Influence of Fixed and Removable Appliances on the Periodontal Health of Orthodontic Patients

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Abstract

AIM: To explore the differences in the impact of fixed appliances and clear aligners on periodontal disease, specifically examining the plaque index (PI), bleeding on probing (BOP), and probing depth (PD).

METHODS: A search for relevant literature published in English over the past decade was conducted on PubMed, along with a manual search from December 2023 to January 2024, yielding 10,890 hits. After reviewing titles and abstracts, and applying publication year filters, 1,096 papers were selected for full-text analysis. Following exclusions of duplicates and irrelevant studies, 21 publications were identified for systematic evaluation.

RESULTS: The studies indicated that fixed appliances generally resulted in higher PD, PI, and BOP values compared to removable appliances. Furthermore, fixed appliances were associated with poorer periodontal outcomes than control groups without orthodontic treatment, and significant worsening of periodontal parameters was noted in patients using fixed appliances.

CONCLUSION: This systematic review suggests that fixed orthodontic appliances may have a greater negative impact on periodontal health than removable appliances. Although differences in PD, PI, and BOP were statistically significant, their clinical relevance may be limited.

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1 Introduction

Orthodontic treatments, designed to correct malocclusions and enhance dental aesthetics, have long been a subject of interest within the dental community. While these interventions primarily focus on aligning teeth and improving occlusion, their impact on periodontal health remains a topic of considerable debate. The periodontium, which encompasses the supporting structure of the teeth, plays a crucial role in maintaining overall oral health (Angelina et al., 2016). As such, understanding the influence of various orthodontic appliances on periodontal tissues is of paramount importance.

There are generally two types of orthodontic appliances: fixed appliances and removable appliances. Fixed orthodontic appliances, such as those manufactured by 3M, Damon, and OPAK systems, are commonly used to correct malocclusions. 3M's Clarity Advanced Ceramic Brackets feature a small, low-profile design that enhances patient comfort and minimizes occlusal interference. Damon system brackets utilise self-ligating slides that reduce friction between the arch wire and bracket, allowing teeth to move more freely. OPAK system brackets feature a mini-twin design and low-profile wings for enhanced aesthetics and comfort (Baxi et al., 2023; Chen et al., 2010).

Removable orthodontic appliances include clear aligners, which have gained popularity in recent years as an alternative to fixed appliances. These appliances can be removed for daily activities such as eating and cleaning—by brushing or flossing—and are typically worn for 20–22 hours per day. Major companies offering clear aligner systems include Invisalign, ClearCorrect, and 3M Clarity Aligners (Eichenauer et al., 2011). Invisalign, developed by Align Technology, is the most well-known clear aligner system. It uses a series of custom-made, clear, removable aligners to gradually move teeth into the desired position. Invisalign treatment has been shown to be effective for mild to moderate malocclusions (Lagravère & Flores-Mir, 2005). ClearCorrect, founded in 2006, offers a similar clear aligner system to Invisalign. Their aligners are made from a thinner material, which may be more comfortable for some patients. 3M Clarity Aligners, introduced in 2018, also use a series of clear, removable aligners to straighten teeth. They feature 3M's proprietary material, which is designed to be more stain-resistant and durable than other clear aligners (Putrino et al., 2021).

Current research has shed light on the potential effects of orthodontic treatment on the periodontium. Studies have indicated that fixed appliances, in particular, can induce changes in periodontal tissues (Uppoor et al., 2010). However, the nature and extent of these changes are not always detrimental and may vary depending on individual cases and the specific type of orthodontic intervention employed (Sanja et al., 2022). Histological evaluations have further corroborated the impact of orthodontic treatments on gingival conditions, emphasizing the need for careful consideration of periodontal health throughout the course of treatment (Ada et al., 2020).

Despite the growing body of evidence, the effects of fixed orthodontic therapy on periodontal health remain diverse and somewhat controversial. Different studies have yielded varying results, highlighting the need for more comprehensive research in this area (Bollen et al., 2008). Comparisons between fixed and removable appliances have suggested that clear aligners may result in better periodontal indices compared to fixed appliances, indicating that the type of orthodontic treatment plays a significant role in influencing periodontal health (Levrini et al., 2015).

The present study aims to delve deeper into the relationship between orthodontic appliances and periodontal health. By conducting a longitudinal literature assessment of pe-

riodontal parameters, such as plaque index (PI), bleeding on probing (BOP), and probing depth (PD), among patients utilising either fixed or removable appliances, this study seeks to contribute to the existing knowledge base and provide valuable insights for orthodontists and periodontists alike. The findings of this study may help guide evidence-based decision-making and promote optimal patient care by elucidating the potential periodontal implications of different orthodontic treatment modalities.

2 Methods

The search strategy for this study was developed by delineating the components of the PICO framework, which stands for Patient, Intervention, Comparison, and Outcome, in order to identify all pertinent literature. In the context of this study, the dimensions of the PICO framework are specified as follows: the patient population includes orthodontic patients, which encompasses individuals with pre-existing periodontal conditions as well as diverse demographic factors such as age, gender, and oral hygiene practices. The intervention focuses on clear aligners, while the comparison is made against fixed orthodontic appliances. The outcome measures include the prevalence of periodontal disease and variations in periodontal health, specifically the increases or decreases in Plaque Index, Probing Depth, and Bleeding on Probing.

A comprehensive electronic search of the PubMed database was conducted between December 2023 and January 2024, aiming to locate all relevant articles published in the preceding decade in the English language, aligned with the research questions outlined in a previous section. The principal search terms utilised were "Periodontal Diseases" AND "Orthodontic Appliances," "Orthodontics" AND "Periodontium," "Orthodontic Procedures" AND "Periodontal Index," and "Clear Dental Aligners" AND "Periodontal Diseases."

In the selection process, a set of criteria was established to determine which studies would be included. Specifically, only randomized controlled trials, original research articles, and clinical studies published within the last decade were considered. Additionally, all included articles were required to be written in English to ensure accessibility and comprehensibility for the target audience.

Conversely, certain types of literature were excluded from consideration to maintain the relevance and focus of the review. This encompassed books and documents, as well as studies involving non-human subjects. Meta-analyses and systematic reviews were also omitted due to their nature of synthesizing existing research rather than presenting new findings. Furthermore, any articles published more than ten years prior to the selection process were not included, as they did not fit within the timeframe established for this review.

With the aid of electronic and manual research, a total of 10,890 hits were identified. After screening the titles and abstracts and applying the publication year filter, 1,096 articles were included for full-text assessment. Finally, duplicated hits and irrelevant studies were excluded. Based on the selection criteria and the availability of the outcomes of interest, 21 articles were selected for analysis.

2.1 Statistics

Descriptive statistics, frequency analysis, and content analysis were employed as part of the qualitative methodology to systematically analyze the textual content of the included

studies. It is important to note that, given the narrative nature of this study, regression analysis and meta-analysis techniques were not deemed suitable for the analytical framework.

3 Results

A comprehensive literature search was conducted to identify studies that evaluated periodontal parameters, including probing depth (PD), plaque index (PI), and bleeding on probing (BOP), in patients undergoing orthodontic treatment with fixed or removable appliances. Twenty-one studies, involving a total of 2,884 patients aged 10 to 74 years, were included in the analysis. A comprehensive overview of the study characteristics, including study design, number of patients, age range, orthodontic approach (fixed or removable), and reported periodontal parameters (PD, PI, and BOP) is presented in supplementary **Table S1**. The follow-up periods for each study are also presented. This systematic presentation of the data allows for a clear comparison of the outcomes associated with fixed and removable orthodontic appliances across multiple studies.

This literature review encompassed a comprehensive collection of 13 prospective cohort studies, 3 randomised controlled trials (RCTs) (Abbate et al., 2015; Chhibber et al., 2018; Thilagrani et al., 2015), 3 cross-sectional studies (Azaripour et al., 2015; Issa et al., 2020; Moosa et al., 2015), one retrospective study (Boke et al., 2014), and one longitudinal comparative study (Shokeen et al., 2022). The number of patients included in the studies ranged from 15 (Bergamo et al., 2019) to 612 (ElNaghy et al., 2023). The age of the analysed patients was between 10 (Abbate et al., 2015) and 74 (Han et al., 2015).

Among the studies, the minimal number of fixed appliances was 15 (Shokeen et al., 2022), and the maximum was 321 (ElNaghy et al., 2023). In all of the 21 studies gathered on different types of orthodontic equipment, 13 studies included both fixed and removable dental appliances. Four studies conducted comparisons between fixed orthodontic appliances and a control group that did not wear any orthodontic equipment (Alnazeh et al., 2020; Kaygisiz et al., 2015; Moosa et al., 2015; Thilagrani et al., 2015). Only one study, conducted by Levrini et al. (2015), incorporated both fixed and removable orthodontic equipment, along with a control group that did not utilise orthodontic appliances. In contrast, the remaining four studies solely focused on fixed orthodontic treatment (Bergamo et al., 2019; Gehlot et al., 2022; Ghijselings et al., 2014; Singla et al., 2022). The follow-up periods ranged from a minimum of 8 weeks (Kaygisiz et al., 2015) to 2 years (Alnazeh et al., 2020). Evaluation of outcome parameters for periodontics included assessment of PD and PI in 16 articles, while evaluation of BOP was conducted in 19 articles.

3.1 Impact of different orthodontic treatments on soft tissue periodontal health

Probing depth. Probing depth is a crucial parameter in assessing periodontal health and is routinely measured during dental examinations. It is defined as the distance from the gingival margin to the base of the gingival sulcus or periodontal pocket (Preshaw, 2015). Increased probing depth (PD) is a key indicator of periodontal destruction and is associated with the progression of periodontal diseases, such as gingivitis and periodontitis (Tonetti et al., 2018).

In this review, a total of five studies that included both fixed and removable appliances were collected (**Table S2**). The age distribution of patients ranged from 10 to 74 years. The number of patients using fixed appliances ranged from 19 to 35 individuals, with follow-up

periods varying from 3 to 12 months. PD ranged from 1.3 mm (Levrini et al., 2015) to 3.8 mm (Abbate et al., 2015). For patients using removable appliances, the number ranged from 16 to 32 individuals, with follow-up periods also varying from 3 to 12 months. PD varied from 1.6 mm (Levrini et al., 2015) to 2.75 mm (Karkhanechi et al., 2013). Among these five studies, removable appliances exhibited significant differences in PD in four studies, with values lower than those observed in patients using fixed appliances.

With regard to the studies that compared one type of orthodontic appliance to orthodontic treatment-free controls, four articles reported results from fixed appliances; no such study for removable appliances was found (**Table S3**). Among the four studies, the age distribution ranged from 12 to 35 years, with case numbers ranging from 18 to 220. The longest follow-up period was 12 months. PD for patients using fixed appliances ranged from 0.70 $\pm$ 0.956 mm (Thilagrani et al., 2015) to 2.48 $\pm$ 0.57 mm (Gehlot et al., 2022). Two studies reported statistically significant differences, indicating that after 12 months of follow-up, the PD of patients using fixed appliances differed significantly from that of the control group.

The final category consists of single-arm observational studies for fixed appliances without controls, with two such articles. Patients' ages ranged from 12 to 28, with up to 41 cases included per study and followed up for 6 to 24 months (**Table S4**). PD ranged from 1.84 mm to 2.1 mm. There was no significant change in PD compared to baseline.

In summary of these observations, it was found that within the same study, the use of fixed appliances, compared to removable appliances after follow-up, could increase PD.

Plaque index. The most commonly used periodontal indices include the gingival index, plaque index (PI), and bleeding on probing (BOP) (Caton et al., 2018). These indices are crucial for diagnosing periodontal conditions, determining treatment needs, and monitoring the efficacy of periodontal therapies (Tonetti et al., 2018).

The first category of articles selected for analysis comprised two-armed studies comparing the two types of appliances and included 10 articles, with follow-up periods ranging approximately from 3 to 24 months (**Table S5**). In the 10 studies that compared fixed to removable appliances, it was observed that the PI index was generally higher for the fixed group compared to the removable group (fixed: 1.02–37.7, removable: 0.20–27.8). In five of these studies, this difference was significant ($p < 0.05$). The study by Azaripour et al. (2015) emphasised plaque accumulation in the interproximal area, resulting in a noticeably higher PI value than the other studies that examined all parts of tooth surfaces. The study by Madariaga et al. (2020) demonstrated a higher PI value, probably due to the fact that brushing instructions were only provided after the attachment of orthodontic devices rather than prior to treatment. The noted decrease in PI at follow-up assessments indicated that patients adhered to the instructions given, though it was not as prominent as the findings of the other studies.

The four appliance-control studies that met the inclusion criteria again only assessed fixed appliances (**Table S6, S7**). Among them, the PI ranged from 0.81 to 1.13, exhibiting a range similar to that observed in the studies of the first category, which compared two types of appliances. It is noteworthy that in these appliance-control studies, no significant difference between the two groups was found, and only one out of two observed a longitudinal intragroup difference from baseline.

In summary, findings from these studies indicated a tendency for greater plaque accumulation in the fixed appliances group compared to the removable appliances group.

Bleeding on probing. BOP is a critical clinical parameter for assessing periodontal health and is widely used in dental practice. BOP is a sign of inflammation in the periodontal tissues and is considered a reliable indicator of active periodontal disease (Lang et al., 1990). The presence of BOP suggests that the state of health of the periodontal tissues is unfavourable and may require further intervention (Chapple et al., 2018). Monitoring BOP is essential for diagnosing and evaluating the severity of periodontal diseases, as well as for assessing the response to periodontal therapy (Tonetti et al., 2018).

A total of 7 studies that compared fixed appliances to removable appliances were collected, with patients' ages ranging from 10 to 46 years and follow-up durations spanning from 3 to 18 months (**Table S8**). Four of these studies indicated statistically significant differences ($p < 0.05$) between the fixed appliance group and the removable appliance group. The lowest BOP value for the fixed appliance group was 0.35% (Karkhanechi et al., 2013) and the highest was 84% (Abbate et al., 2015), whereas for the removable appliance group, the BOP values ranged from a minimum of $0.01 \pm 0.02\%$ (Issa et al., 2020) to a maximum of 13.5% (Madariaga et al., 2020).

The second category comprises two-armed studies involving fixed appliances and no treatment controls, totalling 3 articles (**Table S9**). The BOP values for the fixed appliance group ranged from a low of $0.02 \pm 0.02\%$ (Gehlot et al., 2022) to a high of $2.34 \pm 0.56\%$ (Kaygisiz et al., 2015). Despite this, the BOP values for the fixed appliance group were higher compared to the control group. Among the 3 studies, one showed statistically significant differences between the two groups (fixed vs control, 2.34 ± 0.56 vs 1.97 ± 0.73, $p = 0.024$; Kaygisiz et al., 2015).

The third category comprises single-armed studies for fixed appliances without controls, with only one article available (**Table S10**). In this study, the patients' ages ranged from 13 to 18 years, and 24 fixed appliances were installed. The BOP value at baseline was 0.396, and after 24 months of follow-up, the BOP value increased to 0.794, showing a statistically significant difference.

In summary, patients using fixed appliances generally tended to have higher BOP values compared to those using removable appliances.

4 Discussion

The impact of orthodontic appliances, both fixed and removable, on periodontal health has been a topic of continuous research owing to the varying effects these treatments exert on the gingival and periodontal parameters. This literature review aimed to evaluate the impact of fixed and removable orthodontic appliances on periodontal health by assessing PD, PI, and BOP in a total of 21 studies, including prospective cohort studies, RCTs, cross-sectional studies, a retrospective study, and a longitudinal comparative study, involving 2,884 patients aged 10 to 74 years.

The analysis of PD, conducted in 16 articles, demonstrates a notable trend: removable appliances were associated with significantly lower PD compared to fixed appliances across most studies comparing these two types of appliances. The studies comparing fixed appliances with controls also indicated that patients using fixed appliances had significantly higher PD compared to the control group after 12 months of follow-up. These findings suggest that fixed orthodontic appliances may have a more detrimental effect on periodontal health in terms of increasing PD compared to removable appliances. The reason for such an increase, though mostly transient, could be that fixed appliances tend to obstruct brush-

ing and flossing, which might lead to increased plaque accumulation over tooth surfaces. Removable appliances, on the other hand, cause less mechanical obstruction, which may contribute to lower PD values.

The evaluation of PI, another essential periodontal parameter, was conducted in 14 articles. The studies comparing the two appliances demonstrated a trend for greater plaque accumulation in the fixed appliances group compared to the removable appliances group, with 5 out of 10 studies showing statistically significant differences. Although the studies comparing fixed appliances with controls did not show significant differences in PI between the fixed appliances group and the control group, one single-armed study without controls reported a significant increase in PI at the 6th month visit compared to baseline in patients with fixed appliances. These results indicate that fixed orthodontic appliances may be associated with higher levels of plaque accumulation compared to removable appliances. The reason for such an increase in fixed appliances, as mentioned above, is that the brackets and wires create mechanical barriers, making it difficult to thoroughly clean the tooth surface by brushing and flossing. Due to these limitations in mechanical cleaning, plaque accumulation is significantly higher in the fixed group than in the removable group.

BOP, a reliable indicator of active periodontal disease, was assessed in 19 articles. The two-armed studies comparing fixed to removable appliances revealed that patients using fixed appliances tended to have higher BOP values compared to those using removable appliances, with 4 out of 7 studies showing statistically significant differences. The studies with fixed appliances and controls also found higher BOP values in the fixed appliances group compared to the control group, with one study reporting a statistically significant difference. Furthermore, the single-armed study without controls demonstrated a significant increase in BOP at the 24-month follow-up compared to baseline in patients with fixed appliances. These findings suggest that fixed orthodontic appliances may have a more significant impact on gingival inflammation and bleeding compared to removable appliances. The reason for such an increase with fixed appliances, as mentioned in the previous paragraph, is due to plaque accumulation resulting from inadequate mechanical cleaning, inevitably leading to inflammation in the gingival tissue.

The findings from this review highlight the complex interaction between orthodontic treatment modalities and periodontal health outcomes. While fixed appliances are widely utilized for their efficacy in addressing complex malocclusions, the analysis suggests they may confer a higher risk for adverse periodontal outcomes when compared to removable appliances. This underscores the importance of individualized treatment planning that considers not only the orthodontic requirements but also the periodontal health predispositions and characteristics of each patient. Patients who exhibit better oral hygiene prior to orthodontic treatment and a more complex malocclusion may benefit from fixed orthodontic appliances. In contrast, patients with poorer oral hygiene and less severe malalignment may be indicated for removable appliances to avoid periodontal destruction as an undesirable side effect of orthodontic treatment.

For clinicians, the insights derived from this literature review necessitate a holistic approach to orthodontic treatment, prioritizing both the efficacy of the intervention and the periodontal health of the patient (Ionut et al., 2024). Enhanced oral hygiene strategies, patient education, and regular periodontal assessments should form integral components of orthodontic care, especially for patients with fixed appliances. Future research should aim to longitudinally assess the periodontal outcomes post-treatment to understand the long-term impacts of orthodontic appliances on periodontal health. Additionally, the role of technological advancements in enhancing orthodontic appliance design to mitigate plaque

accumulation and periodontal inflammation warrants exploration.

The limitations of this literature review include the heterogeneity of the included studies in terms of study design, sample size, age range, and follow-up periods. Additionally, the lack of standardized reporting of periodontal parameters and the variation in the definition of fixed and removable appliances may have influenced the comparability of the results across studies.

Conclusions

This review highlights the differential impacts of fixed and removable orthodontic appliances on periodontal health parameters. Despite the limitations, such as the heterogeneity of the included studies and the lack of standardized reporting of periodontal parameters, the systematic review provides evidence that fixed orthodontic appliances may have a more detrimental effect on periodontal health compared to removable appliances. The differences in probing depth (PD), plaque index (PI), and bleeding on probing (BOP) between fixed and removable appliances were generally statistically significant after several months, though they may be mild and clinically insignificant. With the patient's well-being regarded as the foremost concern, this analysis serves as a pivotal reference for clinicians in making informed treatment decisions and in developing preventive and management strategies aimed at preserving periodontal health during orthodontic treatment.

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Not applicable.

Ethical approval

No ethical approval was required for this study as it did not involve human participants, animal subjects, or sensitive data. This study falls under the category of data collection without participant identification.

Consent for publication

Not applicable.

Authors' contributions

The author(s) declare that all the criteria for authorship designated by the International Committee of Medical Journal Editors have been met. More specifically, these are: (a) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (b) Drafting the work or revising it critically for important intellectual content; AND (c) Final approval of the version to be published; AND (d) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Competing interests

The author(s) declare that there are no competing interests related to this work.

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