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The Impact of Orthodontic Treatment on Periodontal Health and Quality of Life in Athletes: Clear Aligners vs Fixed Appliances- Narrative Review

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Abstract

Background:

Orthodontic treatment, although necessary for improving aesthetics and function, poses challenges to periodontal health. Appliance components, such as brackets and wires, impair mechanical plaque control, which may contribute to inflammation, enamel demineralization, and alterations in the oral microbiome.

Aim:

The aim of this narrative review is to compare the impact of fixed appliances and clear aligners on periodontal parameters, microbiological and structural changes, and quality of life, with emphasis on athletes.

Material and methods:

This paper searched the literature in electronic databases, including PubMed, using keywords: “Fixed Appliances vs Clear Aligners”, “White Spot Lesions”, “Periodontal Health”, “Athletes”, “Quality of Life”. Articles included randomized controlled trials, meta-analyses, and systematic reviews since 2015.

Results:

Studies indicate that patients treated with aligners maintain better oral hygiene, as reflected by lower plaque and gingival indices, especially in the early treatment stages. Fixed appliances are associated with greater microbiome dysbiosis, promoting the growth of Gram-negative and anaerobic bacteria. Regarding structural complications, fixed appliances are linked to significantly greater external apical root resorption. For athletes, the reduced pain intensity, decreased risk of mucosal injuries, and no impact of aligners on nutrition compared with braces are particularly relevant.

Conclusions:

Clear aligners provide significant benefits over fixed appliances regarding maintaining periodontal health and improving quality of life. Due to their protective splint-like effect, lower pain intensity, and no impact on chewing comfort, clear aligners may be preferred over fixed appliances in athletes.

Keywords:

Fixed Appliances vs Clear Aligners, White Spot Lesions, Periodontal Health, Athletes, Quality of Life.

1. Introduction

Orthodontic treatment, despite its unquestionable benefits in correcting malocclusions and improving smile aesthetics, is associated with multiple challenges regarding oral and periodontal health. Maintaining periodontal health during orthodontic therapy can be challenging because brackets, wires, and other appliance components may make effective plaque removal more difficult. (1) The presence of these retentive elements promotes increased accumulation of supragingival and subgingival bacterial plaque, consequently leading to notable alterations in the oral microbiome. These changes are directly responsible for the most common adverse effects of orthodontic treatment, including gingivitis, white spot lesions (WSLs), periodontitis, and dental caries. (2)

Oral health status is commonly assessed using the Plaque Index (PI), Gingival Index (GI), Bleeding on Probing (BOP), and Periodontal Pocket Depth (PPD). (3) Fixed appliances may hinder effective oral hygiene maintenance (1), contributing to biofilm accumulation around orthodontic components and subsequent gingival inflammation. (4) The development of clear aligner therapy, such as Invisalign, has expanded orthodontic treatment options, as its main advantage is removability, which allows patients to perform oral hygiene procedures under optimal conditions. (1) Additionally, this type of orthodontic appliance covers the dental crowns, reducing the accumulation of plaque and food debris in these areas. (1,5)

Recent evidence shows that clear aligners tend to provide better biofilm control than fixed appliances, leading to improved periodontal parameters, particularly during the initial and intermediate phases of treatment. (1) However, these differences appear to diminish over time, as oral hygiene proficiency gradually improves in patients with fixed appliances. Furthermore, it is important to evaluate the impact of both systems on oral hygiene, bone structure, root resorption, and overall quality of life during orthodontic treatment.

The selection of an appropriate orthodontic treatment method is especially relevant for sustaining optimal physical performance in athletes, as clear aligner systems are associated with improved quality of life and better sleep quality, which may support effective post-exercise recovery. Moreover, clear aligners constitute a safer option in the course of physical activity, as they are linked to a lower incidence of mucosal injuries and do not significantly interfere with food intake, consequently decreasing the risk of caloric deficits in athletes.

2. Clinical indicators of periodontal status.

Maintaining healthy periodontal tissues throughout orthodontic treatment can be challenging for patients due to the presence of brackets, wires, and other appliance components; mechanical plaque control may become impaired (1), which leads to increased supra- and subgingival bacterial plaque accumulation and subsequent changes in the oral microbiome. These alterations cause the main adverse effects of orthodontic treatment, such as gingivitis, white spot lesions, periodontitis, and dental caries. (2)

The main parameters used for periodontal health assessment include the Plaque Index (PI), Gingival Index (GI), Bleeding on Probing (BOP), Pocket Probing Depth (PPD) (3), as well as alveolar bone loss, gingival recession, and loss of clinical attachment level. (6)

2.1. Plaque Index (PI) and oral hygiene.

The plaque index, introduced by Silness and Loe, is used to assess plaque build-up on tooth surfaces and to evaluate the effectiveness of oral hygiene products in removing and preventing plaque deposits. (7)

The main advantage of clear aligner systems such as Invisalign is their removability, allowing patients to perform oral hygiene procedures under optimal conditions. (1) Additionally, this type of orthodontic appliance covers the tooth crowns, preventing plaque and food debris from accumulating in this area. (1,5) As a result, clear aligners provide a significantly better control of biofilm build-up than fixed appliances (8), especially during the first year of treatment (PI: MD mean difference from -0.35 to -1.10). (1) This effect seems to be time-dependent; short- and medium-term studies (1- 6 months) consistently show lower plaque index (PI) values in a group of aligner patients, while long-term research (>1 year) indicates that these differences diminish over time and eventually disappear. This may be explained by improved oral hygiene efficiency in patients with fixed appliances over time, as they gradually become more skilled at brushing around brackets and archwires. (1)

Additionally, Mummolo et al. reported that patients using clear aligners maintained a stable plaque index (PI) over time, in contrast to patients undergoing treatment with multibracket appliances, whose PI increased throughout the therapy. (9)

Moreover, the type of orthodontic appliance used by the patient is a key factor. The majority of studies have shown clinically significant increases in plaque accumulation and, consequently, higher PI in patients treated with elastomeric ligatures compared with steel ligatures. (10) Notably, Sifakakis et al. found that patient gender and baseline oral hygiene levels were associated with plaque accumulation during treatment. However, age showed no meaningful correlation with plaque index and was not identified as a predictor in the regression model ($p = 0.25$). (8)

2.2. Gingival Index (GI) and Bleeding on Probing/ Sulcus Bleeding Index (BOP/SBI).

The main purpose of the gingival index is to assess gingival condition, distinguishing between the severity of gingival inflammation and its location around the marginal gingiva (buccal, mesial, distal, and lingual surfaces). (7)

As previously mentioned, fixed appliances generally reduce the effectiveness of biofilm control, increasing the risk of gingivitis. (1) This is because dental plaque located along the gingival margin is the main etiological factor in the development of gingival inflammation. (4) Clinically, gingivitis is assessed using the gingival index (GI) and sulcus bleeding index (SBI), which evaluate edema and erythema as well as the presence and severity of bleeding from the periodontal tissues. (1)

Research indicates that clear aligner users maintained stable periodontal parameters such as GI and SBI over time, whereas patients treated with fixed appliances showed increases in GI and bleeding values. (5) During the first year of treatment, full-mouth bleeding scores (FMBS) doubled in adolescents receiving multibracket appliances; on the other hand, they decreased in those managed with clear aligners. (11)

Furthermore, studies have shown that no significant differences regarding periodontal health were observed in patients treated with fixed appliances and clear aligners as long as patients receive regular check-ups and maintain appropriate home care. (4) These findings spotlight the importance of proper professional supervision and patient compliance in maintaining gums and tooth-supporting tissues healthy during orthodontic therapy.

2.3. Pocket Probing Depth (PPD) and Clinical Attachment Loss (CAL).

PPD represents the depth of the gingival sulcus or periodontal pocket and may increase as a result of inflammation, gingival enlargement, or periodontal tissue destruction. CAL reflects

the extent of attachment loss and is considered a major indicator of periodontal support around the teeth. Recent studies have suggested that the worsening of pocket probing depth (PPD) during orthodontic treatment is mainly associated with bacterial biofilm-induced gingival inflammation, which may contribute to gingival overgrowth and the formation of periodontal pseudopockets. Moderate- to high- quality evidence demonstrates that clear aligners are connected with more favorable PPD outcomes than fixed orthodontic appliances. Improved PPD values were observed during short-, medium-, and long-term follow-up periods, indicating less deterioration of periodontal parameters over time. (1)

Although differences in PPD between clear aligners and fixed appliances were statistically significant, Crego- Ruiz et al. reported that the clinical relevance of these differences is still uncertain. The measured reduction in PPD with aligners is <1 mm, which is likely negligible in clinical practice. Similarly, because periodontal indices are ordinal, discrepancies of less than one full score are unlikely to represent clinically meaningful changes. (6)

2.4. Gingival recession and periodontal phenotype.

Gum recession is manifested by the exposure of part of the root through the apical migration of the gingival margin. (12)

The gingival biotype was assessed by probing the mid-buccal sulcus of anterior teeth. Visibility of the periodontal probe through the gingival margin indicated a thin biotype, while its absence signified a thick phenotype. (4)

The movement of teeth outside the alveolar ridge bone has been described as a risk factor for gingival recession. (6) Thus, an excessive incisor proclination should be avoided, as it may lead to movement outside the alveolar envelope, bone dehiscence, and an increased risk of gingival recession. Although these risks exist, arch expansion and controlled proclination may serve as an alternative to extractions for space management in specific cases. (13) Braces apply coronal and buccal force to the teeth's center of resistance, which may lead to tipping and proclination during alignment. In contrast, clear aligners facilitate gradual, segmented tooth movement, which may reduce proclination. Therefore, Crego-Ruiz et al. have postulated that aligners are more suitable for patients with a thin gingival biotype to minimize the risk of gingival recession. (14)

Evidence regarding gingival recession during orthodontic treatment remains limited and largely short-term. Madariaga et al. and Crego-Ruiz et al. reported a statistically significant increase in

gingival recession among patients treated with fixed appliances during short follow-up periods, whereas no marked changes were observed in the clear aligner groups. (1,6) However, these outcomes are based on a limited number of studies and require confirmation in long-term prospective research.

Renkema et al. reported that proclination of the lower incisors was not clearly associated with an increased risk of gingival recession over the long term, although some studies in adolescents or mixed-age samples suggested a potential association. (13) Chambrone and Tatakis emphasized that untreated gingival recessions may progress over time, stressing the clinical importance of avoiding iatrogenic damage during orthodontic treatment. (6)

Due to the direct contact between clear aligners and the gingival margin, the biocompatibility of aligner materials has been linked to periodontal health. Martina et al. noted slight cytotoxicity of aligner materials toward human gingival fibroblasts, which increased with the thermoforming process. Moreover, studies have shown that Invisalign induces the expression of inflammatory proteins in oral epithelial cells; this may lead to the presence of inactive or dead cells as well as inflammatory changes in periodontal tissues, possibly causing gingival recession and loss of papilla fill. (15)

Interestingly, females appear to have a greater susceptibility to gingival recession than males. (15)

2.5. Open Gingival Embrasures (OGEs).

Open gingival embrasures, commonly known as "black triangles," occur when the interdental papilla does not fully fill the space between adjacent teeth. Beyond aesthetic concerns, they may negatively affect periodontal health by promoting plaque retention and making oral hygiene more difficult. (15)

Research indicates that the incidence of OGEs is considerably higher in patients treated with clear aligners compared to those using fixed appliances. (15,16) This may be related to the mechanical stress from aligners and their full crown coverage, which leads to insufficient gingival filling space. Additionally, aligners may have a slight cytotoxic effect on gingival fibroblasts and inflammatory protein expression in oral epithelial cells, which could influence cell behavior and increase the risk of OGEs. (16) Furthermore, aligners facilitate better plaque

control and oral hygiene, which may reduce the risk of gingival inflammation. Consequently, papillary swelling is reduced, making OGEs more visible compared with fixed appliances, where gingivitis is more common. (15) It should be noted that longer treatment duration is correlated with a higher incidence of papillary recession. The type of tooth movement is also crucial. Sagittal movement of the anterior teeth, especially lingual movement of the maxillary central incisors, has been associated with the occurrence of OGEs. (17)

Tab 1. Patient- related risk factors for Open Gingival Embrasures (OGEs). (15–17)

Risk factor	Biological basis & clinical impact
Age	Risk increases with patient age. Susceptibility results from thinning of the oral epithelium and reduced capacity for tissue healing.
Gender	Higher incidence in females due to hormonal changes and differences in gingival biotype.
ICP-ABC distance	When the distance between interproximal contact point (ICP) and alveolar bone crest (ABC) is less than 5 mm, the possibility of OGEs is relatively low.
Tooth shape	The probability of OGEs was higher when the crown shape was divergent or triangular.
Initial crowding	Severe initial crowding, particularly in the mandible, requires extensive root movement that can thin the interdental papilla.
Gingival biotype	A thin biotype is more prone to mechanical or biological irritation compared to a thick biotype.

3. Microbiome, metabolome, and caries lesions during clear aligner vs fixed appliance treatment.

Orthodontic appliances can make effective oral hygiene more difficult and promote the accumulation of dental plaque, leading to quantitative and qualitative changes in the oral microbiota, which contribute to the development of inflammatory processes. As a result, these

changes can increase the risk of several negative effects, including white spot lesions (WSLs), caries, and halitosis, which are connected with higher levels of cariogenic and periodontopathogenic bacteria. (2,5)

3.1. Microbial alterations and dysbiosis related to fixed orthodontic appliances.

Fixed appliances, widely used in orthodontics, are associated with a significant risk of oral microbiota dysbiosis due to impaired mechanical control of biofilm accumulation around brackets, archwires, and ligatures. (18) Additionally, the metallic surfaces enhance bacterial affinity through electrostatic forces. (8)

It has been shown that treatment with fixed appliances is connected with an increase in the abundance of Gram-negative and anaerobic bacteria. (19) Periodontal pathogens, whose levels may be elevated during conventional orthodontic therapy, include *Porphyromonas gingivalis*, *Treponema denticola*, *Tannerella forsythia*, *Prevotella intermedia*, *Bacteroides forsythus*, and *Fusobacterium nucleatum*. (20) These species belong to Socransky's red complex, which is strongly related to the most advanced stages of periodontitis. (21) Furthermore, Xu et al. reported that pathogenic genera, particularly *Prevotella* and *Veillonella*, were enriched in the fixed appliance group, while health-associated genera, such as *Rothia* and *Lautropia*, predominated in the clear aligner group. Notably, *Prevotella* has been identified as a key periopathogen due to its ability to produce a wide range of virulence factors that may directly impair periodontal tissues and stimulate host immune responses, hence promoting the development and progression of periodontitis. (18) Several studies have shown a marked increase in the counts of *S. mutans*, *Lactobacilli*, and *Candida albicans* six months after the placement of both fixed appliances and clear aligners, with higher levels observed in patients undergoing fixed appliance therapy.

Changes in the oral microbiota may persist even after the removal of orthodontic devices. One example is the higher prevalence of *Aggregatibacter actinomycetemcomitans* and *Tannerella forsythia* in the subgingival crevicular fluid among the fixed appliance group, which remained detectable up to six months after treatment completion. (2)

Notably, elastomeric ligatures have been associated with increased biofilm retention compared with metallic ligatures, and this enhanced plaque accumulation may contribute to alterations in the oral microbiome. (10)

3.2. 16S rRNA analysis and metabolomics: bacterial metabolic changes and oxidative stress (ROS).

Advanced techniques, such as 16S rRNA gene sequencing, enable a complete analysis of structural and functional alterations in the oral microbiota. (18)

Microbial diversity.

Compared with clear aligners, fixed appliance therapy is associated with microbial communities characterized by greater richness and evenness. Nevertheless, this increased microbial diversity has been related to worse clinical periodontal parameters, such as Plaque Index (PI), which demonstrates a rising trend during fixed appliance treatment and remains stable in the aligner group. In plaque samples collected from aligner trays, microbial richness and diversity significantly decreased over the course of treatment. However, no relevant changes were detected in either the α -diversity or β -diversity of the microbiota in subgingival plaque samples. (5)

Metabolic pathways.

Xu et al. found that the fixed appliance group showed significant enrichment of pathways involved in carbohydrate metabolism, including glycan biosynthesis and metabolism, glycosaminoglycan degradation, and glycosyltransferases. Carbohydrate metabolism serves as a major source of energy for oral microbiota; therefore, increased activity of these pathways may promote biofilm development. Furthermore, the fixed appliance group showed enhanced biosynthesis of lipopolysaccharide (LPS), a major structural component of the cell wall of Gram-negative bacteria and a potent endotoxin involved in proinflammatory responses. These outcomes suggest that fixed appliance therapy is associated with metabolic pathways related to local inflammatory responses and oxidative stress, which may impair periodontal status.

In contrast, the clear aligner group was connected with enhanced lipid metabolism, which is involved in protecting cell membrane integrity, regulating signal transduction pathways (including inflammatory signaling), and controlling energy storage. These alterations may contribute to the preservation of periodontal homeostasis and lower oxidative stress levels. (18)

Oxidative stress.

In another study, Xu et al. reported that fixed appliances were associated with elevated oxidative stress markers. For example, levels of 8-OHdG (a stable biomarker of oxidative DNA damage) were markedly higher in GCF samples from patients undergoing the FA therapy. (18)

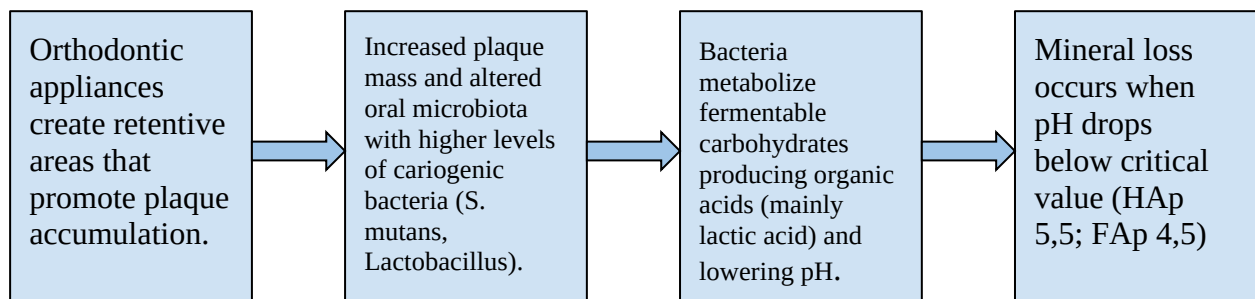
Metabolomic biomarkers.

Specific metabolites correlated with oral health status were identified. The LASSO model identified 13 key biomarkers related to unhealthy oral conditions, including cholyarginine and 2-hydroxypentanoic acid, whose elevated concentrations were associated with carbohydrate fermentation by pathogenic bacteria, thus reducing pH and promoting enamel demineralization. Interestingly, a positive correlation was observed between the presence of the pathogen *Anaeroglobus* and alpha-CEHC glucuronide in the fixed appliance group. *Anaeroglobus* is considered a potential periopathogen involved in the pathogenesis of periodontitis. (22) Furthermore, increased levels of *Lachnoanaerobaculum* and *Rothia* in saliva may serve as predictors of white spot lesion development in the clear aligners group. (5)

3.3. White Spot Lesions (WSLs).

White Spot Lesions are a common complication of orthodontic treatment, presenting as chalky white enamel opacities. WSLs result from subsurface enamel demineralization caused by organic acids produced by bacteria within the dental plaque. (23) The prevalence of WSLs during multibracket appliance treatment varies greatly, with studies reporting rates between 2% and 97%. (9)

Fig. 1. Mechanism of White Spot Lesions formation during orthodontic treatment. (9,10)



Risk comparison and lesion characteristics.

Ana Sandra et al. reported that after 9–24 months of treatment, patients treated with aligners were about ten times less likely to develop new WSLs compared with those treated with conventional fixed appliances. (24) Notably, clear aligner therapy has been associated with a low overall incidence of new WSLs (2.85%); however, 28% of patients developed at least one new lesion affecting the evaluated teeth. (23)

Importantly, Albhaisi et al. demonstrated that clear aligner users had fewer lesions and lower mineral loss compared with patients undergoing fixed appliance treatment. However, WSLs in the clear aligner group tended to affect a larger area of the tooth surfaces. (24) This can be explained by the fact that patients are advised to wear aligners approximately 22 hours per day to achieve the desired treatment outcomes. (23) The prolonged daily wear time impairs the natural cleansing activity of the oral soft tissues, which can promote plaque buildup under the aligners and decrease the protective functions of saliva, including its cleansing, buffering, and remineralizing properties. (23)

Overall, lesions in the fixed appliance group were more common, smaller in size, and associated with greater mineral loss than those observed in the clear aligner group. (24)

These findings may be related to fewer plaque accumulation sites and easier maintenance of oral hygiene among patients treated with clear aligners. (23)

3.4. Halitosis.

Halitosis is described as an unpleasant mouth breath that may result from pathological, non-pathological, physiological, and general conditions. The development of halitosis is mainly associated with the production of volatile sulfur compounds (VSCs) by specific bacteria during proteolytic breakdown of amino acids in epithelium, saliva, gingival crevicular fluid (GCF), dental plaque, blood, and food residues. (25)

The increased risk of oral malodor in patients using fixed appliances may be explained by greater biofilm accumulation and higher levels of proteins in saliva and GCF. (25) Clear aligners facilitate better plaque control, which reduces the potential risk of halitosis. (2)

Current evidence, although of very low quality, indicates that fixed appliances increase the mean concentration of volatile sulfur compounds (VSCs), while the levels remain below the halitosis cut-off values. (25)

4. Structural and radiographic complications.

Orthodontic treatment is associated with structural alterations within anatomical tissues, which may lead to iatrogenic complications such as root resorption and alveolar bone loss. (26,27) Furthermore, orthodontic therapy induces morphological remodeling of the condyle, as well as adaptive changes in the dimensions of the joint spaces and the glenoid fossa. (28,29)

4.1. External apical root resorption (EARR).

External apical root resorption is a potential complication of orthodontic treatment, characterized by irreversible loss or shortening of the hard tissue at the root apex leading to an unfavorable root-to-crown ratio and compromised tooth stability. (27) Although this type of resorption occurs in almost all clinical cases, its severity varies depending on individual patient factors and the type of orthodontic mechanics applied. (26) Radiographic studies indicate that fixed appliances induce significantly greater root resorption compared with clear aligner systems, as summarized in Table 2. Moreover, it has been demonstrated that maxillary and mandibular incisors are the tooth groups most susceptible to this complication. (27) However, other studies have shown that second premolars may also be more prone to EARR. (26) Interestingly, endodontically treated teeth showed greater resistance to EARR during orthodontic movement than teeth with vital pulp. (27)

Tab. 2. Comparison of external apical root resorption (EARR) between fixed appliances and clear aligners. (26,30)

Parameter	Fixed appliances	Clear aligners
Prevalence of EARR	83%	69%
Severity of EARR (mean root shortening)	1,81 mm	0,87 mm

4.2. Incisive canal (IC) changes.

Orthodontic retraction of the maxillary incisors with either clear aligners or fixed appliances may induce adaptive morphological changes within the incisive canal. Significant decreases in

IC width and cortical bone width were observed in both systems, with slightly greater changes in the fixed appliance group. Furthermore, fixed appliances are associated with more frequent root-incisive canal contact or invasion compared to clear aligners. (30)

4.3. Alveolar bone alterations.

Both fixed appliances and clear aligners may lead to reduction of alveolar bone thickness and alveolar bone height. (26)

Patients undergoing fixed appliance therapy showed a significant reduction in palatal alveolar bone thickness, particularly in the incisor region, while clear aligner treatment affected labial bone thickness around maxillary lateral incisors. (26)

Additionally, during clear aligner therapy involving lingual controlled tipping, the labial movement of the root may occur, increasing the risk of fenestration. Consequently, additional lingual root torque may be required to prevent severe labial bone defects. (26)

Both appliance systems were associated with a significant alveolar bone height reduction, with the greatest changes observed on the labial aspect of lateral incisors in the clear aligner group. (26)

Another difference is the type of force generated by the appliance. Fixed appliances deliver continuous forces that induce resorption in pressure areas, while clear aligners apply lower intermittent forces that may facilitate mending processes. (31)

4.4. Structural changes in the temporomandibular joint.

Substantial occlusal changes, achieved during orthodontic treatment, may potentially contribute to structural modifications in the temporomandibular joint (TMJ). (31)

In patients treated with clear aligners, adaptive TMJ changes have been reported, including increased superior joint space, greater articular fossa depth, and reduced condylar bone density. These modifications may be related to the occlusal splint effect of aligners, which promotes prolonged occlusal space opening and mandibular repositioning, possibly facilitating downward and forward condylar adaptation. (28)

Fixed appliance treatment combined with tooth extraction appeared to have a greater impact on condylar position and joint space alterations. In non-extraction treatment with fixed appliances, an increase in anteroposterior condylar position and mediolateral inclination has been observed, while vertical condylar position and a vertical inclination were reduced. Moreover, extraction

treatment with fixed appliances results in a marked increase in anterior joint space and a reduction in posterior joint space, which may reflect a posterior shift of the condyle. Clear aligner therapy has limited impact on these parameters and may be suitable when maintaining condylar position is a priority. (29)

All of these alterations may contribute to TMJ dysfunction if they exceed the patient's capability to adapt.

5. Quality of life in athletes undergoing orthodontic treatment.

Selecting an appropriate orthodontic treatment modality is key for maintaining optimal physical capacity and daily functioning in active individuals and professional athletes. Oral health-related quality of life (OHRQoL) constitutes a multidimensional concept that includes physical, social, and mental well-being. Studies have shown that patients treated with clear aligners reported higher OHRQoL than those wearing fixed appliances; however, these differences diminished by the end of treatment, with similar OHRQoL scores in both groups. (32) Patients treated with fixed appliances experienced difficulties in falling asleep due to pain during the initial phase of treatment. (33) More stable sleep in clear aligner patients may contribute to better post-exercise recovery. This evidence suggests that clear aligners may provide improved comfort and fewer limitations during daily activities and sports participation, which may be particularly relevant for athletes.

5.1. The pain intensity and its impact on training performance.

Research indicates that the pain levels in both groups were highest 24- 48 hours after the initial adjustment and subsequently decreased throughout the initial stage of orthodontic treatment. Although several studies have reported lower pain intensity in patients treated with clear aligners during the first few days of treatment, significant differences between these treatment approaches were observed only on the third and fourth days following the initial adjustment. (32) The initial discomfort experienced during treatment results from the biological reaction to applied forces, which induce compression of the periodontal ligament, leading to ischemia, edema, and the release of inflammatory mediators. These mediators, including prostaglandins and interleukins such as IL-1 β , sensitize periodontal nociceptors, thereby causing pain. Mediator levels in gingival crevicular fluid peak approximately 24 hours after force application and return to baseline within 7 days. The lower pain levels reported with clear aligners may

result from their intermittent forces, which are related to lower tension and pressure than the continuous forces of fixed appliances, therefore reducing activation of inflammatory pathways. (34)

Furthermore, athletes may prefer clear aligners due to a more manageable type of pain. Studies have shown that patients treated with aligners felt more pressure, while those using braces reported throbbing and dull pain (35); in some research, it was described as sharp pain (36), which may be more distracting during exercise. Additionally, clear aligners can be temporarily removed by patients to alleviate discomfort. (34)

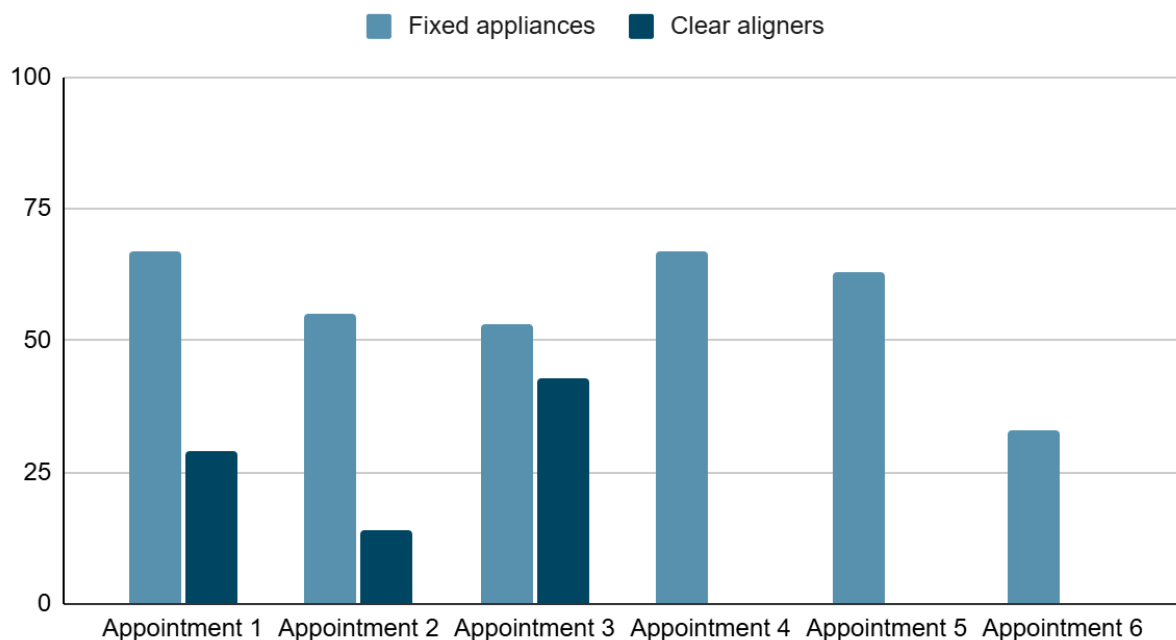
5.2. Analgesic use.

Athletes should carefully monitor the substances they consume and avoid unnecessary analgesic use.

Patients treated with braces showed higher painkiller consumption during the first week of treatment compared with those using clear aligners (67% vs 29%). (36)

Fig. 2. Comparison of analgesic intake at peak pain intensity (48 h post-appointment) between FA and CA groups. (36)

Percentage of patients with pain who used analgesics



For athletes, the onset and duration of pain relief are important factors. Naproxen shows a stronger analgesic effect than ibuprofen and acetaminophen at 2 h and 6 h after administration,

and lasting up to 24 hours. Due to naproxen's long half-life, it can be administered once daily, which may be convenient for athletes since it reduces the need to plan medication intake around their daily activities. Both naproxen and ibuprofen reach their peak pain relief around 6 hours after medication intake, while the effect of acetaminophen increases gradually over the first 24 hours. Interestingly, acetaminophen does not inhibit peripheral prostaglandin synthesis like NSAIDs and consequently does not interfere with osteoclast activity or orthodontic tooth movement. (37)

5.3. Oral trauma during sport activities.

Participation in contact sports and high-intensity physical activity is associated with an increased risk of oral injuries, which should be taken into consideration when selecting an orthodontic treatment modality.

Mucosal injuries occurred in 14.8% of patients treated with clear aligners and in 57.3% of those treated with fixed appliances. Mucosal trauma may be caused by displaced archwires or protruding ligation wires, as well as appliance-related complications such as detachment and accidental ingestion or aspiration. Frequent bracket debonding and archwire fractures in fixed appliances (reported in 60.5% of cases) can create sharp edges that easily injure the oral mucosa. (38) Clear aligners minimize probable irritation of the cheeks and gums, (39) which may help maintain comfort during training. Aligners cover the entire biting surface of the teeth and are usually around 0.77 mm thick, offering a layer of protection. (28) Because of this design, they can help protect the teeth from potential injuries that might occur during athletic activities.

5.4. Impact of orthodontic appliances on nutrition and masticatory function.

Pain during mastication may substantially impair food intake, which in athletes may result in a caloric deficit and consequently decrease energy availability for training. Notably, chewing was reported as the most painful activity by patients treated with fixed appliances (66%), in contrast to clear aligner users who experienced the greatest pain at rest two days after the appointment (37%). (36) Moreover, clear aligner patients showed better outcomes for eating and chewing comfort than brace users (47% vs 24%). (34) This also results from the fact that aligners are removable, so they do not interfere with chewing.

6. Summary and conclusions.

Summarizing the available research findings, clear aligners appear to be more effective in sustaining stable periodontal parameters, such as GI and SBI, while patients treated with fixed appliances show increased gingival index and bleeding values. (5) Furthermore, clear aligners are associated with more favorable periodontal pocket depth outcomes compared with fixed appliances, suggesting better preservation of tooth-supporting tissues. (1)

Regarding gingival aesthetics, clear aligners may be a preferable option for patients with a thin gingival biotype, as they enable more controlled and gradual tooth movement, possibly lowering the risk of gingival recession. (14) However, it should be noted that these systems may contribute to the development of orthodontic gingival embrasures (OGEs) due to mechanical pressure from the aligner and complete crown coverage. (15,16)

From a microbiological perspective, fixed appliances are associated with greater changes in the oral microbiota, including increased abundance of Gram-negative and anaerobic bacteria (19) linked to advanced stages of periodontal inflammation. (21) Radiographic findings display greater root resorption in patients treated with fixed appliances compared with clear aligners, where the average amount of root shortening is almost two times lower. (27) Additionally, clear aligners appear to have a lower impact on temporomandibular joint changes, thus making them a favorable option when maintaining condylar position is a priority. (29)

Oral health-related quality of life (OHRQoL) constitutes a valid aspect, especially for athletes. Clear aligners provide higher scores on this measure due to lower pain intensity, reduced need for analgesic administration, and fewer oral mucosa injuries. (32,36,38) Moreover, their removability ensures chewing comfort and does not affect meal choices or dietary habits. (34)

In conclusion, despite the mentioned differences, patients may demonstrate stable periodontal parameters with both treatment modalities when proper oral hygiene guidance and regular check-ups are provided. This highlights the essential role of professional care in ensuring periodontal stability during orthodontic treatment. (4)

Disclosure

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Not applicable.

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References:

1. Di Spirito F, D'Ambrosio F, Cannatà D, D'Antò V, Giordano F, Martina S. Impact of Clear Aligners versus Fixed Appliances on Periodontal Status of Patients Undergoing Orthodontic Treatment: A Systematic Review of Systematic Reviews. *Healthcare*. 6 maja 2023;11(9):1340. doi:10.3390/healthcare11091340 PubMed PMID: 37174882; PubMed Central PMCID: PMC10178428.
2. Santonocito S, Polizzi A. Oral Microbiota Changes during Orthodontic Treatment. *Front Biosci*. 27 lipca 2022;14(3):19. doi:10.31083/j.fbe1403019 PubMed PMID: 36137992.
3. Cerroni S, Pasquantonio G, Condò R, Cerroni L. Orthodontic Fixed Appliance and Periodontal Status: An Updated Systematic Review. *Open Dent J*. 2018;12:614–22. doi:10.2174/1745017901814010614 PubMed PMID: 30369970; PubMed Central PMCID: PMC6182882.

4. Madariaga ACP, Bucci R, Rongo R, Simeon V, D'Antò V, Valletta R. Impact of Fixed Orthodontic Appliance and Clear Aligners on the Periodontal Health: A Prospective Clinical Study. *Dent J.* 2 stycznia 2020;8(1):4. doi:10.3390/dj8010004 PubMed PMID: 31906577; PubMed Central PMCID: PMC7175220.

5. Tabone M, Carreras-Presas CM, Cenzato N, Del Fabbro M, Soltero RG. Impact of Clear Aligners on the Oral Microbiome: A Systematic Review of Current Evidence. *Clin Exp Dent Res.* kwietnia 2026;12(2):e70265. doi:10.1002/cre2.70265 PubMed PMID: 41849703; PubMed Central PMCID: PMC13140846.

6. Crego-Ruiz M, Jorba-García A. Assessment of the periodontal health status and gingival recession during orthodontic treatment with clear aligners and fixed appliances: A systematic review and meta-analysis. *Med Oral Patol Oral Cirurgia Bucal.* 1 lipca 2023;28(4):e330–40. doi:10.4317/medoral.25760 PubMed PMID: 36641738; PubMed Central PMCID: PMC10314350.

7. Geduk N, Ozdemir M, Erbas Unverdi G, Ballikaya E, Cehreli ZC. Clinical and radiographic performance of preformed zirconia crowns and stainless-steel crowns in permanent first molars: 18-month results of a prospective, randomized trial. *BMC Oral Health.* 3 listopada 2023;23(1):828. doi:10.1186/s12903-023-03501-1 PubMed PMID: 37924021; PubMed Central PMCID: PMC10623757.

8. Sifakakis I, Papaioannou W, Papadimitriou A, Kloukos D, Papageorgiou SN, Eliades T. Salivary levels of cariogenic bacterial species during orthodontic treatment with thermoplastic aligners or fixed appliances: a prospective cohort study. *Prog Orthod.* 1 sierpnia 2018;19(1):25. doi:10.1186/s40510-018-0230-4 PubMed PMID: 30066184; PubMed Central PMCID: PMC6068060.

9. Mummolo S, Nota A, Albani F, Marchetti E, Gatto R, Marzo G, et al. Salivary levels of *Streptococcus mutans* and *Lactobacilli* and other salivary indices in patients wearing clear aligners versus fixed orthodontic appliances: An observational study. *PloS One.* 2020;15(4):e0228798. doi:10.1371/journal.pone.0228798 PubMed PMID: 32330172; PubMed Central PMCID: PMC7182227.

10. Hussain U, Campobasso A, Noman M, Alam S, Mujeeb R, Shehzad S, et al. Influence of elastomeric and steel ligatures on periodontal health during fixed appliance orthodontic

treatment: a systematic review and meta-analysis. *Prog Orthod.* 17 czerwca 2024;25(1):24. doi:10.1186/s40510-024-00520-8 PubMed PMID: 38880839; PubMed Central PMCID: PMC11180646.

11. Partouche AJD, Castro F, Baptista AS, Costa LG, Fernandes JCH, Fernandes GV de O. Effects of Multibracket Orthodontic Treatment versus Clear Aligners on Periodontal Health: An Integrative Review. *Dent J.* 21 września 2022;10(10):177. doi:10.3390/dj10100177 PubMed PMID: 36285987; PubMed Central PMCID: PMC9600623.

12. Niemczyk W, Niemczyk S, Prokurat M, Grudnik K, Migas M, Wągrowaska K, et al. Etiology of gingival recession – a literature review. *Wiad Lek.* maja 2024;77(5):1080–5. doi:10.36740/WLek202405131

13. Tepedino M, Franchi L, Fabbro O, Chimenti C. Post-orthodontic lower incisor inclination and gingival recession-a systematic review. *Prog Orthod.* 18 czerwca 2018;19(1):17. doi:10.1186/s40510-018-0212-6 PubMed PMID: 29911278; PubMed Central PMCID: PMC6004340.

14. Ke Y, Zhu Y, Zhu M. A comparison of treatment effectiveness between clear aligner and fixed appliance therapies. *BMC Oral Health.* 23 stycznia 2019;19(1):24. doi:10.1186/s12903-018-0695-z PubMed PMID: 30674307; PubMed Central PMCID: PMC6343314.

15. Yang T, Jiang L, Sun W, Zhu M, Jiang K, Li H, et al. The incidence and severity of open gingival embrasures in adults treated with clear aligners and fixed appliances: a retrospective cohort study. *Head Face Med.* 17 lipca 2023;19(1):30. doi:10.1186/s13005-023-00375-0 PubMed PMID: 37461116; PubMed Central PMCID: PMC10351162.

16. Cui W, Liu Y, Zhao Y, Lei L, Li H. Risk factors for open gingival embrasures after clear aligners treatment: a retrospective study. *BMC Oral Health.* 11 kwietnia 2025;25(1):547. doi:10.1186/s12903-025-05915-5 PubMed PMID: 40217266; PubMed Central PMCID: PMC11992787.

17. Tian E, Luo K, Zhou Y, Jiang F, Zhang R, Liu L, et al. Factors influencing open gingival embrasures in orthodontic treatment: a retrospective clinical study. *Prog Orthod.* 21 lutego 2025;26(1):6. doi:10.1186/s40510-025-00554-6 PubMed PMID: 39982591; PubMed Central PMCID: PMC11845328.

18. Xu M, Li G, Tian J, Xie F, Zuo J, Hu J, et al. Comparison of the effects of clear aligners and fixed appliances on the oral microbiota and reactive oxygen species: a prospective study. *Front Cell Infect Microbiol.* 2025;15:1738047. doi:10.3389/fcimb.2025.1738047 PubMed PMID: 41659811; PubMed Central PMCID: PMC12876197.
19. Zheng J, Wang X, Zhang T, Jiang J, Wu J. Comparative characterization of supragingival plaque microbiomes in malocclusion adult female patients undergoing orthodontic treatment with removable aligners or fixed appliances: a descriptive cross-sectional study. *Front Cell Infect Microbiol.* 2024;14:1350181. doi:10.3389/fcimb.2024.1350181 PubMed PMID: 38803569; PubMed Central PMCID: PMC11129559.
20. Levrini L, Mangano A, Montanari P, Margherini S, Caprioglio A, Abbate GM. Periodontal health status in patients treated with the Invisalign(®) system and fixed orthodontic appliances: A 3 months clinical and microbiological evaluation. *Eur J Dent.* 2015;9(3):404–10. doi:10.4103/1305-7456.163218 PubMed PMID: 26430371; PubMed Central PMCID: PMC4569994.
21. Sarkar J, McHardy IH, Simanian EJ, Shi W, Lux R. Transcriptional responses of *Treponema denticola* to other oral bacterial species. *PloS One.* 2014;9(2):e88361. doi:10.1371/journal.pone.0088361 PubMed PMID: 24505483; PubMed Central PMCID: PMC3914990.
22. Xie Q, Li D, Ren C, Liang H, Shi G, Chen W. Comprehensive Analysis of Orthodontic Treatment Effects on the Oral Microbiome, Metabolome, and Associated Health Indicators. *Int Dent J.* 1 czerwca 2025;75(3):1585–98. doi:10.1016/j.identj.2025.02.014
23. Raghavan S, Abu Alhaija ES, Duggal MS, Narasimhan S, Al-Maweri SA. White spot lesions, plaque accumulation and salivary caries-associated bacteria in clear aligners compared to fixed orthodontic treatment. A systematic review and meta- analysis. *BMC Oral Health.* 27 sierpnia 2023;23(1):599. doi:10.1186/s12903-023-03257-8 PubMed PMID: 37635207; PubMed Central PMCID: PMC10463770.
24. Llera-Romero AS, Adobes-Martín M, Iranzo-Cortés JE, Montiel-Company JM, Garcovich D. Periodontal health status, oral microbiome, white-spot lesions and oral health related to quality of life-clear aligners versus fixed appliances: A systematic review, meta-

analysis and meta-regression. *Korean J Orthod.* 25 listopada 2023;53(6):374–92. doi:10.4041/kjod22.272 PubMed PMID: 37989575; PubMed Central PMCID: PMC10663575.

25. Abdulraheem S, Paulsson L, Petrén S, Sonesson M. Do fixed orthodontic appliances cause halitosis? A systematic review. *BMC Oral Health.* 2 maja 2019;19(1):72. doi:10.1186/s12903-019-0761-1 PubMed PMID: 31046726; PubMed Central PMCID: PMC6498650.

26. Almagrabi I, Almashraqi AA, Almagrabi BS, Mohamed AS, Wafaie K, Al-Balaa M, et al. A quantitative three-dimensional comparative study of alveolar bone changes and apical root resorption between clear aligners and fixed orthodontic appliances. *Prog Orthod.* 27 lutego 2023;24(1):6. doi:10.1186/s40510-023-00458-3 PubMed PMID: 36843193; PubMed Central PMCID: PMC9968667.

27. Kurnaz S, Buyukcavus MH. Panoramic evaluation of external root resorption in mandibular molars during orthodontic treatment: a comparison between root-filled and vital teeth treated with fixed appliances or clear aligners. *BMC Oral Health.* 28 września 2024;24(1):1152. doi:10.1186/s12903-024-04928-w PubMed PMID: 39342188; PubMed Central PMCID: PMC11439240.

28. Sicilia L, Miranda GHN, Fattori L, Furquim BDA, Normando D. Impact of Clear Aligners on the Temporomandibular Joint: A Systematic Review. *Orthod Craniofac Res.* kwiecień 2026;29(2):209–24. doi:10.1111/ocr.70094 PubMed PMID: 41459810; PubMed Central PMCID: PMC12972227.

29. Al-Somairi MAA, Zheng B, Yang X, Zhang Y, Alhammadi MS, Xu H, et al. Three-dimensional quantitative temporomandibular joint changes in skeletal class I malocclusion treated with extraction and non-extraction protocols: a comparative study of fixed orthodontic appliances and clear aligners. *Prog Orthod.* 20 stycznia 2025;26(1):4. doi:10.1186/s40510-024-00551-1 PubMed PMID: 39828796; PubMed Central PMCID: PMC11743406.

30. Al-Rokhami RK, Sakran KA, Al-Worafi NA, Al-Balaa M, Algahefi A, Li Z. Three-dimensional retrospective analysis of root resorption and incisive canal changes following maxillary incisor retraction in class I and class II extraction cases: a comparison of clear

aligners and fixed appliances. *Sci Rep.* 10 lipca 2025;15(1):24896. doi:10.1038/s41598-025-10210-y PubMed PMID: 40640434; PubMed Central PMCID: PMC12246165.

31. Han JY. A comparative study of combined periodontal and orthodontic treatment with fixed appliances and clear aligners in patients with periodontitis. *J Periodontal Implant Sci.* grudnia 2015;45(6):193–204. doi:10.5051/jpis.2015.45.6.193 PubMed PMID: 26734489; PubMed Central PMCID: PMC4698945.

32. Li Q, Du Y, Yang K. Comparison of pain intensity and impacts on oral health-related quality of life between orthodontic patients treated with clear aligners and fixed appliances: a systematic review and meta-analysis. *BMC Oral Health.* 24 listopada 2023;23(1):920. doi:10.1186/s12903-023-03681-w PubMed PMID: 38001455; PubMed Central PMCID: PMC10675971.

33. Kaklamanos EG, Makrygiannakis MA, Athanasiou AE. Oral Health-Related Quality of Life throughout Treatment with Clear Aligners in Comparison to Conventional Metal Fixed Orthodontic Appliances: A Systematic Review. *Int J Environ Res Public Health.* 17 lutego 2023;20(4):3537. doi:10.3390/ijerph20043537 PubMed PMID: 36834235; PubMed Central PMCID: PMC9961780.

34. Cardoso PC, Espinosa DG, Mecenas P, Flores-Mir C, Normando D. Pain level between clear aligners and fixed appliances: a systematic review. *Prog Orthod.* 20 stycznia 2020;21(1):3. doi:10.1186/s40510-019-0303-z PubMed PMID: 31956934; PubMed Central PMCID: PMC6970090.

35. Oliveira PC de, Vilella B de S, Martins E, Martins M, Mattos CT de, Nascimento V de C, Vilella O de V. Impact of orthodontic appliances on patients' daily lives: a comparison between clear aligners and fixed appliances. *Dent Press J Orthod.* 2026;30(5):e252562. doi:10.1590/2177-6709.30.5.e252562.oar PubMed PMID: 41538529; PubMed Central PMCID: PMC12788501.

36. Chan V, Shroff B, Kravitz ND, Carrico C, Hawkins D, Tran P, et al. Orthodontic pain with fixed appliances and clear aligners: A 6-month comparison. *Am J Orthod Dentofacial Orthop.* 1 listopada 2024;166(5):469–79. doi:10.1016/j.ajodo.2024.07.002 PubMed PMID: 39078353.

37. Cheng C, Xie T, Wang J. The efficacy of analgesics in controlling orthodontic pain: a systematic review and meta-analysis. *BMC Oral Health*. 18 września 2020;20(1):259. doi:10.1186/s12903-020-01245-w PubMed PMID: 32948150; PubMed Central PMCID: PMC7501721.
38. Gou Y, Ungvijanpunya N, Chen L, Zeng Y, Ye H, Cao L. Clear aligner vs fixed self-ligating appliances: Orthodontic emergency during the 2020 coronavirus disease 2019 pandemic. *Am J Orthod Dentofacial Orthop*. 1 kwietnia 2022;161(4):e400–6. doi:10.1016/j.ajodo.2021.12.009 PubMed PMID: 35058102.
39. Ronchi Lemos C, Ventura Fadel MA, Polmann H, Meller Dias de Oliveira J, Pauletto P, Miron Stefani C, et al. Clear aligner's adverse effects: A systematic review protocol. *PloS One*. 2024;19(5):e0302049. doi:10.1371/journal.pone.0302049 PubMed PMID: 38696380; PubMed Central PMCID: PMC11065214.