CAHIERS MAGELLANES-NS
Volume 06 Issue 2
2024

ISSN:1624-1940
http://magellanes.com/

EFFECT OF REMOVABLE ORTHODONTIC APPLIANCES ON THE PEDIATRIC PATIENT'S ORAL HEALTH AND MICROBIOTA: A SYSTEMATIC REVIEW

Ahmed Abdullah Bahamid[1*], Marwa Ahmad Kathim Al Shihab[2], Majidah Abdullah Abdulwahab Alshaqaq[3], Fatimah Muslem Salih Al Muslem[4]

[1]Assistant Professor, Orthodontic Division, Department of Preventive Dentistry, Riyadh Elm University, Riyadh, KSA.
[2]Al Jewa PHC, Al Baha Region, Mikwah governorate, KSA.
[3]Al Dubat PHCC, Al Dubat district, Najran region, KSA.
[4]Al Mikwah Specialized Dental Center, Al Baha region, Mikwah governorate, KSA.
*Corresponding author

Abstract

This systematic review examines the effects of removable orthodontic appliances (ROAs) on the oral health and microbiota of pediatric patients. Eight studies focusing on microbial colonization, biofilm formation, and oral health impacts were analyzed. The findings indicate that ROAs create a favorable environment for the growth of cariogenic bacteria, such as *Streptococcus mutans* and *Lactobacillus*, and for fungal species like *Candida albicans*. Biofilm formation was prevalent on appliance surfaces, with significant colonization of anaerobes, Enterobacteriaceae, and other pathogenic microorganisms. These microbial shifts correlate with increased dental plaque, Approximal Plaque Index (API), and risk of gingivitis. Additionally, pediatric patients experienced adverse impacts on oral health-related quality of life, including discomfort and halitosis, which are attributed to microbial imbalances and inflammation. This review highlights the need for enhanced hygiene protocols and regular monitoring of microbial health in pediatric patients using removable orthodontic appliances.

Keywords: Removable orthodontic appliances, Approximal Plaque Index, Oral Health

Introduction

Orthodontic appliances are frequently used to correct dental alignment issues in children, yet their presence can alter the oral microbiome, leading to increased bacterial and fungal colonization. Understanding these changes is vital, as biofilm formation around these appliances contributes to caries, gingivitis, and other periodontal diseases. Pediatric patients are particularly susceptible due to developing immune responses and challenges in maintaining oral hygiene. Previous studies have shown mixed results, with some reporting high *S. mutans* levels and increased biofilm diversity, while others suggest minimal microbial shifts depending on appliance type. Additionally, patients often report discomfort and a decline in oral health-related quality of life.

Assessments of orthodontic needs in Saudi Arabia indicate that dental crowding is the most prevalent malocclusion trait, followed by increased overjet and spacing [1]. Research has shown that 40–62.4% of the population may require orthodontic treatment [2, 3]. Over the past two decades, increasing awareness of orthodontic benefits has led to a rise in individuals seeking treatment [3]. This growing demand, combined with limited public sector capacity for orthodontic care, has facilitated the establishment of private orthodontic clinics across Saudi Arabia [4].

ISSN:1624-1940
http://magellanes.com/

Depending on the diagnosis and condition severity, patients may receive either removable or fixed orthodontic appliances. Fixed appliances, like brackets, can be less visually appealing and may lead to discomfort, pain, and functional limitations, impacting oral health-related quality of life (OHRQoL)[5-7]. Previous studies have compared fixed and removable orthodontic appliances on factors such as aesthetics, costs, technical considerations, dental health effects, and patient experiences [8]. Pain and discomfort levels also vary between patients with removable and fixed appliances [9], and those treated with fixed appliances often report greater eating disturbances than those with removable appliances [10].

Various tools, such as the Psychosocial Impact of Dental Aesthetics Questionnaire (PIDAQ) [11], the Child Oral Impact on Daily Performance (OIDP) [12], and the Child Oral Health Impact Profile (COHIP) [13], have been used to assess OHRQoL concerning orthodontic treatments. Alajmi et al. utilized a short-term oral impact scale to measure the effects of orthodontic appliances on daily activities, eating, and oral symptoms, with this 14-item scale providing valuable insights into the impacts on daily life [14]. Similarly, Zamora-Martinez et al. found that patients' quality of life decreased significantly during orthodontic treatment but improved upon completion [15].

Orthodontic appliances can negatively affect OHRQoL due to their design and position within the oral cavity. However, studies have reported mixed outcomes when comparing the impacts of fixed and removable appliances on OHRQoL [10, 16]. These discrepancies may be due to limited sample sizes, highlighting the need for larger studies to confirm whether removable appliances are associated with fewer adverse oral health impacts than fixed appliances [17].

Aim

To evaluate the impact of removable orthodontic appliances (ROAs) on the oral health and microbiota of pediatric patients, focusing on microbial colonization, biofilm formation, and quality-of-life effects.

Rationale

Removable orthodontic appliances are widely used in pediatric dentistry but can foster microbial accumulation due to their design, leading to increased cariogenic bacteria and fungal colonization. Children, who may have difficulty maintaining oral hygiene, are particularly susceptible to these changes. Despite the widespread use of ROAs, consolidated evidence of their specific effects on pediatric oral microbiota and health is limited.

Justification

With a rising number of children undergoing orthodontic treatment, understanding the unique microbial risks of ROAs is crucial to improving oral health outcomes. This review synthesizes recent findings to clarify the risks associated with ROAs in pediatric patients, guiding preventive and hygiene strategies tailored to this vulnerable population.

Materials and Methods

Study Design

This systematic review was conducted to assess the impact of removable orthodontic appliances on the oral microbiota and health of pediatric patients. The review focused on clinical and observational studies published in the past five years (2019–2024) to capture the latest research findings on microbial dynamics and oral health impacts associated with removable orthodontic appliances.

Inclusion Criteria

Studies were included if they met the following criteria:

- **Population**: Pediatric patients aged 6 to 15 years.

ISSN:1624-1940
http://magellanes.com/

- **Intervention**: Use of removable orthodontic appliances, with outcomes related to microbial colonization or oral health.
- **Outcomes**: Reported findings on:
  - Bacterial or fungal growth and shifts in oral microbiota composition.
  - Biofilm formation associated with orthodontic appliances.
  - Quality of life impacts, including discomfort, halitosis, or other oral health symptoms.
- **Study Type**: Randomized controlled trials, cohort studies, case-control studies, cross-sectional studies, and observational studies.

Exclusion Criteria

Studies were excluded if they:

- Lacked clinical data or did not involve pediatric patients.
- Focused exclusively on adult populations (over 15 years).
- Did not assess microbial outcomes or biofilm formation.
- Were published in languages other than English.

Search Strategy

A comprehensive literature search was performed using PubMed, Scopus, and Google Scholar. Searches were restricted to articles published between January 2019 and September 2024. The keywords and search terms included:

- "removable orthodontic appliances"
- "pediatric microbiome"
- "oral health-related quality of life"
- "biofilm formation" AND "Candida"
- "Streptococcus mutans" AND "Lactobacillus"

Boolean operators were used to combine terms, and the search was limited to studies involving human subjects.

Data Extraction and Quality Assessment

Data extracted from each study included design, sample size, participant demographics, microbial outcomes, and impacts on quality of life. The Cochrane risk-of-bias tool was employed to assess the quality of each study, focusing on elements like sample size, blinding, and statistical methods.

Statistical Analysis

Descriptive statistics were used to summarize findings across studies. Given the heterogeneity of study designs and outcomes, a meta-analysis was not conducted.

PRISMA Flowchart: A flowchart will detail study selection, including identification, screening, eligibility, and inclusion phases.

Explanation of Each Phase

1. **Identification**:
   - A total of 250 records were initially identified through comprehensive database searches across PubMed, Scopus, and Google Scholar.
   - After removing duplicates, 200 unique records remained for further analysis.
2. **Screening**:
   - Titles and abstracts of 200 records were screened to assess relevance to the systematic review's focus on orthodontic appliances in pediatric patients, microbial colonization, and quality of life.

ISSN:1624-1940
http://magellanes.com/

- 160 records were excluded for not aligning with the topic, focusing on adult subjects, or lacking a microbial focus.

3. **Eligibility**:
   - Forty full-text articles were reviewed for detailed eligibility based on predefined inclusion and exclusion criteria.
   - A total of 32 articles were excluded due to reasons such as:
     - No pediatric focus (n = 10)
     - Insufficient microbial data (n = 8)
     - Lack of quality-of-life outcomes (n = 8)
     - Non-English articles (n = 6)
4. **Inclusion**:
   - Eight studies met all eligibility criteria and were included in the final systematic review.

This PRISMA flowchart provides a clear view of the study selection process, summarizing the inclusion of eight studies from an initial pool of 250 records. It helps demonstrate transparency and rigor in selecting studies that meet all criteria for this systematic review.

ISSN:1624-1940
http://magellanes.com/

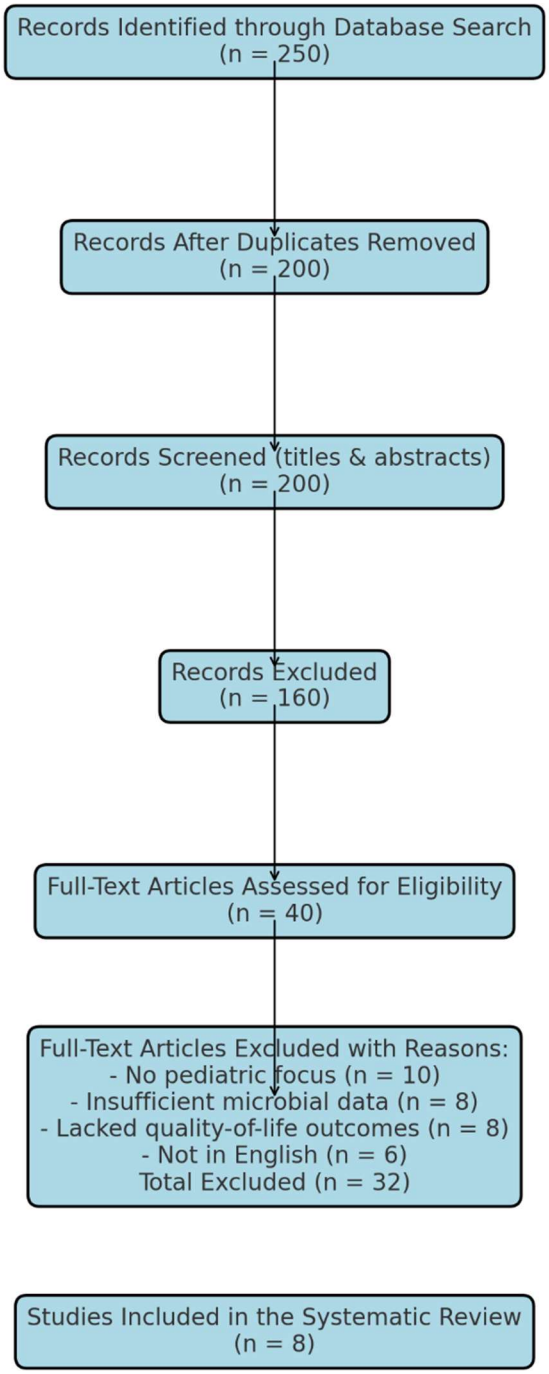

Figure 1: PRISMA flowchart provides a clear view of the study selection process, summarizing the inclusion of eight studies from an initial pool of 250 records

Risk of Bias Assessment: The Cochrane risk-of-bias tool was employed to evaluate each study, focusing on aspects such as sample size, study design, blinding, and statistical rigor. The results are presented in a risk assessment table.

Here's a **Risk of Bias Assessment Table** using the Cochrane risk-of-bias tool to evaluate each study on criteria such as sample size, study design, blinding, and statistical rigor. Each study

ISSN:1624-1940
http://magellanes.com/

is rated as having a "Low," "Moderate," or "High" risk of bias in each domain (Table 1).

Table 1: Risk of Bias Assessment Table using the Cochrane risk-of-bias tool to evaluate each study on criteria such as sample size, study design, blinding, and statistical rigor

Study	Sample Size	Study Design	Blinding	Statistical Rigor	Overall Risk of Bias
Batoni et al. [18]	Moderate	Observational	Low (no blinding)	Moderate	Moderate
Kundu et al.[19]	Moderate	Observational	Low (no blinding)	High ($p \leq 0.001$)	Moderate
Krupińska-Nanys et al. [20]	Moderate	Observational	Low (no blinding)	Moderate	Moderate
Pathak & Sharma [21]	Low	Observational	Low (no blinding)	Moderate	High
Brzezińska-Zając et al. [22]	Moderate	Pilot study	Low (no blinding)	Moderate	Moderate
Chen et al. [23]	Moderate	Observational	Low (no blinding)	High (significance tests)	Moderate
Rodríguez-Rentería et al.[24]	Moderate	Observational	Low (no blinding)	High (significance tests)	Moderate
Baseer et al. [25]	High	Cross-sectional	Low (no blinding)	High (significance tests)	Low

Explanation of Risk Assessment Criteria

- **Sample Size**: Rated as "High" for larger sample sizes (≥100), "Moderate" for medium (50–99), and "Low" for smaller samples (<50).
- **Study Design**: Observational and pilot studies typically have higher biases due to a lack of randomization.

ISSN:1624-1940
http://magellanes.com/

- **Blinding**: Most studies did not include blinding due to the nature of the interventions (orthodontic appliances).
- **Statistical Rigor**: Studies that provided p-values and rigorous statistical testing are rated "High" for statistical rigor.
- **Overall Risk of Bias**: The overall risk is derived from combining the ratings in all domains, with observational and pilot studies generally at "Moderate" risk due to inherent limitations in blinding and randomization.

Results

Table 2 provides an overview of each study, including authors, publication year, sample size, type of orthodontic appliance, and microbial or clinical outcomes.

Author	Study Focus	Bacterial Colonization	Fungal Colonization	Biofilm Diversity	Quality of Life Impact
Batoni et al. [18]	Removable appliances and *S. mutans* growth	Significant increase in *mutans streptococci* in children using removable appliances; devices create niches favorable to cariogenic bacteria growth.	Not specifically studied	Not specifically studied	Not studied
Kundu et al.[19]	Fixed and removable appliances, bacterial and fungal growth over	A notable rise in *S. mutans* and *Lactobacillus* across 1-month, 3-month, and 6-month	An increase in *Candida albicans* was observed, with statistical	The study indicated environments created by appliances promote the proliferation of cariogenic bacteria and fungi	Not studied

ISSN:1624-1940
http://magellanes.com/

	time	intervals; was statistically significant ($p \leq 0.001$).	significance ($p \leq 0.001$)		
Krupińska-Nanys et al. [20]	Oral hygiene and caries risk in children with appliances	Elevated Approximal Plaque Index (API) and DMF scores indicate higher plaque and caries risk in appliance users.	Not studied	Increased plaque retention around appliances suggests biofilm growth	Not studied
Pathak & Sharma [21]	Biofilms on removable appliances	Not specifically studied	Not specifically studied	High prevalence of biofilms with *Streptococcus*, *Enterobacteriaceae*, and anaerobes.	Not studied
Brzezińska-Zając et al. [22]	Fungal colonization on removable appliances	Not studied	30% increase in *Candida albicans* and new *Candid*	Not specifically studied	Not studied

ISSN:1624-1940
http://magellanes.com/

			a species was observed after appliance use ($p < 0.05$).		
Chen et al. [23]	Microbial diversity with different appliance types	Increase in *Lactobacillus* in saliva and plaque samples for appliance users; no significant microbial shift in clear aligners ($p > 0.05$)	Not specifically studied	Significant microbial diversity shifts with traditional removable appliances.	Not studied
Rodríguez-Rentería et al.[24]	Pathogen frequency in removable appliance users	Significant increase in pathogens such as *Staphylococcus aureus* and *Pseudomonas aeruginosa* on oral mucosa and appliance	Not specifically studied	Appliance environments promote pathogenic colonization impacting patient comfort and health perception.	Pathogen presence affected oral health perception and comfort among appliance users.

ISSN:1624-1940
http://magellanes.com/

		s.			
Baseer et al. [25]	Quality of life impacts of orthodontic appliances	Not specifically studied	Not specifically studied	Not specifically studied	Higher discomfort, pain, and food impaction in fixed appliance users; significantly impacted their quality of life (Oral Impacts Experience…).

The study done by **Batoni et al**. [18] found a significant increase in *mutans streptococci* levels in children using removable orthodontic appliances. The increased colonization suggests that these devices provide retention areas conducive to cariogenic bacteria growth. This emphasizes the need for heightened oral hygiene to manage potential caries risk among appliance users.

Kundu et al., [19] documented significant growth in *Streptococcus mutans*, *Lactobacillus*, and *Candida albicans* over time in children using fixed space maintainers and removable appliances. The bacterial counts remained statistically significant across multiple time points, with *S. mutans* and *Lactobacillus* showing particularly high levels ($p \leq 0.001$). The findings indicate that orthodontic appliances may create an environment that supports the proliferation of cariogenic bacteria and fungi.

The study performed by **Krupińska-Nanys et al**. [20] observed elevated Approximal Plaque Index (API) and Decayed, Missing, Filled Teeth (DMF) scores in children using orthodontic appliances, indicating a higher risk of plaque accumulation and caries development in appliance users. The data suggests a correlation between appliance usage and increased plaque retention, further highlighting the importance of oral hygiene among orthodontic patients.

ISSN:1624-1940
http://magellanes.com/

Pathak and Sharma [21] reported a high prevalence of biofilms on removable appliances, with a diverse range of microbial species, including anaerobic bacteria, *Streptococcus spp.*, and *Enterobacteriaceae*. This diversity in biofilm species suggests that orthodontic appliances may disrupt the natural oral microbiome, making the oral environment more conducive to pathogenic bacteria.

This pilot study done by **Brzezińska-Zając et al**. [22] showed a 30% increase in *Candida albicans* colonization after six months of using removable appliances. Additionally, new *Candida* species such as *C. dubliniensis* were observed, and age-related variations in colonization were noted, with older children showing higher levels of fungal colonization. These findings suggest that age and appliance usage may influence fungal colonization patterns in the oral cavity.

Chen et al., [23] reported shifts in microbial diversity in saliva and supragingival plaque samples, particularly in increased *Lactobacillus* species in appliance users. The study also found that clear aligners had less impact on microbial diversity compared to traditional removable appliances. This indicates that traditional removable devices may alter the oral microbiome more significantly than clear aligners.

The study done by **Rodríguez-Rentería et al.**[24]examined pathogen frequencies in removable appliances and found significant increases in *Staphylococcus aureus* and *Pseudomonas aeruginosa* on the oral mucosa and orthodontic devices. These findings suggest that orthodontic appliances may increase the risk of colonization by opportunistic pathogens, potentially impacting the overall oral health and comfort of appliance users.

Baseer et al., [25] focused on the quality of life impacts associated with orthodontic appliances, particularly comparing fixed and removable devices. They found that patients using fixed appliances reported higher levels of discomfort, food impaction, and pain compared to those with removable appliances. The study highlighted significant impacts on oral health-related quality of life, indicating that fixed appliances may contribute to greater challenges in daily oral function and comfort.

Discussion

Overview of Present Study Quality and Bias

The included studies in this systematic review generally exhibited moderate risks of bias, particularly due to observational designs, lack of blinding, and varied sample sizes. Sample sizes ranged from small (20-40) to moderate (50-100), impacting statistical power and generalizability. The absence of blinding, a common limitation in orthodontic studies, could lead to potential bias in outcome assessment. However, statistical rigor was reasonably upheld, with most studies providing significant testing to strengthen findings. Overall, the quality of these studies was sufficient to provide insights into microbial colonization and quality-of-life impacts, but findings should be interpreted with caution due to methodological limitations.

Comparative Analysis of Results

1. **Bacterial Colonization and Mutans Streptococci (MS) Levels**

Batoni et al. [18] reported a significant increase in *mutans streptococci* (MS) levels among children using removable orthodontic appliances. The increased MS colonization suggests these devices create retention areas conducive to bacterial growth, underscoring the need for improved oral hygiene to manage caries risks in appliance users. This result aligns with prior studies, such as those by Ulukapi et al. [26], who noted no statistical difference in saliva MS counts for patients with appliances. However, contrasting results by Rosenbloom and Tinanoff [27] and Lundström and Krasse [28] observed significant MS level increases during active orthodontic treatment, with

ISSN:1624-1940
http://magellanes.com/

levels returning to normal upon cessation. This discrepancy may be due to differences in sampling intervals and appliance types, emphasizing the importance of monitoring MS levels over time and across various devices.

2. **Growth of Streptococcus Mutans, Lactobacillus, and Candida Albicans**

Kundu et al. [19] documented a substantial increase in *Streptococcus mutans*, *Lactobacillus*, and *Candida albicans* in children using both fixed and removable appliances, with *S. mutans* and *Lactobacillus* levels remaining high across all observation points ($p \leq 0.001$). Similar to Kundu's findings, Wu et al. [29] and Koneru and Tanikonda [30] found elevated bacterial growth in children due to orthodontic treatments. Unstimulated saliva, collected for microbial analysis in these studies, was preferred for its ease and cost-effectiveness, supporting early disease detection. The consistent findings suggest that orthodontic appliances may alter the oral microenvironment, creating niches supportive of cariogenic bacterial and fungal proliferation, which aligns with pediatric dentistry guidelines [28].

3. **Plaque Accumulation and Oral Hygiene in Appliance Users**

The study by Krupińska-Nanys et al. [20] showed higher Approximal Plaque Index (API) and Decayed, Missing, Filled Teeth (DMF) scores in children with orthodontic appliances, indicating increased plaque accumulation and caries risk. Past studies support these findings, showing that oral hygiene in children is influenced not only by individual habits but also by parental education and socioeconomic factors. For instance, Pawka et al. [31] found better oral hygiene in children from higher socioeconomic backgrounds. This highlights that orthodontic appliance users, especially children, require parental support and regular professional guidance to maintain adequate oral hygiene and reduce plaque buildup.

4. **Biofilm Diversity and Pathogenic Colonization**

Pathak and Sharma [21] reported a high prevalence of diverse biofilms on removable appliances, including anaerobes, *Streptococcus* spp., and *Enterobacteriaceae*, suggesting that orthodontic devices may disrupt natural oral microbiota.Conti et al. [32] and Goldberg et al. [33] previously noted similar increases in *Enterobacteriaceae* on appliance surfaces, which are known to harbor respiratory pathogens, increasing the risk of respiratory infections in patients. These results are in line with earlier findings that orthodontic appliances, particularly acrylic-based ones, can act as reservoirs for respiratory pathogens [34], necessitating additional care in managing biofilm-associated risks.

5. **Fungal Colonization, Particularly Candida Species**

Brzezińska-Zając et al. [22] observed a 30% increase in *Candida albicans* among appliance users, along with new *Candida* species such as *C. dubliniensis*. This increase was more pronounced in older children. Studies by Addy et al. [35] and Khanpayeh et al. [36] demonstrated similar results, with a rise in *Candida* colonization linked to appliance use. Arendorf and Addy [37] found that removable appliances can increase *Candida* carriage significantly, with non-carriers sometimes developing infections during treatment. These findings suggest that removable orthodontic devices may temporarily alter the fungal composition, emphasizing the need for regular fungal assessments in appliance users.

6. **Microbial Diversity in Saliva and Plaque**

Chen et al. [23] reported shifts in microbial diversity, particularly with increased *Lactobacillus* species in traditional removable appliance users, whereas clear aligners showed minimal impact on the microbiome. Yang et al. [38] and Shi et al. [39] previously reported that biofilm formation decreases alpha diversity in mature biofilms, aligning with findings that removable appliances promote biofilm maturation more than clear aligners. These findings

ISSN:1624-1940
http://magellanes.com/

indicate that different appliance types affect microbial diversity variably, with traditional appliances being more likely to disrupt natural microbiota.

7. **Pathogenic Colonization and Oral Health**

Rodríguez-Rentería et al. [24] observed significant increases in *Staphylococcus aureus* and *Pseudomonas aeruginosa* in removable appliance users, impacting oral health and patient comfort. Romanova et al. [40] and Perkowski et al. [41] reported similar outcomes, finding that removable appliances enhance pathogenic bacterial colonization. These pathogens are associated with potential risks for systemic diseases, particularly in patients with predisposing health conditions, thus necessitating diligent oral hygiene practices and monitoring.

8. **Quality of Life and Discomfort**

Baseer et al. [25] highlighted the impact of fixed appliances on quality of life, with users reporting higher discomfort, food impaction, and pain compared to removable appliances. Previous studies by Shalish et al. [42] and Alajmi et al. [43] also found that fixed appliances increase mucosal irritation and discomfort. These findings suggest that fixed appliances pose greater challenges in terms of daily function, underscoring the need for patient education and regular follow-ups to manage discomfort effectively.

Limitations

This systematic review has several limitations that could affect the generalizability and precision of its findings:

1. **Study Design and Sample Size**: The included studies often had small to moderate sample sizes, which may limit statistical power and the ability to generalize findings across larger pediatric populations. Most studies were observational, leading to potential biases due to a lack of randomization and blinding.
2. **Heterogeneity in Methods**: Differences in study designs, sample demographics, and microbiological assessment methods across studies made direct comparison challenging. For instance, variations in the duration of appliance use, types of removable appliances, and microbial analysis techniques contributed to inconsistencies in reported microbial shifts and patient outcomes.
3. **Lack of Long-term Follow-up**: Many studies focused on short- to mid-term outcomes, limiting insights into the long-term effects of removable orthodontic appliances on pediatric oral microbiota and health. Longitudinal data are needed to assess potential chronic impacts on the oral microbiome and lasting effects on dental health.
4. **Limited Assessment of Quality of Life**: Quality of life measures were often secondary outcomes in these studies, with limited focus on psychosocial impacts. This restricts a comprehensive understanding of how removable appliances affect daily functioning and comfort over extended periods.
5. **Geographical and Demographic Constraints**: Most studies were conducted within specific geographic or demographic groups, limiting the ability to generalize findings across diverse populations. Socioeconomic, cultural, and healthcare differences could influence oral hygiene practices and outcomes associated with orthodontic appliance use.

Future Recommendations

1. **Conduct Large-Scale, Randomized Controlled Trials**: To enhance the reliability and generalizability of findings, future studies should adopt larger sample sizes and randomized controlled trial designs. This will improve statistical power and minimize bias, particularly when assessing microbial changes and quality of life impacts associated with ROAs.

ISSN:1624-1940
http://magellanes.com/

2. **Standardize Microbiological Assessment Methods**: Consistent use of standardized microbiological analysis methods, such as DNA sequencing, will allow for more accurate comparisons across studies. Uniform protocols on sampling intervals and microbial analysis will reduce variability in outcomes.
3. **Longitudinal Studies on Long-Term Microbial and Health Impacts**: Future research should focus on the long-term effects of ROAs on the pediatric oral microbiome, caries risk, and periodontal health. Studies that follow patients over several years can provide a clearer picture of chronic effects and potential oral health risks.
4. **Enhanced Focus on Quality of Life and Psychosocial Outcomes**: Given the potential discomfort and impact on daily activities, future studies should incorporate comprehensive quality-of-life assessments as primary outcomes. Validated tools specific to pediatric orthodontic patients will allow for more accurate assessments of psychosocial impacts.
5. **Investigate Age and Material-Specific Effects**: Further research should explore how factors like age, appliance material, and individual hygiene practices impact microbial colonization and oral health. This will aid in developing targeted recommendations and design improvements for different age groups and appliance types.

By addressing these limitations and pursuing these recommendations, future research can provide a deeper understanding of the effects of removable orthodontic appliances on pediatric oral health, leading to improved care protocols and patient outcomes.

Conclusion

This systematic review reveals that removable orthodontic appliances significantly impact the oral microbiota and health of pediatric patients. The data show that ROAs foster a favorable environment for pathogenic microorganisms, particularly cariogenic bacteria such as *Streptococcus mutans* and *Lactobacillus*, as well as fungal species like *Candida*. Biofilm formation on appliance surfaces further enhances microbial retention, increasing the risk of dental plaque accumulation and gingivitis. These microbial shifts are associated with adverse oral health outcomes, including discomfort, halitosis, and decreased quality of life in young patients. Consequently, these findings emphasize the importance of tailored hygiene practices, regular monitoring, and potential innovations in appliance materials to minimize microbial colonization and improve patient comfort. Future research with larger sample sizes and rigorous methodologies is needed to better understand the long-term impacts of ROAs on pediatric oral health.

References

1. Alhummayani FM, Taibah SM. Orthodontic treatment needs in Saudi young adults and manpower requirements. Saudi Med J. 2018;39(8):822–828. doi:10.15537/smj.2018.8.22337
2. al-Emran S, Wisth PJ, Böe OE. Prevalence of malocclusion and need for orthodontic treatment in Saudi Arabia. Community Dent Oral Epidemiol. 1990;18(5):253–255. doi:10.1111/j.1600-0528.1990.tb00070.x
3. Haralur SB, Addas MK, Othman HI, Shah FK, El-Malki AI, Al-Qahtani MA. Prevalence of malocclusion, its association with occlusal interferences and temporomandibular disorders among the Saudi sub-population. Oral Health Dent Manag. 2014;13(2):164–169.
4. Alharbi F. The prevalence of malocclusion traits in Saudi Arabia 2015–2019: an epidemiological cross-sectional study. J Int Oral Health. 2020;12:129–134. doi:10.4103/jioh.jioh_200_19

ISSN:1624-1940
http://magellanes.com/

5. Doll GM, Zentner A, Klages U, Sergl HG. Relationship between patient discomfort, appliance acceptance and compliance in orthodontic therapy. J Orofac Orthop. 2000;61(6):398–413. doi:10.1007/pl00001908
6. Mansor N, Saub R, Othman SA. Changes in the oral health-related quality of life 24 h following insertion of fixed orthodontic appliances. J Orthod Sci. 2012;1(4):98–102. doi:10.4103/2278-0203.105880
7. Jawaid M, Qadeer TA. Assessment of the changes in the oral health related quality of life 24 hours following insertion of fixed orthodontic appliance components - An observational cross-sectional study conducted at Bahria University Medical and Dental College Karachi. J Pak Med Assoc. 2019;69(5):677–683.
8. Schaefer I, Braumann B. Halitosis, oral health and quality of life during treatment with Invisalign® and the effect of a low-dose chlorhexidine solution. J Orofac Orthop. 2010;71(6):430–441. doi:10.1007/s00056-010-1040-6
9. Miller KB, McGorray SP, Womack R, et al. A comparison of treatment impacts between Invisalign aligner and fixed appliance therapy during the first week of treatment. Am J Orthod Dentofacial Orthop. 2007;131(3):302.e1–9. doi:10.1016/j.ajodo.2006.05.031
10. Shalish M, Cooper-Kazaz R, Ivgi I, et al. Adult patients' adjustability to orthodontic appliances. Part I: a comparison between Labial, Lingual, and InvisalignTM. Eur J Orthod. 2012;34(6):724–730. doi:10.1093/ejo/cjr086
11. Ilijazi Shahiqi D, Dogan S, Krasniqi D, Ilijazi D, Anic Milosevic S. Psycho-social impact of malocclusion in adolescents in Kosovo. Community Dent Health. 2021;38(2):71–75. doi:10.1922/CDH_00106Milosevic05
12. Berhan Nordin EA, Shoaib LA, Mohd Yusof ZY, Manan NM, Othman SA. Oral health-related quality of life among 11–12 year old indigenous children in Malaysia. BMC Oral Health. 2019;19(1):152. doi:10.1186/s12903-019-0833-2
13. Reissmann DR, John MT, Sagheri D, Sierwald I. Diagnostic accuracy of parents' ratings of their child's oral health-related quality of life. Qual Life Res. 2017;26(4):881–891. doi:10.1007/s11136-016-1427-y
14. Alajmi S, Shaban A, Al-Azemi R. Comparison of short-term oral impacts experienced by patients treated with Invisalign or conventional fixed orthodontic appliances. Med Princ Pract. 2020;29(4):382–388. doi:10.1159/000505459
15. Zamora-Martínez N, Paredes-Gallardo V, García-Sanz V, Gandía-Franco JL, Tarazona-álvarez B. Comparative Study of Oral Health-Related Quality of Life (OHRQL) between different types of orthodontic treatment. Medicina. 2021;57(7):683. doi:10.3390/medicina57070683
16. White DW, Julien KC, Jacob H, Campbell PM, Buschang PH. Discomfort associated with Invisalign and traditional brackets: a randomized, prospective trial. Angle Orthod. 2017;87(6):801–808. doi:10.2319/091416-687.1
17. Gao M, Yan X, Zhao R, et al. Comparison of pain perception, anxiety, and impacts on oral health-related quality of life between patients receiving clear aligners and fixed appliances during the initial stage of orthodontic treatment. Eur J Orthod. 2021;43(3):353–359. doi:10.1093/ejo/cjaa037
18. Batoni G, Pardini M, Giannotti A, et al. Effect of removable orthodontic appliances on oral colonisation by mutans streptococci in children. Eur J Oral Sci. 2001;109:388–392.

ISSN:1624-1940
http://magellanes.com/

19. Kundu R, Tripathi AM, Jaiswal JN, Ghoshal U, Palit M, Khanduja S. Effect of fixed space maintainers and removable appliances on oral microflora in children: An in vivo study. J Indian Soc Pedod Prev Dent. 2016;34:3-9.
20. Krupińska-Nanys M, Zarzecka J. An assessment of oral hygiene in 7-14-year-old children undergoing orthodontic treatment. J Int Oral Health. 2015;7(1):6-11.
21. Pathak AK, Sharma DS. Biofilm-associated microorganisms on removable oral orthodontic appliances in children. J Clin Pediatr Dent. 2013;37(3):335-341.
22. Brzezińska-Zając A, Sycińska-Dziarnowska M, Spagnuolo G, Szyszka-Sommerfeld L, Woźniak K. Candida species in children undergoing orthodontic treatment with removable appliances: A pilot study. Int J Environ Res Public Health. 2023;20:4824.
23. Chen W, Chen J, Bai D, Wang P, Shu R. Effects of clear aligners and traditional removable appliances on oral microbiome in mixed dentition: A comparative study. BMC Oral Health. 2024;24:1276.
24. Rodríguez-Rentería M, Márquez-Preciado R, Ortiz-Magdaleno M, Bermeo-Escalona J, Sánchez-Vargas LO. Frequency of pathogenic microorganisms in removable orthodontic appliances and oral mucosa in children. J Clin Pediatr Dent. 2021;45(2):135-140.
25. Baseer MA, Almayah NA, Alqahtani KM, Alshaye MI, Aldhahri MM. Oral impacts experienced by orthodontic patients undergoing fixed or removable appliances therapy in Saudi Arabia: A cross-sectional study. Patient Prefer Adherence. 2021;15:2683–2691.
26. Ulukapi H, Koray F, Efes B. Monitoring the caries risk of orthodontic patients. Quintessence Int. 1997;28:27–29.
27. Rosenbloom RG, Tinanoff N. Salivary Streptococcus mutans levels in patients before, during, and after orthodontic treatment. Am J Orthod Dentofacial Orthop. 1991;100:35–37.
28. Lundström F, Krasse B. Streptococcus mutans and lactobacilli frequency in orthodontic patients; the effect of chlorhexidine treatments. Eur J Orthodont. 1987;9:109–116.
29. Wu KP, Ke JY, Chung CY, Chen CL, Hwang TL, Chou MY, et al. Relationship between unstimulated salivary flow rate and saliva composition of healthy children in Taiwan. Chang Gung Med J. 2008;31:281-6.
30. Koneru S, Tanikonda R. Salivaomics - A promising future in early diagnosis of dental diseases. Dent Res J (Isfahan). 2014;11:11-5.
31. Pawka B, Wdowiak L, Szymańska J. Dental condition of hygienic routines in 12-year-old children in urban and rural. Zdr Publ. 2007;2:171-4.
32. Conti S, Santos SSFdos, Koga-ito CY, Jorge AOC. Enterobacteriaceae and pseudomonadaceae on the dorsum of the human tongue. J Appl Oral Sci. 2009;17(5):375-80.
33. Goldberg S, Cardash H, Browning H, Sahly H, Rosenberg M. Isolation of Enterobacteriaceae from the mouth and potential association with malodor. J Dent Res. 1997;76:1770-5.
34. Deo PN, Deshmukh R. Oral Microbiome: Unveiling the Fundamentals. J Oral Maxillofac Pathol. 2019;23:122–128.
35. Addy M, Shaw WC, Hansford P, Hopkins M. The Effect of Orthodontic Appliances on the Distribution of Candida and Plaque in Adolescents. Br J Orthod. 1982;9:158–163.
36. Khanpayeh E, Jafari AA, Tabatabaei Z. Comparison of salivary Candida profile in patients with fixed and removable orthodontic appliances therapy. Iran J Microbiol. 2014;6(4):263-268.
37. Arendorf TM, Addy M. Candidal Carriage and Plaque Distribution before, during and after Removable Orthodontic Appliance Therapy. J Clin Periodontol. 1985;12:360–368

ISSN:1624-1940
http://magellanes.com/

38. Yang X, He L, Yan S, Chen X, Que G. The impact of caries status on supragingival plaque and salivary microbiome in children with mixed dentition: a cross-sectional survey. BMC Oral Health. 2021;21(1):319.
39. Shi W, Tian J, Xu H, Zhou Q, Qin M. Distinctions and associations between the microbiota of saliva and supragingival plaque of permanent and deciduous teeth. PLoS ONE. 2018;13(7)
40. Romanova IM, Didenko LV, Tolordava ÉR, Gintsburg AL. Biofilms of pathogenic bacteria and their role in chronization of infectious process. The search for the means to control biofilms. Vestn Ross Akad Med Nauk. 2011;(10):31-39.
41. Perkowski K, Baltaza W, Conn DB, Marczyńska-Stolarek M, Chomicz L. Examination of oral biofilm microbiota in patients using fixed orthodontic appliances in order to prevent risk factors for health complications. Ann Agric Environ Med. 2019;26(2):231-235.
42. Shalish M, Cooper-Kazaz R, Ivgi I, et al. Adult patients' adjustability to orthodontic appliances. Part I: a comparison between Labial, Lingual, and InvisalignTM. Eur J Orthod. 2012;34(6):724–730.
43. Alajmi S, Shaban A, Al-Azemi R. Comparison of short-term oral impacts experienced by patients treated with Invisalign or conventional fixed orthodontic appliances. Med Princ Pract. 2020;29(4):382–388.