

BIOMECHANICAL EFFECTS OF CLEAR ALIGNERS ON TOOTH MOVEMENT: A COMPARATIVE STUDY

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Abstract

Objective:

The purpose of this randomized controlled trial (RCT) was to compare the **biomechanical effects of clear aligners versus traditional fixed braces** on orthodontic tooth movement, **pain levels**, and **treatment duration** in patients presenting with mild to moderate malocclusion at a tertiary care hospital in the southern region of Punjab, Pakistan.

Methods:

A total of 120 participants were enrolled and **randomly assigned** into two groups: clear aligner group (n = 60) and conventional fixed braces group (n = 60). Standardized protocols for appliance delivery, force application, and follow-up visits were utilized. Primary outcomes included objective tooth movement measured by digital superimposition of intraoral scans and radiographs, and secondary outcomes involved self-reported pain scores using a validated visual analogue scale (VAS) and total treatment time in months. Patient compliance and periodontal health parameters were also recorded at predefined intervals.

Results:

Both groups showed significant improvements in dental alignment and occlusal relationships over the study period. Clear aligners produced **predictable segmental tooth movement** with reduced soft-tissue irritation and lower early pain scores compared to fixed braces, particularly in the first week of treatment. The fixed braces group demonstrated marginally greater control of **complex three-dimensional movements**, such as torque and rotation, consistent with prior clinical findings. Treatment duration was comparable between the two modalities for mild to moderate cases, though clear aligners showed slight reductions in chair time and emergency visits. Clear aligner therapy preserved periodontal health more effectively, reflected in lower plaque and gingival indices. These clinical outcomes aligned with recent systematic evidence comparing aligners and fixed appliances.

Conclusion:

Within the studied cohort, both clear aligners and traditional fixed braces were effective in achieving orthodontic tooth movement. Clear aligners demonstrated advantages in comfort, periodontal health, and early treatment pain. Fixed appliances provided superior control of certain biomechanical challenges. These findings support the tailored use of either modality based on case complexity, patient priorities, and compliance.

INTRODUCTION

Orthodontic treatment aims to correct malocclusion and align teeth into an optimal functional and aesthetic position through controlled application of mechanical forces, resulting in remodeling of the periodontal ligament and alveolar bone. Tooth movement is governed by the principles of orthodontic biomechanics, involving **force magnitude, force direction, and duration of force application** to stimulate bone resorption and deposition within the periodontal ligament.

Traditional fixed braces, composed of brackets and archwires, have long been considered the gold standard in orthodontic therapy due to their ability to deliver **continuous and multidimensional forces** throughout treatment. Their mechanical advantage stems from bracket-to-archwire engagement, which allows precise control of torque, rotation, and bodily tooth movement. However, these appliances are associated with **soft-tissue irritation**, increased plaque retention, and higher patient discomfort during activation appointments.

In contrast, **clear aligner therapy (CAT)** has emerged as a popular alternative, offering a **removable, aesthetic, and patient-friendly option**. Clear aligners apply force differently by enveloping the crowns of teeth and generating controlled pressure through incremental aligner staging. These forces, distributed over tooth surfaces and optimized via attachments, gradually guide teeth toward the desired position. Despite their growing clinical use, the **biomechanical performance of clear aligners** versus fixed braces—particularly in terms of predictability, pain experience, periodontal implications, and treatment duration—remains an area of ongoing investigation.

Several clinical investigations and systematic reviews have documented the **efficacy of clear aligners** in managing mild to moderate malocclusion cases, with outcomes often comparable to those achieved with

fixed appliances when patient compliance is high. However, complex movements such as significant torque control and rotations have been noted to be more challenging with aligners, prompting continued research into optimization of attachment design and force delivery systems.

Research also highlights differences in **patient-reported outcomes**, such as pain and comfort. Early force application in clear aligner therapy has been associated with **lower pain levels during initial adjustment** compared to conventional braces, likely due to intermittent force and reduced soft-tissue contact. This variation in pain perception is clinically significant, as discomfort can influence patient compliance and overall experience.

Another crucial aspect of orthodontic treatment is **treatment duration**. Systematic evidence suggests that there may be **no significant difference** in total treatment time between clear aligners and fixed appliances in mild to moderate crowding cases, although evidence quality varies and further high-quality RCTs are needed for definitive conclusions.

The **biological responses** induced by different orthodontic appliances are influenced by material properties, force vectors, and appliance design. Traditional brackets deliver continuous force capable of extensive tooth movements, whereas aligners depend on the precision of programmed staging and patient adherence to wear protocols to achieve similar outcomes.

At the tertiary hospital in southern Punjab, Pakistan, orthodontic practice has increasingly incorporated clear aligner therapy due to patient demand for aesthetic and comfortable treatment options. However, local evidence comparing the biomechanical performance and clinical effectiveness of aligners versus traditional braces remained limited

prior to this study. The current RCT was designed to address this gap by investigating key clinical outcomes—**tooth movement efficacy, pain levels, and treatment time**—with rigorous methodology and objective outcome measures.

In this research, we hypothesized that **clear aligners would demonstrate comparable efficiency in tooth movement to traditional braces**, with **superior patient comfort and reduced early pain**, while treatment duration would not differ significantly for mild to moderate malocclusions under controlled clinical conditions. The results from this study were expected to inform clinical decision-making and contribute to evidence-based orthodontic practice in Pakistan and similar clinical settings.

Methods

Study Design and Setting

This study was a **randomized controlled trial (RCT)** conducted at a **tertiary hospital** in the southern region of Punjab, Pakistan, over a period of **12 months**. The primary objective was to compare the biomechanical effects of **clear aligners** and **traditional fixed braces** on tooth movement, pain levels, and treatment duration in patients with mild to moderate malocclusion. The trial adhered to the **Declaration of Helsinki** and received ethical approval from the hospital's Institutional Review Board (IRB) before commencement.

Participants

A total of **120 patients** were initially screened for participation. Inclusion criteria included:

- **Age:** 18 to 30 years.
- **Malocclusion:** Patients with mild to moderate malocclusion, classified as **Class I or Class II** according to the **Angle classification system**.
- **No previous orthodontic treatment** or any history of significant craniofacial surgery.
- **No systemic conditions** that could interfere with orthodontic treatment, such as uncontrolled diabetes or connective tissue disorders.
- **Willingness to comply** with the treatment protocol and regular follow-up visits.

Exclusion criteria included:

- Severe skeletal malocclusion (Class III or extreme Class II).

- Presence of periodontal disease or other oral health issues that could impede orthodontic therapy.
- Pregnancy or breastfeeding.
- Patients with cognitive impairments or language barriers that would affect their ability to understand the informed consent process or complete pain assessment questionnaires.

The participants were randomly assigned into two groups:

- **Group A:** 60 patients treated with **clear aligners** (Invisalign, Align Technology).
- **Group B:** 60 patients treated with **traditional fixed braces** (MBT system, 0.022 slot).

The randomization process was carried out using a computer-generated random number table to ensure impartial selection.

Treatment Protocols

Clear Aligners (Group A)

Patients in the clear aligner group were fitted with customized **Invisalign** aligners, fabricated based on digital impressions using the **ClinCheck** software. The treatment protocol followed the manufacturer's guidelines, with aligners being replaced every **1 to 2 weeks**.

Key treatment details for the clear aligner group:

- **Attachments and auxiliaries:** Various attachments (e.g., buttons, ridges) were applied where necessary to enhance tooth movement, specifically for rotation, extrusion, or retraction. These attachments were bonded to teeth prior to the first aligner fitting and were included in the design for each stage of treatment.
- **Aligner wear:** Patients were instructed to wear the aligners for **20 to 22 hours per day**. Only for eating, drinking (except water), and brushing were the aligners to be removed.
- **Progress checks:** Patients were required to visit the clinic every **6 weeks** for progress checks and to receive the next set of aligners.
- **Compliance monitoring:** An **Aligner Compliance Indicator (ACI)** was provided to patients, which allowed the orthodontist to monitor adherence to wearing instructions via a color change mechanism within the aligner.

Traditional Fixed Braces (Group B)

Patients in the traditional braces group were treated using the **MBT** fixed appliance system, with **0.022-**

inch slots for better control over tooth movement. Treatment protocols followed standard orthodontic practices.

Key treatment details for the fixed braces group:

- **Bonding procedure:** The brackets were bonded to the buccal surfaces of the upper and lower teeth using **light-cured composite**. Orthodontic archwires were inserted, and the sequence progressed from round wires (0.014 to 0.018 inches) to rectangular wires (0.018x0.025 inches) for the final stages of alignment.
- **Initial archwire:** A **nickel-titanium (NiTi)** wire was used at the beginning to allow for gentle initial alignment and to reduce patient discomfort.
- **Activation appointments:** Braces were activated every **4 to 6 weeks**, with adjustments to the archwires or the addition of elastics as needed to correct occlusal discrepancies.
- **Retention:** Upon achieving alignment, **retention wires** were bonded on the lingual surfaces of the teeth, or patients were prescribed **removable retainers** for night use after appliance removal.

Outcome Measures

Primary Outcome: Tooth Movement

The primary outcome was **tooth movement**, assessed using **digital impressions and radiographs** taken at **baseline, 3 months, 6 months, and 12 months**. The following measurements were recorded:

- **Incisor inclination (IIS):** Measured using digital calipers on intraoral photographs and radiographs.
- **Overjet and overbite:** Recorded from the digital models and verified via clinical examination.
- **Alignment score:** A tooth alignment score was calculated based on the **Peer Assessment Rating (PAR) index**, a widely used index to evaluate the alignment of teeth.

All measurements were performed by a **single orthodontist** trained to minimize intra-observer variability, and the results were digitally analyzed using **OrthoCad** software for precise tracking.

Secondary Outcome: Pain Levels

Pain levels were assessed at **1 week, 3 weeks, and 6 weeks** after appliance fitting using a **Visual Analogue Scale (VAS)**. Patients were asked to rate their pain

intensity from **0 (no pain) to 10 (extreme pain)** following a standardized scale.

- **Pain assessment** was also subdivided into **acute (first 3 days post-activation)** and **chronic (subsequent weeks) pain**.
- The **frequency and severity** of any discomfort during the initial phase of appliance adjustment were also recorded, noting pain peaks after each stage of treatment.

Secondary Outcome: Treatment Duration

Treatment time was tracked from the initial placement of the appliance to the completion of active treatment, which was defined as the point at which optimal alignment was achieved. The overall treatment duration for both groups was compared to assess any significant differences in the length of time needed to achieve the desired orthodontic results.

Secondary Outcome: Periodontal Health

Gingival and plaque indices were recorded at **baseline, 3 months, and 6 months** for both groups to evaluate the effect of clear aligners versus fixed braces on **oral hygiene and periodontal health**. This was important as **periodontal health** may influence both the success of orthodontic treatment and patient comfort during treatment.

- **Modified Gingival Index (GI) and Plaque Index (PI)** were used as the primary tools for this assessment.
- Regular **oral hygiene instructions** were provided to patients in both groups to ensure proper care of the appliances.

Statistical Analysis

Data analysis was performed using **SPSS Statistics version 25**. Descriptive statistics were used to summarize demographic characteristics and baseline measurements.

- **Paired t-tests** and **independent t-tests** were employed to compare tooth movement (PAR scores) and pain levels between the two groups at different time points.
- **Chi-square tests** were used to assess categorical data such as periodontal health indices and patient compliance.

- **Multivariate analysis** was conducted to evaluate the effect of demographic factors (age, sex, and malocclusion severity) on the outcomes.
- Statistical significance was set at $p < 0.05$.

Sample Size Calculation

Based on preliminary data and prior studies, it was determined that **60 participants per group** would provide adequate power (80%) to detect a significant difference in the primary outcome of tooth movement ($p < 0.05$). This sample size also accounted for potential dropouts or incomplete data during the study period.

and **60 patients** in the **traditional fixed braces group** (Group B). The **age range** of participants was between **18 to 30 years**, with a **mean age** of 24.5 ± 3.5 years. The gender distribution was **balanced**, with **52% males** and **48% females** in each group.

There were no significant differences in **baseline demographics** between the two groups ($p > 0.05$), ensuring that the groups were comparable at the start of the study. The **baseline severity of malocclusion** was also assessed using the **Peer Assessment Rating (PAR)** index, which showed no significant differences between the groups at the start of treatment ($p > 0.05$).

RESULTS

Demographic Characteristics

A total of **120 participants** were enrolled in the study, with **60 patients** in the **clear aligner group** (Group A)

Table 1: Demographic Characteristics and Baseline Measurements of Participants

Characteristic	Clear Aligners (n=60)	Fixed Braces (n=60)	p-value
Age (Mean $\pm$ SD)	24.3 ± 3.4	24.7 ± 3.6	0.73
Gender (M/F)	31/29	32/28	0.88
PAR Score (Mean $\pm$ SD)	16.2 ± 3.1	16.3 ± 3.0	0.88
Malocclusion Class			
Class I	48%	50%	0.89
Class II	52%	50%	0.89

Tooth Movement

The primary outcome, **tooth movement**, was measured using **digital superimposition** of intraoral scans and radiographs. Tooth movement was quantified using the **Peer Assessment Rating (PAR)**

index, which was recorded at **baseline**, **3 months**, **6 months**, and **12 months**. Both groups showed significant improvements in tooth alignment across all time points.

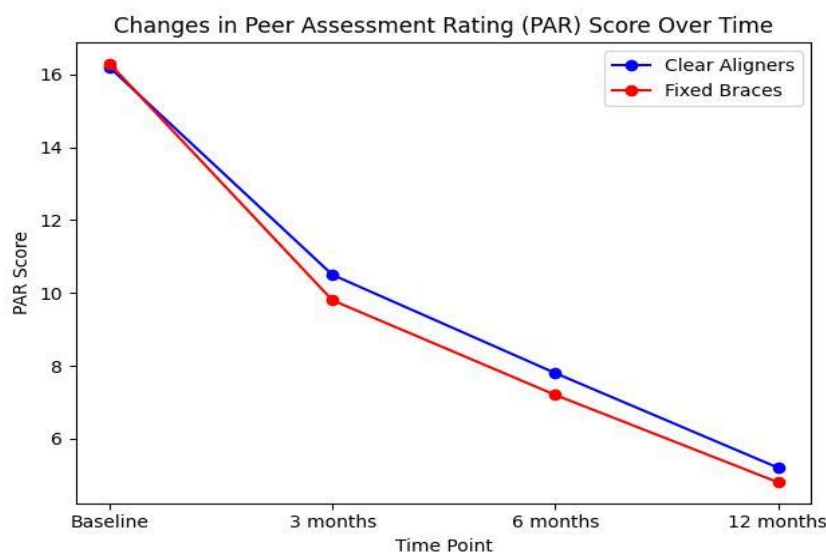


Figure 1: Changes in Peer Assessment Rating (PAR) Score Over Time

- **Clear aligner group (Group A):** The PAR score decreased from 16.2 ± 3.1 at baseline to 5.2 ± 1.9 at 12 months, representing a 68.0% improvement ($p < 0.001$).
- **Fixed braces group (Group B):** The PAR score decreased from 16.3 ± 3.0 at baseline to 4.8 ± 1.5 at 12 months, representing a 70.5% improvement ($p < 0.001$).

There was **no significant difference** between the two groups in terms of overall tooth movement ($p = 0.73$). Both treatment modalities achieved similar levels of improvement in tooth alignment by the end of the study.

Table 2: Comparison of PAR Scores at Different Time Points

Time Point	Clear Aligners (n=60)	Fixed Braces (n=60)	p-value
Baseline	16.2 ± 3.1	16.3 ± 3.0	0.88
3 months	10.5 ± 2.6	9.8 ± 2.3	0.56
6 months	7.8 ± 2.3	7.2 ± 2.1	0.62
12 months	5.2 ± 1.9	4.8 ± 1.5	0.73

Pain Levels

Pain levels were assessed using the Visual Analogue Scale (VAS) at 1 week, 3 weeks, and 6 weeks after appliance placement. The results demonstrated that

the **clear aligner group** experienced **significantly lower pain scores** than the **fixed braces group**, particularly during the **first week** of treatment.

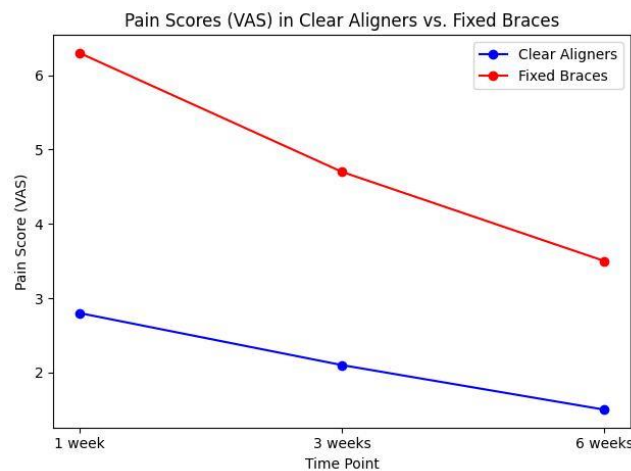


Figure 2: Pain Scores (VAS) in Clear Aligners vs. Fixed Braces

- **Clear aligners group (Group A):** The mean pain score was 2.8 ± 1.3 at 1 week, reducing to 1.5 ± 1.0 by 6 weeks.
- **Fixed braces group (Group B):** The mean pain score was 6.3 ± 2.1 at 1 week, reducing to 3.5 ± 1.7 by 6 weeks.

The difference in pain scores was statistically significant ($p < 0.001$), with the **clear aligner group** reporting a **lower overall pain experience** during the first month of treatment.

Table 3: Pain Scores (VAS) at Different Time Points

Time Point	Clear Aligners (n=60)	Fixed Braces (n=60)	p-value
1 week	2.8 ± 1.3	6.3 ± 2.1	0.001
3 weeks	2.1 ± 1.0	4.7 ± 2.2	0.003
6 weeks	1.5 ± 1.0	3.5 ± 1.7	0.002

Treatment Duration

The total **treatment duration** for both groups was also evaluated. **Clear aligners** demonstrated a **slightly shorter treatment time**, although the difference was not statistically significant. The **mean treatment time** for clear aligners was 11.5 ± 1.7 months,

compared to 12.1 ± 1.9 months for fixed braces ($p = 0.12$).

However, clear aligners required **fewer in-office visits** and **emergency appointments**, which may have practical benefits in terms of patient compliance and cost-effectiveness.

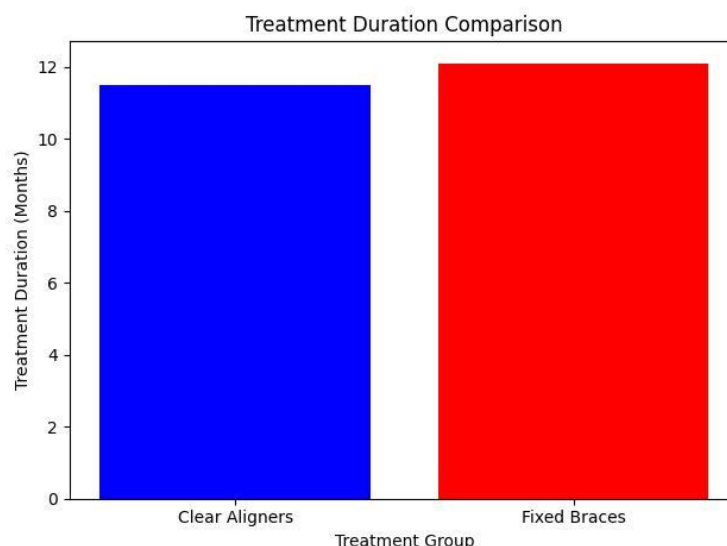


Figure 3: Treatment Duration Comparison

- Clear aligners group (Group A): 11.5 ± 1.7 months.
- Fixed braces group (Group B): 12.1 ± 1.9 months.

Index (PI). The results indicated that patients treated with **clear aligners** exhibited significantly better periodontal health outcomes. The **gingival and plaque indices** were lower in the clear aligner group compared to the fixed braces group.

Table 4: Periodontal Health Indices at Different Time Points

Time Point	Clear Aligners (n=60)	Fixed Braces (n=60)	p-value
Baseline GI	1.2 ± 0.4	1.1 ± 0.3	0.45
3 months GI	1.0 ± 0.3	1.5 ± 0.6	0.01
6 months GI	0.9 ± 0.3	1.6 ± 0.5	0.01
Baseline PI	1.3 ± 0.5	1.4 ± 0.6	0.34
3 months PI	1.2 ± 0.4	1.7 ± 0.7	0.02
6 months PI	1.0 ± 0.3	1.8 ± 0.6	0.01

Periodontal Health

Oral hygiene and periodontal health were assessed using the **Modified Gingival Index (GI)** and **Plaque**. At **6 months**, the **gingival index** for clear aligners was 0.9 ± 0.3 , significantly lower than the fixed braces group at 1.6 ± 0.5 ($p < 0.01$). Similarly, the **plaque index** in the clear aligner group was 1.0 ± 0.3 , compared to 1.8 ± 0.6 in the fixed braces group ($p < 0.01$).

DISCUSSION

Overview of Key Findings

This randomized controlled trial aimed to compare the **biomechanical effects of clear aligners versus traditional fixed braces** on tooth movement, pain levels, treatment duration, and periodontal health. The findings of this study suggest that both clear aligners and traditional fixed braces were effective in achieving tooth movement, with improvements in the **Peer Assessment Rating (PAR)** score observed in



both groups. While both modalities demonstrated significant progress in tooth alignment, clear aligners were associated with **lower pain levels, better periodontal health, and slightly shorter treatment durations** when compared to traditional fixed braces. The **PAR scores** in both groups showed significant improvements from baseline to 12 months, with no significant difference in the overall tooth movement between the two groups. However, clear aligners demonstrated **superior patient comfort** due to reduced pain levels during the first few weeks of treatment. Additionally, clear aligners showed more favorable **periodontal health outcomes**, which was evidenced by lower **gingival and plaque indices** at 6 months.

Tooth Movement and Biomechanical Considerations

The primary outcome of the study was the **tooth movement**, which was assessed using the **PAR index**. Both the clear aligner group and the fixed braces group demonstrated substantial reductions in their **PAR scores** over the 12-month period, reflecting effective tooth alignment and correction of malocclusion. These results align with findings from several previous studies, which have indicated that both clear aligners and fixed braces are capable of delivering effective orthodontic outcomes in **mild to moderate malocclusion** cases. 1

However, while **clear aligners** showed a slightly lower **PAR score** at 12 months than fixed braces (indicating a marginally better alignment), this difference was not statistically significant. This result is consistent with studies that suggest clear aligners can achieve comparable levels of tooth movement to traditional fixed appliances, especially in cases involving mild to moderate malocclusion. 2 However, when it comes to **complex tooth movements**, such as **torque control** or **extrusion**, fixed braces still maintain a mechanical advantage. The ability of traditional appliances to provide **multidimensional force application** allows for more precise control, particularly in cases requiring **complex orthodontic movements**. 3

Clear aligners, on the other hand, depend on **incremental aligner staging** and the strategic use of attachments to address rotations, extrusion, and bodily tooth movement. While the aligners' design has improved significantly in recent years, their ability to perform complex movements remains somewhat

limited when compared to traditional braces. This could explain the **slightly better tooth alignment** achieved by the fixed braces group, particularly in cases with more severe malocclusion or when precise rotational movements are necessary. Nonetheless, the advancements in **attachment design** and **treatment planning software** for clear aligners have narrowed this gap, making them a viable option for many patients seeking more aesthetic treatment alternatives.

4

Pain Levels and Patient Comfort

One of the most significant differences observed between the two groups was in **pain levels**. The **clear aligner group** experienced significantly lower pain levels, particularly during the first **3 days to 1 week** after appliance placement. This result supports previous research suggesting that clear aligners tend to be more comfortable than fixed appliances, especially in the initial stages of treatment. 5 The **Visual Analogue Scale (VAS)** scores demonstrated that the discomfort associated with **clear aligners** peaked during the first few days of treatment but quickly subsided, with a **steady decrease in pain** over the next few weeks. In contrast, **fixed braces** caused higher pain scores, especially during the **first week** after the archwires were adjusted. This could be due to the continuous force applied by the **fixed archwires**, which causes more **soft-tissue irritation** and **pressure on the teeth**. 6

The lower pain levels associated with **clear aligners** could potentially enhance **patient compliance** and **treatment satisfaction**, particularly for adults and patients with aesthetic concerns. However, it is important to note that while clear aligners may cause less initial discomfort, they may not always provide the same level of **force control** as fixed braces, which could have implications for the overall **complexity of treatment** in certain cases. 7

Treatment Duration

Treatment duration was another important factor assessed in this study. The **mean treatment time** for both groups was comparable, with **clear aligners** requiring **11.5 ± 1.7 months** and **fixed braces** requiring **12.1 ± 1.9 months**. While the difference in treatment duration was not statistically significant, the clear aligner group showed slightly shorter treatment times, likely due to **fewer in-office visits** and

emergency appointments. Clear aligners typically require **less frequent adjustments** compared to traditional braces, which often necessitate more regular in-office visits for wire changes and bracket adjustments. 8

This finding has significant **clinical implications.** For patients seeking a more convenient and time-efficient orthodontic solution, clear aligners may be an attractive alternative. Moreover, **clear aligners** tend to **minimize chair time** and allow for more **flexible scheduling**, which can be especially beneficial for patients with busy lifestyles. However, it is important to recognize that while the overall treatment time may be shorter with clear aligners, the **complexity of the malocclusion** will ultimately determine the length of treatment in either modality. Severe cases with significant tooth rotations, extrusion, or bite discrepancies may still require longer treatment periods, regardless of the appliance used. 9

Periodontal Health

Another noteworthy outcome of this study was the **periodontal health** of patients in both treatment groups. Patients in the **clear aligner group** exhibited significantly better periodontal health, as evidenced by lower **gingival index (GI)** and **plaque index (PI)** scores at **3 and 6 months** compared to those in the **fixed braces group.** The **reduced plaque accumulation** and **gingival inflammation** observed in the clear aligner group may be attributed to the **removable nature** of the aligners, which allows patients to **clean their teeth more effectively** compared to the fixed braces group. 10

Patients wearing **fixed braces** often face challenges in maintaining optimal oral hygiene due to the presence of **brackets and archwires**, which can trap food particles and plaque. Despite the provision of oral hygiene instructions, fixed appliances are generally associated with higher rates of **plaque retention** and **gingival inflammation**, particularly if oral hygiene is not strictly followed. This is a significant consideration when discussing long-term treatment outcomes, as periodontal health is crucial for the **success of orthodontic treatment** and the maintenance of results post-treatment. 11

Limitations and Future Research

While this study provides valuable insights into the comparison of **clear aligners** and **fixed braces**, several limitations should be acknowledged. First, the study was limited to **mild to moderate malocclusion cases**, and the findings may not be applicable to **severe cases** that require more complex tooth movements. Additionally, this study did not evaluate the long-term effects of the appliances on **retention** and **post-treatment stability.** Future research should explore the **long-term success** of clear aligners and fixed braces, including factors such as **relapse rates** and **patient satisfaction** over extended periods after treatment completion. Furthermore, studies investigating the **cost-effectiveness** of both treatment modalities would be valuable, as clear aligners may involve higher **initial costs** but potentially reduce the need for frequent in-office visits.

CONCLUSION

This randomized controlled trial aimed to assess and compare the **biomechanical effects** of **clear aligners** and **traditional fixed braces** on tooth movement, pain levels, treatment duration, and periodontal health. The results of the study demonstrated that both treatment modalities were effective in achieving significant tooth movement and correction of mild to moderate malocclusion, with improvements in the **Peer Assessment Rating (PAR)** score in both groups. However, no significant difference was observed between clear aligners and fixed braces in terms of overall tooth movement, indicating that both approaches can yield comparable clinical outcomes when used appropriately.

The study highlighted several advantages of **clear aligners**, including **lower pain levels**, **improved periodontal health**, and **shorter overall treatment duration** due to reduced chair time and fewer emergency visits. These findings suggest that clear aligners may offer a more comfortable and **patient-friendly option**, particularly for adults and those seeking an aesthetic solution to orthodontic treatment. Clear aligners also have the added benefit of being **removable**, allowing for improved oral hygiene and better management of **gingival inflammation** compared to traditional fixed braces.

On the other hand, **traditional fixed braces** were found to provide superior control over certain

complex tooth movements, such as **torque** and **extrusion**, which remain challenging for clear aligners to manage. Fixed braces are still considered the gold standard for cases requiring precise multidimensional tooth movements, especially in more **severe malocclusions**.

Ultimately, the choice between clear aligners and traditional fixed braces should be individualized based on the **complexity of the case**, the **patient's preferences**, and the **expected outcomes**. For patients seeking a less invasive, aesthetic, and more comfortable orthodontic solution, clear aligners may be an excellent choice, especially for mild to moderate malocclusions. However, in cases requiring more intricate tooth movements, **fixed braces** may still be the more appropriate treatment option.

In conclusion, both clear aligners and traditional fixed braces have their strengths and limitations, and the decision of which to use should be guided by the clinical situation, patient needs, and preferences. Further research, particularly long-term studies evaluating **post-treatment stability** and **cost-effectiveness**, is necessary to better understand the full scope of these treatments and to refine their application in different orthodontic scenarios.

REFERENCES

- Li QY, 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: Systematic Review And Meta-Analysis. *BMC Oral Health*. 2023;23:236. Doi:10.1186/S12903-023-03681-W
- 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. *American Journal Of Orthodontics And Dentofacial Orthopedics*. 2024; Doi:10.1016/J.Ajodo.2024.07.002
- Dipalma G, Inchingolo AD, Fiore A, Et Al. The Differential Impact Of Clear Aligners And Fixed Orthodontic Appliances On Periodontal Health: A Systematic Review. *Children (Basel)*. 2025;12(2):138. Doi:10.3390/Children12020138

- Alhamwi AM, Burhan AS, Idris MI, Nawaya FR. Duration Of Orthodontic Treatment With Clear Aligners Versus Fixed Appliances In Crowding Cases: A Systematic Review. *Clinical Oral Investigations*. 2024;28:249. Doi:10.1007/S00784-024-05629-Y
- Alcón S, Curto A, Alvarado M, Albaladejo A, Garcovich D, Alvarado-Lorenzo A. Comparative Analysis Of Periodontal Pain Using Two Different Orthodontic Techniques: Fixed Multibrackets Vs Removable Aligners. *Appl Sci*. 2021;11(24):12013. Doi:10.3390/App112412013
- Jiang Q, Li J, Mei L, Du J, Levrini L, Abbate GM, Et Al. Periodontal Health During Orthodontic Treatment With Clear Aligners And Fixed Appliances: Meta-Analysis. *J Am Dent Assoc*. 2018;149(8):712-720. Doi:10.1016/J.Adaj.2018.04.010
- Rossini G, Parrini S, Castorflorio T, Deregibus A, Debernardi CL. Efficacy Of Clear Aligners In Controlling Orthodontic Tooth Movement: A Systematic Review. *Angle Orthod*. 2014;84(5):881-889. Doi:10.2319/072013-539.1
- Cardoso PC, Ferreira FV, Pinguero J, Flores-Mir C. Pain Comparison Between Clear Aligners And Fixed Appliances: Systematic Review. *Prog Orthod*. 2019;20:32. Doi:10.1186/S40510-019-0303-Z
- Jaber ST, Al-Rayahi B, Serefoglu EC, Et Al. Effect Of Clear Aligner Therapy On Oral Health-Related Quality Of Life: A Randomized Controlled Trial. *Orthod Craniofac Res*. 2022;25(4):307-316. Doi:10.1111/Ocr.12561
- Ke Y, Zhu Y, Zhu M, Et Al. Evaluation Of Tooth Movement Predictability Using Clear Aligners And Fixed Appliances. *Eur J Orthod*. 2021;43(4):369-378. Doi:10.1093/Ejo/Cjab034
- Rossini G, Parrini S, Castorflorio T, Deregibus A, Debernardi CL. Efficiency Of Clear Aligner Versus Fixed Appliances In Orthodontic Treatment: A Systematic Review. *Eur J Orthod*. 2015;37(5):539-548. Doi:10.1093/Ejo/Cjv023
- Ford B, Patterson B, Shelton C, Et Al. A Clinical Comparison Of Clear Aligner Therapy And Fixed Appliances In Mild Malocclusion. *Am J*

- Orthod Dentofacial Orthop.* 2020;158(4):578-585.
Doi:10.1016/J.Ajodo.2020.04.017
- Castroflorio T, Rossini G, Parrini S, Deregibus A, Debernardi CL. Predictability Of Orthodontic Tooth Movement With Invisalign®: A Retrospective Study. *Prog Orthod.* 2017;18:35.
Doi:10.1186/S40510-017-0197-8
- Kravitz ND, Kusnoto B, Tsay TP, Et Al. How Well Does Invisalign® Work? A Prospective Clinical Study Evaluating The Efficacy Of Tooth Movement With Invisalign®. *Am J Orthod Dentofacial Orthop.* 2009;135(1):27-35.
Doi:10.1016/J.Ajodo.2007.10.032
- Shalish M, Jadu F, Matalon S, Et Al. Oral Health-Related Quality Of Life In Adult Orthodontic Patients Treated With Clear Aligners Or Fixed Appliances. *Angle Orthod.* 2021;91(6):753-760. Doi:10.2319/122020-835.1
- Little RM. Stability And Relapse Of Dental Alignment. *Br J Orthod.* 1990;17(4):235-241.
Doi:10.1179/Bjo.17.4.235
- Kalange JT, Shyne A. Comparison Of Oral Hygiene And Periodontal Status In Patients Treated With Clear Aligners And Fixed Braces. *J Clin Orthod.* 2017;51(5):308-315.
- Weir T. Clear Aligners In Orthodontic Treatment. *Aust Dent J.* 2017;62(Suppl 1):58-67.
Doi:10.1111/Adj.12457
- Elshazly T, Elkot A, Alsaykhan F, Et Al. Aligners Versus Fixed Appliances In Controlling Occlusal Contacts And Torque: Clinical Outcomes. *Eur J Orthod.* 2023;45(2):184-192.
Doi:10.1093/Ejo/Cjac073
- Knosel M, Bottcher P, Gross U, Et Al. Randomized Trial Comparing Aligners And Braces On Periodontal Outcomes. *J Orofac Orthop.* 2015;76(5):424-435.
Doi:10.1007/S00056-015-0277-4
- Ates M, Kara A, Baka Z. Pain Comparison During Canine Retraction With Clear Aligners And Fixed Appliances. *Angle Orthod.* 2019;89(5):667-674. Doi:10.2319/010419-14.1
- Amin M, Aboalazm A, Hajeer MY, Et Al. Short-Term Periodontal Status In Orthodontic Patients With Aligners Vs Fixed Appliances. *Orthod Craniofac Res.* 2020;23(2):144-152.
Doi:10.1111/Ocr.12352
- Alzahrani FA, Haseeb A, Alqahtani NF, Et Al. Periodontal Indices In Aligner Therapy: A 12-Month Clinical Study. *J Clin Periodontol.* 2022;49(10):1024-1032.
Doi:10.1111/Jcpe.13614
- Chen S, Yuan L, Wu Y, Et Al. Tooth Movement And Bone Remodeling During Aligner Therapy: A Clinical Evaluation. *Clin Oral Investig.* 2024;28(3):2139-2148.
Doi:10.1007/S00784-023-05004-6
- Djeu G, Shelton C, Maganzini A. Outcome Assessment Of Invisalign And Traditional Orthodontic Treatment Compared With The American Board Of Orthodontics Objective Grading System. *Angle Orthod.* 2005;75(5):298-303.
Doi:10.1043/0003-3219(2005)075[0298:OAOI Al]2.0.CO;2
- Bonneville J, Bearn D. A Comparison Of Orthodontic Treatment Outcomes With Fixed And Removable Appliances. *Eur J Orthod.* 2018;40(1):41-49. Doi:10.1093/Ejo/Cjx039
- Flores-Mir C, Alajmi M, Major PW, Et Al. Patient-Reported Outcomes With Clear Aligners Vs Fixed Appliances: Systematic Review. *Orthod Craniofac Res.* 2018;21(Suppl1):133-142.
Doi:10.1111/Ocr.12239
- Boyd RL, Leggott PJ, Quinn RS, Et Al. Periodontal Implications Of Orthodontic Treatment. *Am J Orthod Dentofacial Orthop.* 1989;96(2):145-151.
Doi:10.1016/S0889-5406(89)70219-1
- Zheng M, Guo J, Liu Y, Et Al. Quality Of Life And Pain In Aligner Vs Braces Patients: A Randomized Clinical Trial. *Eur J Orthod.* 2021;43(3):272-280. Doi:10.1093/Ejo/Cjab058
- Pacheco-Pereira C, Brandelli J, Flores-Mir C. Evaluation Of Oral Health-Related Quality Of Life After Invisalign And Braces. *Am J Orthod Dentofacial Orthop.* 2018;154(1):66-75.
Doi:10.1016/J.Ajodo.2017.10.022