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INFLUENCE OF CLEAR ALIGNERS ON ORAL HEALTH AND MICROBIAL COMPOSITION DURING ORTHODONTIC TREATMENT: A NARRATIVE REVIEW

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Abstract

Objective: To critically evaluate current evidence regarding the effects of clear aligner therapy on periodontal health, oral microbiome composition, biofilm formation, and caries risk compared with fixed orthodontic appliances.

Materials and Methods: A narrative review informed by a structured literature search was conducted in PubMed, Scopus, Web of Science, and CNKI (2015–2025). Eligible studies included randomized controlled trials, cohort studies, observational studies, systematic reviews, and microbiological investigations. A total of 165 studies were identified, and 35 met the criteria for qualitative narrative synthesis.

Results: Evidence indicates that clear aligners are generally associated with more favorable short- and medium-term periodontal and hygiene-related indices, including reduced plaque accumulation and mild improvements in gingival bleeding compared with fixed appliances. Microbiome analyses suggest that aligners maintain relatively stable microbial diversity, although mild increases in cariogenic species may occur under poor oral hygiene compliance. Biofilm formation can occur on thermoplastic surfaces due to salivary pellicle deposition and microabrasion. Fixed appliances demonstrate a stronger association with microbial dysbiosis and enamel demineralization.

Conclusions: Clear aligner therapy offers more favorable periodontal and hygiene-related indices compared with fixed orthodontic appliances; however, the long-term clinical significance of these differences remains modest. Furthermore, these biological benefits are not automatic and depend greatly on patient compliance, individualized risk assessment, specific appliance designs, and dedicated hygiene protocols.

Keywords: clear aligners; orthodontics; oral microbiome; biofilm; periodontal health; caries risk

INTRODUCTION

Malocclusion is one of the most prevalent dental conditions globally and represents a major concern in orthodontic and periodontal practice due to its functional, esthetic, and psychosocial consequences^{1,2}. Orthodontic treatment aims to correct these discrepancies by achieving functional occlusion, improving facial esthetics, and enhancing patient well-being³.

However, orthodontic intervention inevitably influences the oral ecological system. Any orthodontic appliance may disrupt microbial homeostasis, leading to increased plaque accumulation, shifts in bacterial composition, and a higher risk of gingival inflammation and enamel demineralization⁴.

Fixed orthodontic appliances create retentive niches that promote plaque accumulation and hinder effective oral hygiene. Clinical studies consistently report increased plaque index, gingival inflammation, bleeding on probing, and enamel demineralization in patients undergoing fixed appliance therapy⁵⁻⁷. These effects are mainly due to limited access for mechanical cleaning and enhanced bacterial colonization on orthodontic components⁸.

In contrast, clear aligners have emerged as an alternative orthodontic modality offering esthetic, functional, and biological advantages⁹⁻¹². Clear aligner systems such as Smartee and similar thermoplastic devices are removable and allow patients to maintain normal oral hygiene practices during treatment. Studies have demonstrated lower gingival inflammation and improved short-term

periodontal indices in patients treated with aligners, highlighting their favorable hygiene-related profile¹³⁻¹⁵.

Mechanistically, clear aligners introduce a distinct oral microenvironment. Unlike fixed appliances, aligners fully cover the dentition for approximately 18–22 hours per day, creating a sealed ecological niche. This continuous coverage may alter salivary flow dynamics, oxygen availability, and microbial adhesion patterns on tooth surfaces^{13,16,17}. Although aligners are removable, their prolonged wear time may still influence biofilm formation and microbial stability within the oral cavity¹⁴⁻¹⁸.

Recent microbiological studies indicate that clear aligners have a relatively neutral effect on overall oral microbiome diversity. However, minor shifts in bacterial composition may occur during early treatment phases, particularly in patients with suboptimal oral hygiene. Increased levels of cariogenic bacteria such as *Streptococcus mutans* have been observed under poor compliance conditions¹⁹. Compared with fixed appliances, aligners tend to maintain a more stable microbial environment with fewer dysbiotic changes^{20,21}.

Biofilm formation on aligner surfaces represents an important clinical consideration. Surface microabrasions caused by mechanical wear, combined with salivary protein deposition, facilitate bacterial colonization over time. If cleaning protocols are insufficient, aligners may act as reservoirs for both cariogenic and periodontopathogenic bacteria²².

From a clinical perspective, clear aligners are generally associated with more favorable periodontal and hygiene-related indices compared to fixed appliances. Reduced plaque accumulation, lower gingival inflammation, and decreased bleeding on probing have been noted in multiple short-term clinical studies^{23,24}. However, these biological benefits are highly conditional and depend greatly on patient behavior, wear time, and cleaning habits.

In terms of white spot lesions and enamel demineralization, fixed appliances are associated with a higher incidence due to prolonged plaque retention around brackets. In contrast, aligners reduce this risk by allowing effective oral hygiene practices^{22,25}. However, the risk of true caries incidence and enamel demineralization may still increase if patients consume fermentable carbohydrates or sugary beverages while wearing aligners, or if the presence of numerous attachments and auxiliaries compromises the self-cleansing capacity of the dentition^{13,25}.

Comparative evidence between aligners and fixed appliances demonstrates differences in periodontal and hygiene-related outcomes. Fixed appliances are

superior in managing complex orthodontic cases requiring precise tooth movement and torque control, whereas aligners provide advantages in esthetics, hygiene control, and patient comfort^{14,26}. Therefore, treatment selection should be individualized based on malocclusion severity, biological response, and patient compliance. Despite increasing clinical evidence, limitations remain in the current literature. Many studies are short-term, in vitro, or heavily dependent on indirect microbiological data rather than long-term clinical trials. Standardized methodologies are required to improve comparability and strengthen evidence quality.

Overall, clear aligners represent a significant advancement in orthodontic therapy, offering more favorable periodontal and hygiene-related indices compared with fixed appliances^{16,23}. However, their biological advantages are not automatic. In real clinical practice, aligner therapy becomes biologically favorable only when combined with robust patient education, strict cleaning protocols, and careful tracking of attachments or auxiliaries that can impede routine hygiene²⁷.

This narrative review aims to critically evaluate the current evidence—categorizing insights from clinical, microbiological, and in vitro models—regarding periodontal outcomes, oral microbiome changes, and biofilm formation associated with clear aligner therapy compared with fixed orthodontic appliances.

To facilitate understanding of the clinical environment discussed throughout this review, Figure 1 illustrates a representative intraoral view of a patient undergoing clear aligner therapy. The image demonstrates the presence of thermoplastic aligners and composite attachments that are commonly used to improve the predictability and control of orthodontic tooth movement. These auxiliary elements are clinically relevant because they may influence plaque retention, oral hygiene accessibility, and biofilm accumulation, which are central topics addressed in the present review.



Figure 1. Clinical intraoral photograph illustrating clear aligner therapy with composite attachments

2. MATERIALS AND METHODS

2.1 Study Design

This study is a narrative review conducted using a structured and transparent literature search approach to summarize current evidence on the effects of clear aligner therapy on periodontal health, oral microbiome composition, biofilm formation, and caries risk in comparison with fixed orthodontic appliances. The review was designed to synthesize existing scientific literature rather than to perform a strict systematic review or meta-analysis. To maintain methodological clarity, we avoid full PRISMA compliance framing to match its narrative identity, while preserving a structured search architecture.

2.2 Literature Search Strategy

A comprehensive electronic search was conducted in the PubMed, Scopus, Web of Science, and CNKI databases covering the period from January 2015 to August 2025. The following keywords and their combinations were used: clear aligners, attachments, orthodontic appliances, oral microbiome, periodontal health, biofilm formation, gingivitis, Streptococcus mutans, and caries risk. Boolean operators (AND, OR) were applied to refine the search strategy. Additionally, manual screening of reference lists from relevant studies was performed to identify further eligible publications.

2.3 Study Selection and Data Extraction

All identified records were screened based on title and abstract relevance. Full-text articles were then assessed for eligibility. A total of 165 studies were initially identified. After removal of duplicates and exclusion of irrelevant or non-eligible studies, 35 studies were included in the final qualitative narrative synthesis. This process was conducted to ensure comprehensive coverage of the literature while maintaining focus on clinically relevant evidence. Data were extracted and organized into predefined categories: periodontal parameters, oral microbiome composition changes, biofilm formation characteristics, and white spot lesions versus true caries incidence. Included papers were evaluated contextually according to their specific tier of evidence (e.g., separating direct clinical metrics from indirect in vitro or microbiological data). Formal meta-analytic quality scoring systems (e.g., Cochrane Risk of Bias tools) were not applied due to the narrative framework of this synthesis.

3. RESULTS

The included studies demonstrated notable variations in periodontal indices, microbial profiles, and demineralization risks between clear aligner therapy and conventional fixed orthodontic appliances. Most clinical investigations reported that removable aligner

systems were associated with more favorable short- and medium-term periodontal indices and reduced microbial dysbiosis during active treatment. In contrast, fixed appliances introduced complex, permanent plaque-retentive surfaces that promoted biofilm maturation and subsequent inflammatory changes.

3.1 Periodontal Health Outcomes (Clinical Evidence)

When distinguishing between different types of evidence, direct clinical trials demonstrate that patients treated with clear aligners, including systems such as Smartee, generally exhibit lower plaque indices, decreased gingival inflammation, and improved bleeding scores compared with patients undergoing fixed appliance therapy¹⁴.

Quantitative data from clinical studies demonstrate that patients treated with clear aligners show approximately 20–35% lower plaque index (PI) scores and 15–30% lower gingival index (GI) values compared with fixed appliance groups during the first 6–12 months of treatment. Several clinical trials also reported reduced bleeding on probing (BOP), with mean reductions ranging from 18% to 40% in aligner-treated patients. However, the long-term clinical significance of these differences remains modest, as long-term longitudinal studies show a narrowing gap between the two modalities as patients adapt over time. A comparative summary of periodontal outcomes is presented in Table 1.

Table 1. Comparison of periodontal outcomes between clear aligners and fixed appliances

Clinical Parameter	Clear Aligners	Fixed Appliances	Evidence Summary
Plaque Index (PI)	↓20–35%	Higher PI values	Multiple prospective studies
Gingival Index (GI)	↓15–30%	Higher GI values	Moderate evidence
Bleeding on Probing	Reduced	Increased	Consistent findings
Oral Hygiene Accessibility	Excellent	Limited	Strong consensus
White Spot Lesions	Lower prevalence	Higher prevalence (25–50%)	Clinical studies

3.2 Oral Microbiome and In Vitro Biofilm Changes (Microbiological & In Vitro Evidence)

Microbiological and in vitro studies provide a mechanistic look at the appliance environments. Fixed appliances are consistently linked to a higher pathogenic bacterial load, including Streptococcus mutans, Lactobacillus spp., Porphyromonas gingivalis, Prevotella intermedia, and Tannerella forsythia, showing significant

elevations within the first three months of therapy 8,16,20,28,29.

In contrast, clear aligner therapy demonstrates a more stable oral microbiome composition. While mild transient increases in cariogenic taxa such as *Streptococcus mutans* and *Actinomyces* spp. are occasionally observed in microbiological profiles during early treatment stages, these changes are less severe than those associated with fixed appliances and are heavily modulated by patient compliance and diet^{11,13,22,25}.

A detailed comparison of microbial changes is summarized in Table 2.

Table 2. Microbiological differences between aligners and fixed appliances

Microbiological Outcome	Clear Aligners	Fixed Appliances	Clinical Significance
Streptococcus mutans	Mild transient increase	Significant increase	Higher caries risk in fixed appliances
Lactobacillus spp.	Stable	Increased	Associated with acidic biofilm
Microbial Diversity	Preserved	Reduced	Less dysbiosis with aligners
Periodontal Pathogens	Limited increase	Marked increase	Greater periodontal inflammation

The mechanism of biofilm development is summarized in Table 3 (embedded conceptual synthesis).

Table 3. Factors influencing biofilm formation on clear aligners

Risk Factor	Mechanism	Clinical Consequence	Prevention Strategy
Extended wear time (>20 h/day)	Reduced salivary clearance	Biofilm accumulation	Regular cleaning
Surface micro-abrasions	Increased bacterial adhesion	Mature biofilm formation	Timely aligner replacement
Salivary pellicle formation	Protein deposition	Microbial colonization	Mechanical cleaning
Poor hygiene compliance	Plaque retention	Caries and gingivitis risk	Patient education

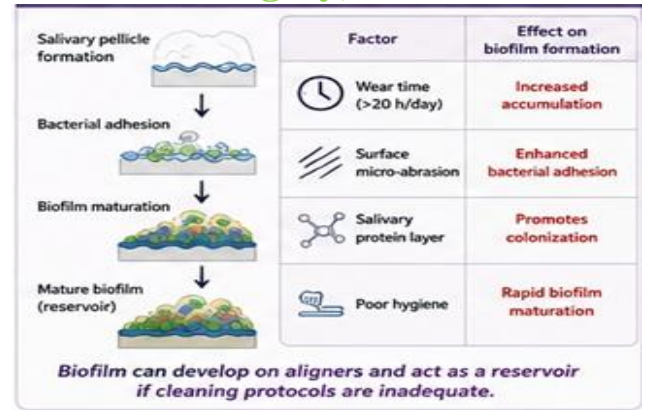


Figure 2. Factors influencing biofilm formation on clear aligners

3.3 White Spot Lesions vs. True Caries Incidence

A critical distinction must be made between enamel demineralization (white spot lesions) and true caries incidence. Clinical studies show that fixed appliances are more frequently associated with early enamel demineralization and white spot lesion formation around brackets, with a reported prevalence ranging from 25% to 50%^{17,21,23}.

Aligner-treated patients consistently demonstrate substantially lower rates of early white spot lesions due to the ability to remove the appliance for routine brushing and flossing^{17,21,23}.

However, true caries incidence between the two groups does not show as drastic a divergence. While aligners protect against general plaque accumulation, they can trap fermentable carbohydrates or sugary beverage residues against the enamel surface for 18–22 hours a day if patient compliance and dietary discipline are poor, potentially escalating a localized demineralization into true caries.

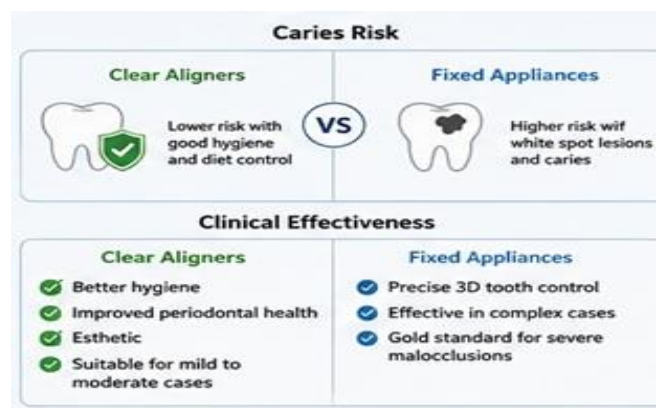


Figure 3. Comparison of Caries Risk and Enamel Demineralization of clear aligner therapy and fixed orthodontic appliances

The comparative analysis of the included studies revealed consistent differences between clear aligner therapy and conventional fixed orthodontic appliances with respect to periodontal health, microbial composition, oral hygiene accessibility, and enamel demineralization risk. Overall, clear aligners demonstrated a more favorable biological

profile, whereas fixed appliances were associated with greater plaque retention and microbial dysbiosis. A schematic overview of these key differences is presented in Figure 4.

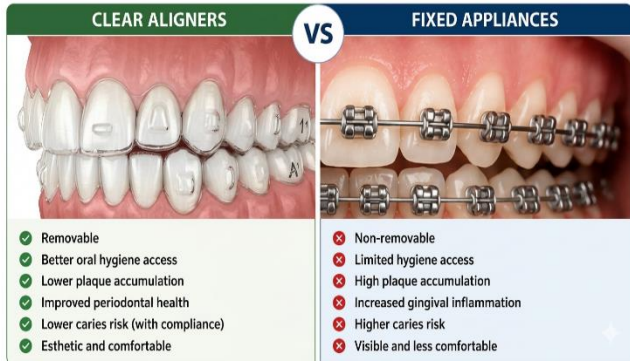


Figure 4. Schematic comparison of periodontal, microbiological, and oral hygiene-related characteristics associated with clear aligner therapy and fixed orthodontic appliances.

Table 4 summarizes the strength and consistency of the available evidence regarding the biological effects of clear aligner therapy, including periodontal outcomes, microbiological changes, and caries-related risks.

Table 4. Strength of evidence regarding the biological effects of clear aligner therapy

Outcome	Evidence Level	Consistency
Periodontal health	High	Strong
Plaque control	High	Strong
White spot lesion prevention	Moderate–High	Strong
Oral microbiome stability	Moderate	Moderate
Long-term caries reduction	Low–Moderate	Limited

DISCUSSION

The present narrative review evaluated the effects of clear aligner therapy on periodontal health, oral microbiome composition, and biofilm formation in comparison with fixed orthodontic appliances.

Overall, the available evidence indicates that aligner-based therapy may be associated with more favorable periodontal and oral hygiene outcomes; however, these differences appear modest and highly dependent on clinical conditions^{6,21,23,30}. A critical contribution of this review is highlighting that these biological and hygiene-related advantages are not automatic. While the removability of clear aligners facilitates mechanical plaque control, this advantage can be significantly compromised in daily clinical practice

Experimental findings suggest that such conditions may promote early biofilm formation on both teeth and aligner surfaces^{11,22,31,32}. From a clinical perspective, clear aligners offer advantages in periodontal health, aesthetics, and patient comfort. These benefits are closely linked to improved oral hygiene accessibility^{23,24,33}. Additionally, thermoplastic materials may undergo surface changes over time that increase microbial retention^{11,25,30}. Fixed appliances demonstrate a stronger and more consistent association with microbial dysbiosis, characterized by increased biofilm thickness, reduced microbial diversity, and elevated pathogenic bacterial load^{4,16,20,28,29}. These findings reinforce the role of appliance design in shaping the oral microbiome during orthodontic treatment.

Clinical studies consistently report higher levels of *Streptococcus mutans* and *Lactobacillus* species, increased gingival inflammation, and greater risk of white spot lesion formation in fixed appliance patients^{17,19,20,29}. Early deterioration of oral hygiene during fixed orthodontic therapy has also been documented, particularly in the initial months of treatment^{3,6,20,29}.

4.1 Practical Implications for Daily Aligner Practice

***Attachment-Rich Design & Auxiliaries:** The presence of numerous composite attachments, elastics, cutouts, or buttons changes the topography of the dentition. They create localized, fixed retentive niches similar to brackets, which can quickly reduce the inherent hygiene advantage of the aligner if not carefully cleaned^{21,23,30}.

*** Patient Compliance & Education:** Clear aligners are only "cleaner" if the patient follows a strict protocol. Without proper patient education regarding aligner cleaning, a disciplined diet (avoiding liquids other than water while wearing appliances), and compliance with the 22-hour wear rule, the aligner can transition from a protective shield to a closed biological reservoir for cariogenic shifts^{22,32}.

*** Individualized Risk Assessment:** Orthodontists should balance biological benefits with biomechanical requirements. Fixed systems remain the gold standard for severe rotational or complex skeletal corrections^{15,34,35}. However, for patients with pre-existing periodontal vulnerabilities or high initial demineralization risks, clear aligners represent an excellent therapeutic path—provided that an individualized risk profile is established at the start of treatment^{6,21,23}.

In this context, since clear aligner technology is rapidly evolving, dedicated research arms within major clinical pioneers, play a vital role^{11,34}. By facilitating collaborations with practicing orthodontists, generating large-scale clinical data, and exploring advanced material

sciences that resist surface microabrasions, such efforts help bridge the gap between indirect microbiological evidence and long-term clinical success.

Future research should focus on long-term longitudinal studies, standardized microbiome assessment protocols, and advanced sequencing methods to better understand microbial dynamics during orthodontic therapy^{16,20,25,31}.

5. CONCLUSIONS

Clear aligner therapy is associated with more favorable short- and medium-term periodontal and hygiene-related indices compared with fixed orthodontic appliances. However, these benefits are modest, conditional, and highly dependent on patient behavior, appliance design (such as the burden of attachments and auxiliaries), strict cleaning habits, and individualized risk assessment.

DECLARATIONS

Ethical Approval

Not applicable.

Competing Interests

The authors declare no conflict of interest.

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