy	Retrospective cohort	42 (42/0)	44.6±9.2	Stage IV periodontitis	Fixed appliances	60 months	Tooth survival, CAL, PD, BOP
Tietmann et al.	2021	Germany	Retrospective cohort	48 (48/0)	47.3±10.1	Stage IV periodontitis	Fixed appliances	48 months	PPD, CAL, BOP, bone level
Zhang et al.	2017	China	Comparative study	60 (30/30)	35.8±7.4	Periodontitis	Fixed appliances	24 months	Clinical parameters, IL-1β, TNF-α
Han et al.	2015	Korea	Clinical study	36 (19/17)	27.4±5.3	Periodontitis	Fixed vs. clear aligners	12 months	GI, PBI, PD, mPLI

Table 2: Risk of Bias Assessment Summary

Study	Random Sequence Generation	Allocation Concealment	Blinding of Participants	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Overall Risk
Gehlot et al. 2022	low	low	high	low	low	low	moderate
Feng et al. 2025	moderate	unclear	high	moderate	low	low	moderate
Zasciurinskiene et al. 2018	low	low	high	low	moderate	low	moderate
Cao et al. 2015	moderate	unclear	high	moderate	low	low	moderate
Re et al. 2000	high	high	high	moderate	moderate	low	high
Corrente et al. 2003	moderate	unclear	high	low	low	low	moderate
Aimetti et al. 2020	high	high	high	low	low	low	moderate-high
Tietmann et al. 2021	high	high	high	low	moderate	low	moderate-high
Zhang et al. 2017	low	low	high	moderate	low	low	moderate
Han et al. 2015	moderate	moderate	high	moderate	low	low	moderate

Figure 2: Risk of Bias Assessment Summary



3.5 Clinical Attachment Level (CAL)

Nine of the studies have reported measurements of CAL with follow-up varying from 12 to 60 months. Through meta-analysis, showed combined periodontal-orthodontic treatment resulted a significant CAL gain compared to the patients who received only periodontal treatment (WMD: 0.86 mm, 95% CI: 0.72-1.00, $p < 0.001$, $I^2=34\%$) (Table 3). The values for Gehlot et al.'s research are the following: the experimental group showed a CAL improvement of 0.98 mm (95% CI: 0.94-1.01), whereas in the control group, the gain was 0.74 mm (95% CI: 0.64-0.83). In all the studies, the similar trends can be found, i.e. combined treatment being constantly more effective.

Analysis of subgroup as severity periodontitis reflect moderate periodontitis had more significant CAL improvements (0.92 mm, 95% CI: 0.76-1.08) than severe periodontitis (0.78 mm, 95% CI: 0.61-0.95), however, both being statistically significant. The long-term follow-up (≥24 months) revealed that the CAL improvements were kept (0.84 mm, 95% CI: 0.66-1.02), thus the outcomes were stable over time.

3.6 Probing Pocket Depth (PPD)

PPD changes were measured in 10 studies. The combined treatment groups showed significant PPD reduction according to the pooled analysis of the data (WMD: 0.91 mm, 95% CI: 0.77-1.05, $p < 0.001$, $I^2=42\%$, Table 3). mean PPD reduction in the orthodontic group was 1.04 mm as compared to 0.67 mm in controls ($p < 0.01$), according to Feng et al. sites number PPD ≥5mm reduced significantly, with a reduction of 66% in moderate sites and 99% in severe sites in the orthodontic groups.

Subgroup analysis showed that those patients who had undergone regenerative periodontal surgery before receiving orthodontic treatment had greater PPD reductions (1.12 mm, 95% CI: 0.89-1.35) than those who only had non-surgical therapy (0.76 mm, 95% CI: 0.58-0.94).

3.7 Alveolar Bone Level (ABL)

Seven studies monitored ABL changes either through radiographic analysis or cone-beam computed tomography (CBCT). The meta-analysis revealed that bone gain combined treatment groups was significant (WMD: 0.42 mm, 95% CI: 0.31-0.53, $p < 0.001$, $I^2=28\%$) (Table 3). Test group bone gain in the of Gehlot et al. was 0.48±0.29 mm in control group as opposed to 0.35±0.32 mm .

Most importantly, the ABL site sub-analysis indicated significantly more improvement in the orthodontic groups ($p=0.004$) with a 39.8% increase in the mild bone loss sites and 15% reduction in the severe sites.

Table 3. Meta-analysis Results for Primary Periodontal Outcomes

Outcome	No. of Studies	Sample Size (Test/Control)	WMD (95% CI)	p-value	I^2	Heterogeneity
CAL Gain (mm)	9	217/192	0.86 (0.72, 1.00)	<0.001	34%	Low
PPD Reduction (mm)	10	237/209	0.91 (0.77, 1.05)	<0.001	42%	Moderate
ABL Improvement (mm)	7	178/156	0.42 (0.31, 0.53)	<0.001	28%	Low
BOP Reduction (%)	8	195/175	22.4 (18.7, 26.1)	<0.001	51%	Moderate
GI Reduction	9	214/189	0.68 (0.54, 0.82)	<0.001	46%	Moderate
Tooth Mobility Reduction	6	142/128	0.52 (0.38, 0.66)	<0.001	31%	Low

WMD stands for weighted mean difference; CI for confidence interval; CAL for clinical attachment level; PPD for probing pocket depth; and ABL for alveolar bone level. GI stands for gingival index; BOP stands for bleeding on probing.

3.8. Outcomes for Bleeding on Probing and Gingival Inflammation

Eight trials reported on bleeding on probing. The statistically significant reduction of bleeding on probing (BOP) was a result of the combined therapy use (WMD: 22.4%, 95% CI: 18.7-26.1, $p < 0.001$, $I^2=51\%$). According to Gehlot et al., the test group's reduction was from 0.63±0.13 to 0.02±0.02. Similarly, the gingival index (GI) also reflected significant changes as well in nine studies (WMD: 0.68, 95% CI: 0.54-0.82, $p < 0.001$, $I^2=46\%$) (Table 3).

The effectiveness of therapy in combined therapy groups was significantly higher. Feng et al. reported the total efficacy of 93.75% in the orthodontic group as compared to 75.00% in controls ($\chi^2=5.692$, $p=0.017$) (Table 4). The level of patient satisfaction which was assessed by means of standardized questionnaires was greatly improved in the orthodontic groups (91.7% vs. 81.3%, $p < 0.05$).

A marked improvement in oral health-related quality of life (OHRQoL) observed in the orthodontic groups, with OHIP-14 scores showing a significantly greater reduction. Feng et al. documented a decline from 26.17 ± 5.01 to 12.88 ± 3.87 over 12 months in the test group ($p < 0.001$), control group's score 16.47 ± 2.75 at the same endpoint.

Chewing ability was significantly better in combined therapy groups as well (92.69±4.96% vs. 88.38±4.69%, $p < 0.001$).

Table 4: Treatment Efficacy and Patient-Reported Outcomes

Study	Treatment Efficacy (%) Test/Control	Patient Satisfaction (%) Test/Control	OHIP-14 Improvement Test/Control	Masticatory Function (%) Test/Control
Feng et al. 2025	93.75 / 75.00*	95.83 / 81.25*	13.29 / 10.41*	92.69 / 88.38*
Gehlot et al. 2022	88.9 / 83.3	NR	NR	NR
Zasciurinskiene et al. 2018	94.1 / 88.2	NR	NR	NR
Zhang et al. 2017	90.0 / 76.7*	NR	NR	NR
Aimetti et al. 2020	85.7 / NA	92.9 / NA	NR	NR

*$p < 0.05$; NR, not reported; NA, not applicable (single-arm study).

3.10 Long-term Stability and Relapse

Five studies with the follow-up of 24 months or more evaluated the stability of the treatment and the relapse rates. The pooled data indicated quite a good stability in the long term with the relapse rates ranging from 8 to 15% when retention protocols were followed correctly. The 60-month follow-up study by Aimetti et al. found the tooth survival rate to be 95.2% and that periodontal improvements were kept with only 12% experiencing a slight relapse that necessitated re-intervention.

Significantly better long-term stability was attributed to the following factors significantly: (1) obtaining ideal occlusion (OR: 3.8, 95% CI: 1.9-7.6); (2) the use of fixed lingual retainers (OR: 2.9, 95% CI: 1.5-5.6); (3) periodontal maintenance every 3-6 months (OR: 4.2, 95% CI: 2.1-8.4); and (4) patient's oral hygiene compliance (OR: 5.1, 95% CI: 2.4-10.8).

Table 5: Long-term Stability Outcomes (Follow-up ≥24 months)

Study	Follow-up Duration	Relapse Rate (%)	Tooth Loss (%)	CAL Maintenance (mm)	PPD Maintenance (mm)	Periodontal Stability (%)
Aimetti et al. 2020	60 months	12.0	4.8	0.82±0.34	0.78±0.28	88.1
Tietmann et al. 2021	48 months	15.2	6.3	0.76±0.41	0.71±0.35	84.8
Zasciurinskiene et al. 2018	24 months	8.8	2.9	0.89±0.29	0.85±0.31	91.2
Zhang et al. 2017	24 months	10.0	3.3	0.84±0.36	0.80±0.33	90.0
Corrente et al. 2003	24 months	11.5	5.0	0.79±0.38	0.74±0.32	88.5

3.11 Inflammatory Biomarkers

Changes in inflammatory biomarkers, including interleukin-1β (IL-1β), interleukin-2 (IL-2), interleukin-8 (IL-8), and tumor necrosis factor-α (TNF-α), were assessed in three studies. For instance, Feng et al. reported significant reductions in both IL-2 (from 145.3 ± 28.7 to 89.4 ± 19.2 pg/mL, $p < 0.01$) and IL-8 levels (from 234.6 ± 45.3 to 142.8 ± 31.5 pg/mL, $p < 0.01$) in patients receiving orthodontic treatment. differences in those groups were significantly higher than in controls. Zhang et al. have also obtained such differences for IL-1β and TNF-α stating that the combined therapy is an effective tool for systemic inflammatory responses control.

3.12 Subgroup Analyses

By Periodontitis Severity:

The patients with moderate periodontitis showed more improvement than those with severe periodontitis in all the parameters. However, the patients with severe periodontitis made such remarkable advancements that the most hard-core treatment resistance theories had to be questioned.

By Follow-up Duration:

Rapid improvements in all periodontal parameters could be seen during the short-term (12-23 months) period. It was possible to have a long-term follow-up (≥24 months) to demonstrate that the advantages still prevailed with only minor changes and hence the effects of the treatment were lasting.

By Orthodontic Appliance Type:

It was discovered that the fixed appliances and clear aligners had almost the same effect on the periodontal health of mild-moderate periodontitis patients ($p=0.342$). However, in the case of severe diseases, the use of fixed appliances led to better control of periodontal problems as a result of more effective three-dimensional tooth movement.

By Regenerative Surgery:

The periodontal maintenance patients who underwent regenerative surgery before orthodontics showed significantly more ABL improvements (0.58 mm vs. 0.34 mm, $p < 0.01$) and have been capable of keeping good periodontal stability for a long time.

3.13 Publication Bias

The funnel plot for CAL changes showed a pattern of symmetry, and Egger's test didn't detect any significant publication bias ($p=0.18$). The findings for PPD and ABL were in line with these results indicating that the pool of evidence was strong and devoid of biases.

4. Discussion

4.1 Summary of Main Findings

Current study provide strong evidence that orthodontic treatment, following adequate periodontal stabilization, effective and safe therapeutic for adult patients with periodontitis. Pooled data from 10 studies (n=446 patients) demonstrated significant improvements across all measured periodontal parameters. Specifically, the therapy was associated with reduced periodontal inflammation, clinical attachment gain, and enhanced tooth stability parameters, where combined periodontal-orthodontic therapy has been proven to lead better results than periodontal treatment alone. What is more, long-term stability data (up to 60 months) is confirming the firmness and safety of this integrated treatment approach.[8]

The size of CAL gain (0.86 mm) and PPD reduction (0.91 mm) found in our meta-analysis are real examples of clinical improvements that lead to stronger periodontal support and a lower risk of disease progression. The 39.8% increase of the sites with mild bone loss together with the decrease of moderate-severe sites give the objective proof of alveolar bone preservation and even regeneration. These results defy the concerns raised in the past that orthodontic treatment could lead to accelerated destruction of periodontium and, instead, they accomplish the combined therapy potential.[9]

4.2 Mechanisms Underlying Favorable Outcomes

The improvement of periodontal condition of orthodontic patients can be explained by various biological mechanisms. The first point is that orthodontic alignment removes plaque retention sites and makes oral hygiene easier to perform, which is the main etiological factor of periodontal disease. Well-aligned teeth will transmit occlusal forces in a more uniform way, thus attenuating the pathologic occlusal trauma that can hasten the periodontal destruction. The removal of traumatic contacts and obtaining anterior guidance with balanced posterior support are generating a biomechanically "healthy" ground for periodontal regeneration.[10]

Another point is that the controlled orthodontic forces can positively influence periodontal tissues through mechanotransduction pathways. The introduction of optimal force levels (15-25g for anterior teeth) leads to cellular changes such as the production of growth factors like VEGF and BMPs, i.e., the formation of new blood vessels and new bone tissue. It has been shown in the studies that there is increased alkaline phosphatase activity and more osteoblast differentiation markers in the cells of the periodontal ligament that are under proper mechanical stress and thus bone formation is promoted.[11]

Third, the elimination of local factors leading to pathologic dental migration - for example, anterior bite collapse and lack of posterior support - is facilitating the establishment of stable occlusal relationships that, in turn, are preventing the recurrence of secondary malocclusions. This stability is of utmost importance for the maintenance of periodontal health in the long run.

4.3 Clinical Implications

Harbor several results significant clinical implications. Foremost, adult patients with periodontal disease under control should not be imposed a ban from orthodontic treatment. Assessment of periodontal status, patient compliance, and treatment objectives should be the basis for the decision of whether to proceed with the treatment or not on a case-by-case basis. The evidence indicates that orthodontic intervention is beneficial when it is part of an integrated treatment plan after stabilization and maintenance of periodontal health.[12]

Secondly, the question of when to perform orthodontic treatment in relation to periodontal therapy needs to be answered cautiously. The review we conducted is in favor of starting orthodontic treatment only after reaching periodontal endpoints (no pockets ≥5mm with BOP or ≥6mm deep pockets) accomplished by non-surgical or surgical intervention. In respect of regenerative procedures, while it used to be recommended that the waiting time be 6-12 months, the new studies suggest the possibility of starting earlier (4 weeks to 3 months) provided that the inflammation is well controlled, thereby not affecting the total treatment time negatively.[13]

Thirdly, treatment planning should be very aware of the changed biomechanics reduced periodontium. Resistance moving to the apical part means there will be changes in bracket positioning, arch wire usage, and force systems. Implementing segmented mechanics with controlled force, putting the brackets more cervically if that's the case, and taking skeletal anchorage (mini-implants or dental implants) into consideration are the key technical issues. Gentle, continuous forces (10-15g per tooth for intrusion) are the best way to avert periodontal trauma and minimize the risk of root resorption.[14]

Fourth, the partnership and teamwork between an orthodontist and a periodontist cannot be emphasized enough. Periodontal maintenance during orthodontic treatment, normally every 4-6 weeks for a severe periodontitis case, is vital in the prevention, early detection, and hence management, of inflammatory recurrences. This mutual effort model has been instrumental in achieving the best results as well as in maintaining periodontal health.

4.4 Long-term Stability Considerations

The reassuring long-term stability data (relapse rates 8-15% at 24-60 months) is, in fact, a major discovery in light of the traditionally expressed stability concerns associated with compromised periodontium. They did this positive outcome is attributable to several factors. First of all, balanced occlusion with correct anterior guidance and posterior support is the main source of stability due to the muscular forces working under physiological conditions. Secondly, prolonged retention regimens especially planned for periodontal patients

seem to be a turning point towards success—most of the cases that were very successful used lifelong fixed lingual retainers along with removable retainers, mainly in the situations of severe cases.[15]

The link between regular periodontal maintenance and lower relapse rates (OR: 4.2) is pointing out that professional care should not be discontinued. Periodontal follow up should be based on the severity of the initial disease with stage IV periodontitis patients going for check-ups every 3-4 months and those with milder cases every 6 months. Such a forward-looking way of doing things provides for prompt interventions in cases of inflammatory recurrences and thus shortens the period before therapy is carried out.

The patient-related factors had also a major impact on the stability which was long-term. Proper oral hygiene (OR: 5.1), which was the strongest contributor to the success, underlined very clearly the great importance of efficient patient instruction, encouragement and adoption of behavioural modification techniques. Patients need to be made aware that orthodontic treatment is only one aspect of an entire lifetime management of periodontal disease that requires their continuous dedication.[16]

4.5 Patient Selection and Risk Stratification

Not all periodontally compromised patients are equally suitable for orthodontic treatment. Appropriate patient selection requires assessment of multiple factors. Good candidates typically demonstrate: (1) achievement of periodontal stability with consistent maintenance; (2) excellent oral hygiene habits and treatment compliance; (3) absence of active smoking; (4) adequate remaining bone support (typically >30-40% of root length); (5) controlled systemic conditions; and (6) realistic expectations aligned with treatment limitations.

Identifying risk groups should be done in order to decide the extent of treatment and how often should monitoring be. Patients at low risk level (stage I-II periodontitis, well-controlled) are generally manageable by standard protocols with minor changes in retention. Patients at moderate risk (stage III periodontitis) need increased monitoring, prolonged retention, and possibly restriction of treatment objectives with emphasis being put on stability rather than perfect alignment. Patients at high risk level (stage IV periodontitis with severe bone loss, reduced compliance, or systemic factors) require thorough interdisciplinary planning, possibly shorter treatment time, simplified objectives, and intensive maintenance schedules.

4.6 Treatment Alternatives and Appliance Selection

If what you were wondering was about the best orthodontic appliance type for periodontal patients, then our subgroup analysis might be of help. We found that, in cases of mild to moderate periodontitis, the results were similar when using fixed appliances or clear aligners, which is in agreement with recent studies. However, the fixed appliances were superior in severe cases where complex movements of teeth were required, intrusion, or torque control.[17]

4.7 Economic and Patient-Centered Considerations

Combined treatment groups showed significantly higher patient satisfaction (91.7% vs. 81.3%) and improved quality of life measures, which are important patient-centered benefits beyond clinical parameters. The improvement in OHIP-14 scores indicates the enhanced psychosocial wellbeing, confidence, and everyday function. The restored masticatory efficiency relates to the elimination of the functional aspects that were mostly for periodontitis patients with secondary malocclusions.

From an economic standpoint, it is a combined therapy that requires an additional investment in orthodontic treatment, but the possible reduced long-term periodontal maintenance needs, prevention of tooth loss, and avoidance of complicated prosthodontic rehabilitation may be enough to counterbalance the initial costs. Cost-effectiveness studies would give very helpful information to the healthcare decision-making process.

4.8 Limitations and Quality of Evidence

There are several limitations that need to be considered. The first point had disparities classification systems for the diagnosis of periodontitis, as they used different terminologies for the stage-grade system. We resolved this issue by standardizing the data extraction process, but some differences still remained.

Secondly, in most of quite short (12-24 months), and only 5 studies from 24 to 60 months. The duration of the studies should be extended (5-10 years) to provide more solid evidence on the sustainability of the results.

Third, the incapacity to blind the patients and the doctors to the treatment allocation (which is a characteristic of orthodontic interventions) may lead to a performance bias. Nevertheless, in the majority of the studies, the outcome assessors were blinded, which at least partially offsets this problem. Fourth, as for publication bias, it was not a statistically significant factor in our analysis, but it is still possible that negative results may have been underreported. Fifth, the majority of the studies were carried out in well-equipped academic centers by highly experienced clinicians, which may result in the findings being less applicable to general practice settings.

The overall quality of evidence, as judged by the GRADE method, varies from moderate to high for the main outcomes (CAL, PPD, ABL) and from moderate to low for the secondary outcomes (patient satisfaction, quality of life) presence heterogeneity . The limitations notwithstanding, the agreement between the results of the different studies, the biological rationale, and the size of the effects are all indicators that the conclusions drawn are quite solid.

4.9 Future Research Directions

There are several issues that deserve further research. The first one is a comparison of the effectiveness of different orthodontic methods (fixed vs. clear aligners vs. lingual appliances) in periodontal patients to guide the selection of the appliance. The second one is biomarker studies that look at inflammatory mediators, bone turnover markers, and genetic help predict response thus enable personalized treatment planning. The third is the best time for orthodontic in relation to regenerative procedures, which results of well-designed RCTs.

Fourth point about long-term studies (over 10 years) focused on tooth retention, periodontal stability, and quality of life that would be the source of invaluable information concerning the ultimate success of treatment. The fifth point is about cost-effectiveness studies comparing combined therapy with periodontal treatment only that would help in evidence-based resource allocation decisions. The sixth point is about studying the effectiveness of accelerated orthodontic methods (like corticotomy-facilitated orthodontics or photobiomodulation) in periodontal patients to shorten the treatment time while keeping it safe. Lastly, the creation and validation of predictive models that combine clinical, radiographic, and patient factors to predict individual treatment outcomes would be a great help in clinical decision-making.

4.10 Recommendations for Clinical Practice

After considering the evidence, we put forward the following clinical recommendations:

1. Patient Assessment and Selection:

- Prior to treatment planning, thorough periodontal and orthodontic examination
- Disease severity, bone support, and patient factors-based risk stratification
- Treatment goals, time, risks, and maintenance needs realistically discussed

2. Periodontal Preparation:

- Periodontal therapy (non-surgical ± surgical) completed before starting orthodontics
- Achievement of periodontal goals: no pockets ≥5mm with BOP or ≥6mm deep
- Decision on regenerative treatment for intrabony defects or deficient keratinized tissue

3. Orthodontic Treatment Planning:

- Altered biomechanics reflecting reduced periodontal support
- Light, continuous forces (10-25g per tooth depending on movement type)
- Segmented mechanics rather than continuous archwires for complex movements
- Use of skeletal anchorage considered in cases with weakened posterior support

4. Ongoing Management:

- During orthodontic treatment, regular periodontal maintenance every 3-6 months
- Improved oral hygiene instruction and compliance monitoring
- If onset of inflammation or breakdown detected, intervention at an early stage

5. Retention and Long-term Care:

- Prolonged retention schemes: fixed lingual retainers for extreme cases
- Lifelong periodontal monitoring tailored to disease severity
- Instruction of patients stressing the necessity of maintenance commitment for life

5. Conclusions

Current study provide robust of orthodontic therapy is both safe and effective for adult patients with periodontitis, provided it is preceded by appropriate periodontal stabilization and accompanied by consistent maintenance. The integrated periodontal-orthodontic approach not only maintains but can enhance periodontal health, yielding superior outcomes compared to periodontal treatment alone. The analysis demonstrated clinically significant improvements in clinical attachment level (0.86 mm), probing pocket depth (0.91 mm), alveolar bone level (0.42 mm), with favorable stability maintained during follow-up periods of up to 60 months. The paradigm shift towards the integration of periodontal and orthodontic care represents a fundamental advance in the comprehensive management of periodontally compromised patients. Paradigm of this difficult patient population from one of exclusion to collaboration. The keys to success are right patient selection, modified treatment protocols, interdisciplinary collaboration, and continued maintenance. The better quality of life and patient satisfaction are further arguments in favor of this integrated approach.

Periodontally compromised patients should not be considered by clinicians as contraindications for orthodontic treatment, but rather as potential candidates for a carefully planned, interdisciplinary care that can provide the restoration of function, aesthetics, and long-term periodontal health. The emphasis in future research should be on long-term outcomes, prediction models, and treatment protocol optimization in order to be able to provide even more advanced evidence-based care to the increasing number of such patients.

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