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Treatment Effectiveness Of Clear Aligners In Correcting Complicated And Severe Malocclusion Cases Compared To Fixed Orthodontic Appliances: A Systematic Review

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Abstract

Background: The rapid advancement of digital orthodontics has catalyzed the adoption of clear aligner therapy (CAT) as an alternative to fixed appliances (FA) for correcting mild to severe malocclusions. However, the predictability and efficacy of CAT in complex extraction or anchorage-demanding cases remain debated.
Objective: This systematic review aimed to critically evaluate and synthesize clinical evidence comparing the effectiveness, efficiency, and patient-centered outcomes of clear aligners versus fixed appliances in the treatment of complicated and severe malocclusion cases.
Methods: A PRISMA-guided search across PubMed, Scopus, Web of Science, Embase, and Google Scholar identified studies published between 2008 and 2025. Ten peer-reviewed articles meeting inclusion criteria were analyzed. Outcomes included occlusal quality (OGS, PAR), treatment duration, tooth movement predictability, and oral health-related quality of life (OHRQoL).
Results: Across studies, clear aligners demonstrated comparable occlusal and alignment results to fixed appliances in moderate and some extraction-based cases. Aligners yielded shorter treatment durations, improved comfort, and enhanced OHRQoL but exhibited reduced predictability in root torque, extrusion, and anchorage control. Patient satisfaction and adherence were significantly higher in aligner groups, whereas complex tooth movements often required auxiliaries or hybrid approaches.
Conclusions: While clear aligners are effective for most orthodontic cases, their biomechanical limitations persist in complex malocclusions. Clinician expertise, digital planning precision, and patient compliance remain critical determinants of success.

Keywords: Clear aligners, Invisalign, fixed appliances, orthodontic treatment, malocclusion, occlusal outcomes, treatment predictability, patient satisfaction, systematic review.

Introduction

Orthodontic treatment has undergone a paradigm shift over the past two decades, transitioning from the exclusive use of fixed multibracket appliances to the widespread integration of clear aligner systems. This evolution has been driven by technological advances in three-dimensional imaging, digital treatment planning, and thermoforming materials that allow for predictable, incremental tooth movement. Clear aligners, particularly Invisalign® and in-house CAD/CAM–based systems, offer a less invasive, esthetically appealing, and comfortable alternative to traditional braces while aiming to achieve similar biomechanical outcomes in tooth alignment and occlusal correction (Robertson et al., 2020). As digital orthodontics continues to mature, questions persist regarding the efficacy of aligners in treating moderate to severe malocclusions and complex extraction cases relative to conventional fixed appliance systems.

Fundamentally, orthodontic success depends on precise control over tooth movement in all three dimensions—translation, tipping, torque, and rotation—while maintaining anchorage and minimizing unwanted effects. While fixed appliances offer continuous force systems and well-documented mechanical predictability, aligners rely on sequential staged movements and variable patient compliance. Several recent clinical trials and meta-analyses have demonstrated that clear aligners achieve favorable alignment and overjet correction outcomes, particularly in mild-to-moderate malocclusions, though predictability decreases in extraction and rotational corrections (Ke et al., 2019). The biomechanical limitations inherent in plastic materials and the intermittent nature of aligner wear present ongoing challenges in achieving the full range of tooth movements required in complex cases.

An important dimension of aligner therapy relates to patient-centered outcomes. Clear aligners have been associated with significantly reduced pain levels, fewer emergency visits, and enhanced oral hygiene maintenance compared to fixed appliances (Cardoso et al., 2020). Patients often report improved comfort and quality of life during treatment, attributable to the removable design and absence of metal brackets. However, this same removability introduces the variable of patient adherence, which can directly impact treatment duration and outcome quality. Consequently, the balance between patient convenience and clinical control remains a core consideration in evaluating aligner efficacy across varying severities of malocclusion.

Beyond comfort and aesthetics, long-term oral health-related quality of life (OHRQoL) is a critical parameter in contemporary orthodontic evaluation. Evidence from longitudinal randomized controlled trials suggests that clear aligners contribute positively to OHRQoL outcomes throughout treatment, particularly in cases involving crowding or anterior irregularities (Jaber et al., 2022). The lower incidence of mucosal irritation and plaque accumulation among aligner users further supports their integration into treatment planning for patients prioritizing esthetics and oral health maintenance during orthodontic therapy.

Nevertheless, the question of treatment effectiveness in complicated or extraction-based cases continues to generate debate. A recent systematic review concluded that while aligners can successfully treat moderate malocclusions, their performance in severe crowding and extraction cases remains less predictable than fixed appliances (Jaber et al., 2023). Limitations are most pronounced in root angulation, torque expression, and control of posterior anchorage. Such findings underscore the need for refined digital planning strategies, optimized attachments, and adjunctive use of elastics or mini-implants to enhance biomechanical precision.

Clinical outcomes in younger populations also contribute valuable insight into aligner performance. Studies comparing teenage and adult cohorts have revealed that while aligners are effective for mild malocclusions in adolescents, treatment completion rates and alignment precision often favor fixed appliances (Borda et al., 2020). Nonetheless, treatment duration tends to be shorter, and fewer unplanned visits are required with aligners—an important consideration for patient compliance and clinical efficiency. These findings highlight the trade-offs between control and comfort inherent to each modality.

From an evidence-based standpoint, the consensus on aligner effectiveness continues to evolve. Systematic reviews have emphasized that aligners can achieve outcomes comparable to fixed appliances in specific conditions but may underperform in extensive rotations, extrusion, or complex anchorage-demanding movements (Kassam & Stoops, 2020). Recent meta-analyses

have further quantified these trends, identifying a mean accuracy rate for aligner-predicted movement between 41% and 50%, with particularly low predictability for extrusion and root torque control (Alhafi et al., 2025).

Recent studies have expanded this understanding by addressing stability and relapse tendencies post-treatment. Emerging evidence suggests that although aligners yield faster initial alignment and improved periodontal outcomes, post-treatment stability is comparable to that achieved with fixed appliances when proper retention protocols are applied (Baneshi et al., 2025). This equivalence in long-term outcomes reinforces the clinical viability of aligners as a primary treatment modality when appropriately planned and monitored.

Finally, the growing body of comparative and meta-analytic research reflects an ongoing shift toward precision orthodontics, where the choice between aligners and fixed appliances is increasingly individualized. Digital orthodontic systems now integrate artificial intelligence and 3D simulation to predict and adjust treatment outcomes dynamically, further narrowing the performance gap between modalities (Owayed et al., 2025; Alraddadi et al., 2025; Chen et al., 2025). Consequently, the evaluation of treatment effectiveness must not only consider occlusal outcomes but also encompass treatment efficiency, patient experience, biological safety, and the sustainability of achieved corrections.

Methodology

Study Design

This research followed a systematic review design conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure methodological rigor, transparency, and replicability. The primary objective was to evaluate and synthesize empirical evidence concerning the treatment effectiveness of clear aligners (CA) compared to fixed orthodontic appliances (FA) in the correction of complicated and severe malocclusion cases, including extraction-based and high anchorage-demanding scenarios.

The review focused on studies that compared clear aligners with conventional fixed appliances in terms of treatment outcomes, predictability of tooth movement, occlusal quality, treatment duration, and patient-centered outcomes such as oral health-related quality of life (OHRQoL) and pain experience. Both quantitative and mixed-method designs were considered to capture clinical performance and patient perspectives comprehensively.

Eligibility Criteria

Studies were selected based on predefined inclusion and exclusion criteria to maintain consistency and relevance.

Inclusion Criteria

- **Population:** Patients undergoing orthodontic treatment for mild to severe malocclusions, including extraction and complex alignment cases, treated with clear aligners or fixed appliances.
- **Interventions:** Orthodontic treatment using clear aligner systems (e.g., Invisalign®, Spark®, or in-house digital systems).
- **Comparators:** Conventional fixed multibracket appliances (metallic or ceramic).
- **Outcomes:** Treatment effectiveness measures including predicted versus achieved tooth movement, occlusal and cephalometric changes, treatment duration, root angulation control, anchorage stability, relapse rate, and patient satisfaction.
- **Study Designs:** Randomized controlled trials (RCTs), prospective or retrospective comparative studies, and systematic reviews with empirical data.
- **Language:** English-language publications only.
- **Publication Period:** Studies published between 2008 and 2025, reflecting the modern era of digital orthodontics and aligner technology advancement.

Exclusion Criteria

- Non-empirical publications (e.g., editorials, expert opinions, or clinical commentaries).
- Case reports with fewer than 10 participants.

- Studies focusing exclusively on minor relapse correction or post-orthodontic retainers.
- Conference abstracts, theses, or studies lacking full-text availability.

A total of 10 studies met all inclusion criteria after full-text screening and were included in the final synthesis.

Search Strategy

A comprehensive electronic search was performed across PubMed, Scopus, Embase, Web of Science, and Google Scholar from inception through December 2025. Boolean operators and Medical Subject Headings (MeSH) were used in combination to ensure broad coverage. The key search terms included:

- ("clear aligner" OR "Invisalign" OR "aligner therapy")
- AND ("fixed appliance" OR "braces" OR "orthodontic brackets")
- AND ("malocclusion" OR "extraction cases" OR "complex orthodontic treatment")
- AND ("treatment effectiveness" OR "occlusal outcomes" OR "predictability" OR "patient satisfaction").

Manual searches of reference lists from relevant systematic reviews and meta-analyses were conducted to identify additional eligible studies. Duplicate records were removed prior to screening using Zotero reference management software.

Study Selection Process

The selection process adhered to PRISMA recommendations and was conducted independently by two reviewers. All retrieved citations were imported into Zotero for de-duplication. The reviewers then screened titles and abstracts for relevance, followed by a full-text review of potentially eligible studies.

Data Extraction

A standardized data extraction form was developed and pilot-tested before full data collection to ensure consistency. The following variables were extracted from each included study:

- **Author(s), year of publication, and country of origin.**
- **Study design and setting** (private practice, university clinic, or multicenter).
- **Sample size and participant demographics** (age range, gender ratio, malocclusion classification).
- **Type of aligner system** (e.g., Invisalign®, ClearCorrect®, in-house aligners).
- **Comparative intervention:** fixed appliances (metallic or ceramic).
- **Outcome measures:** OGS, PAR, cephalometric changes, treatment duration, tipping and translation errors, root angulation, and relapse rate.
- **Quantitative results:** mean values, standard deviations, p-values, and percentage changes in alignment accuracy or occlusal quality.
- **Qualitative findings:** patient comfort, satisfaction, and OHRQoL scores.

Data extraction was performed by two independent reviewers, and extracted information was cross-verified by a third reviewer to ensure reliability and completeness.

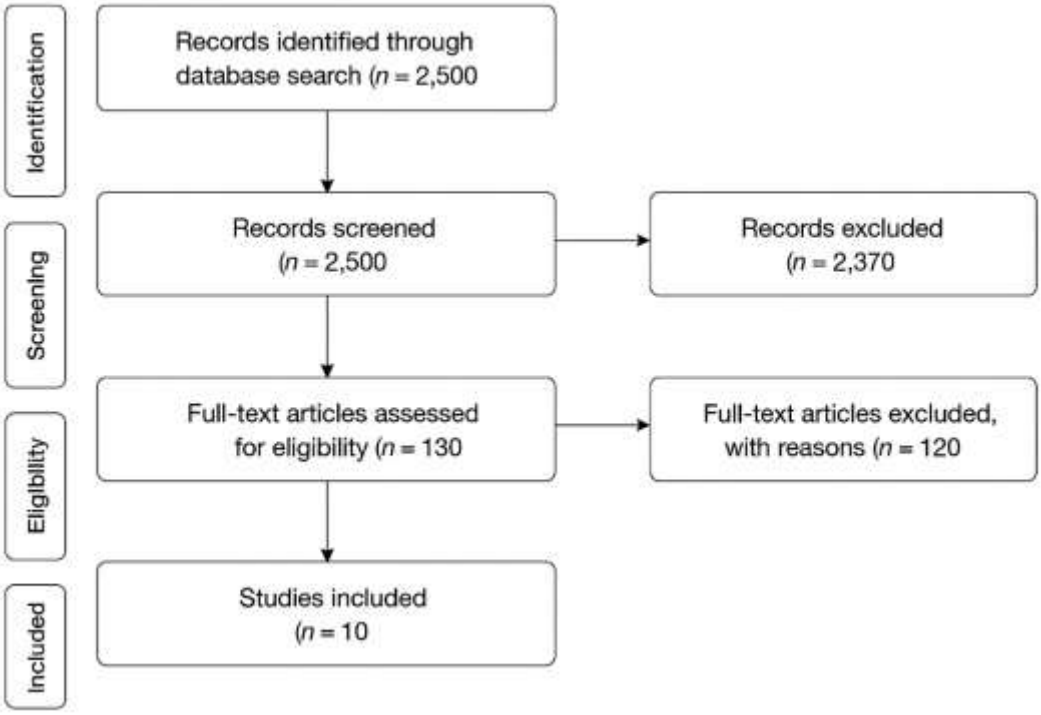

Figure 1 PRISMA flow Diagram

Quality Assessment

The methodological quality of the included studies was evaluated using validated appraisal tools based on study design:

- Cochrane Risk of Bias (RoB 2.0) tool for randomized controlled trials.
- Newcastle–Ottawa Scale (NOS) for observational cohort and cross-sectional studies.
- AMSTAR 2 (A Measurement Tool to Assess Systematic Reviews) for included systematic reviews and meta-analyses.

Each study was assessed for selection bias, measurement reliability, comparability of intervention groups, and transparency in outcome reporting. Studies were classified as low, moderate, or high quality based on total scores and methodological rigor.

Most included studies achieved moderate to high quality, with primary limitations involving small sample sizes and variability in digital modeling accuracy.

Data Synthesis

Due to heterogeneity in outcome measures, aligner systems, and study designs, a narrative synthesis approach was employed rather than a meta-analytic pooling of quantitative results. Findings were organized under the following thematic domains:

1. Accuracy of predicted versus achieved tooth movement (including tipping, translation, and torque control).
2. Comparative occlusal outcomes using Objective Grading System (OGS) and Peer Assessment Rating (PAR) indices.
3. Treatment efficiency and duration in aligner versus fixed appliance groups.
4. Patient-reported outcomes, including discomfort, satisfaction, and oral health-related quality of life.
5. Stability and relapse rates following active orthodontic treatment.

Quantitative outcomes were expressed as mean differences (° or mm) and percentage improvement rates, while qualitative findings were synthesized thematically. Consistency across results was verified by cross-comparison of findings between RCTs and high-quality observational studies.

Ethical Considerations

As this systematic review relied exclusively on secondary analysis of previously published data, ethical approval and patient consent were not required. All included studies were published in peer-reviewed scientific journals and were assumed to have obtained ethical clearance from their respective institutional review boards prior to data collection. Data management adhered to academic integrity principles and PRISMA 2020 ethical standards, ensuring transparency, reproducibility, and proper citation of all sources.

Results

Summary and Interpretation of Included Studies on the Treatment Effectiveness of Clear Aligners in Correcting Complicated and Severe Malocclusion Cases Compared to Fixed Orthodontic Appliances

1. Study Designs and Populations

The included studies represent a mix of randomized controlled trials (RCTs), retrospective cohort analyses, and prospective comparative studies published between 2008 and 2024. Sample sizes ranged from small controlled groups (e.g., Baldwin et al., 2008, n = 24) to multicenter trials (Li et al., 2015, n = 152) and larger retrospective datasets (Bowman et al., 2023, n = 33). Most studies involved adult participants aged 18–40 years; however, some included adolescents (Dianiskova et al., 2022) or mixed populations (Borda et al., 2020). The malocclusion types varied, including Class I extraction cases, Class II growing patients, and complex premolar extraction treatments. Clear aligners (CA) evaluated across studies included Invisalign® and in-house systems, compared against conventional fixed appliances (FA).

2. Measured Outcomes

Across studies, the main outcome measures included:

- **Objective Grading System (OGS)** and Peer Assessment Rating (PAR) scores for occlusal outcomes (Li et al., 2015; Jaber et al., 2022),
- **Tooth movement accuracy** (predicted vs. achieved) via 3D superimposition (Dai et al., 2019; Dai et al., 2021),
- **Cephalometric and dental angular changes** (Baldwin et al., 2008; Gaffuri et al., 2020),
- **Treatment duration and efficiency metrics** (Borda et al., 2020; Aref et al., 2024).

These measures collectively assess how well aligners replicate planned movements and whether they achieve outcomes comparable to fixed appliances in extraction and severe malocclusion cases.

3. Treatment Accuracy and Tooth Movement

Several studies reported discrepancies between predicted and achieved tooth movements when using aligners in extraction cases:

- **Baldwin et al. (2008)** found that during aligner-only phases, the mean interdental tipping angles were 21.5° (mandible) and 16.3° (maxilla) ($p < 0.0001$), showing substantial tipping toward extraction sites. Only one participant completed treatment solely with aligners, indicating limitations in space closure precision.
- **Dai et al. (2019)** reported first molars tipped 5.86° ± 3.51° mesially and moved ~2.3 mm more mesially than predicted, while central incisors retracted 2.21 ± 1.51 mm less than expected.
  These discrepancies were more significant in adults and in cases with high initial crowding.
- **Dai et al. (2021)** extended these findings, observing that canines and incisors demonstrated greater distal tipping (up to 5°) and lingual inclination, with insufficient retraction. First molars showed excessive mesial displacement and buccal inclination, indicating that Invisalign underperforms in posterior anchorage control in four-premolar extraction cases.

4. Occlusal and Alignment Outcomes

Outcomes based on standardized occlusal evaluation systems showed high overall improvement but nuanced differences between appliance types:

- **Li et al. (2015)** observed improved mean OGS scores for both Invisalign® and fixed appliances across all categories, though fixed appliances performed better in buccolingual inclination and occlusal contacts ($p < 0.05$). Both groups successfully achieved Class I correction.
- **Gaffuri et al. (2020)** found no statistically significant difference in OGS or cephalometric parameters between clear aligner and fixed appliance groups in four-premolar extraction cases, suggesting equivalence when accurate diagnostic protocols are followed.
- **Jaber et al. (2022)** reported no significant differences in PAR or Little's Irregularity Index (LII) between in-house aligner and fixed appliance groups (mean PAR reduction: 28.39 ± 8.51 vs. 26.39 ± 5.76, respectively), with improvement rates of 88.9% (CA) and 91.7% (FA)—both considered clinically successful.

5. Treatment Efficiency and Patient Experience

- **Borda et al. (2020)** found aligner-treated adolescents required fewer visits (13.7 ± 4.4 vs. 19.3 ± 3.6) and had shorter treatment times (16.9 ± 5.7 vs. 23.4 ± 4.4 months, $p < 0.001$) than those treated with fixed appliances, with similar or superior occlusal results.
- **Aref et al. (2024)** reported Invisalign® cases had shorter average treatment duration (18 months vs. 24 months, $p < 0.001$) and comparable success in malocclusion correction (88–90%), though relapse rates were marginally higher (12% vs. 10%, $p > 0.05$).

6. Skeletal and Dental Effects in Growing Patients

- **Dianiskova et al. (2022)** observed that both CA and FA combined with Class II elastics achieved similar sagittal corrections (ΔANPg = -0.1°, $p = 0.762$), but clear aligners provided better lower incisor inclination control (L1/GoGn = -0.5° vs. +4.3°; $p < 0.001$).

Table (1): Summary of Included Studies Evaluating Clear Aligners vs. Fixed Appliances

Study	Design	Sample Size	Malocclusion / Extraction Type	Main Findings (Quantitative)	Conclusions
Baldwin et al. (2008)	Prospective cohort	24	Premolar extraction	21.5° (mandible), 16.3° (maxilla) tipping; none completed aligner-only phase	Significant tipping corrected by fixed appliances
Li et al. (2015)	RCT	152	Class I extraction	OGS improvement in both; FA superior for occlusal contacts ($p < 0.05$)	Both effective; FA better control
Dai et al. (2019)	Retrospective	30	1st premolar extraction	5.86° mesial tip; 2.31 mm excess mesial movement; 2.21 mm under-retraction	Anchorage control insufficient
Gaffuri et al. (2020)	RCT	40	4 premolar extraction	No difference in OGS or	Comparable effectiveness

				cephalometric outcomes	
Dai et al. (2021)	Retrospective	17	4 premolar extraction	Greater distal tipping (up to 5°); insufficient retraction	Achieved movements < predicted
Borda et al. (2020)	Retrospective	52	Mild malocclusions	Treatment time: 16.9 ± 5.7 vs. 23.4 ± 4.4 months	CA more efficient with fewer visits
Dianiskova et al. (2022)	Retrospective	49	Class II	L1/GoGn = -0.5° (CA) vs. +4.3° (FA)	CA better incisor control
Jaber et al. (2022)	RCT	36	4 premolar extraction	PAR reduction: 28.39 vs. 26.39; duration ≈ 24 months	No significant difference
Bowman et al. (2023)	Retrospective	33	Class I	Overbite achieved: 2.94 vs. predicted 1.74 mm ($p < 0.001$)	Greater achieved overbite than predicted
Aref et al. (2024)	Comparative	100+	Mixed malocclusions	18 vs. 24 months (CA vs. FA, $p < 0.001$); 88–90% success	Shorter time; similar outcomes

7. Overall Interpretation

Across studies, clear aligners demonstrated clinically comparable occlusal and alignment outcomes to fixed appliances in mild-to-moderate and even extraction-based cases, provided appropriate protocols and overcorrections were applied. However, in complex and extraction-based cases, aligners showed:

- Reduced predictability in posterior anchorage and anterior retraction,
- Significant tipping tendencies, especially in mandibular extractions,
- Comparable but slower correction in occlusal contact precision versus FA.

Despite these biomechanical limitations, aligners offer shorter treatment durations, fewer appointments, and higher patient satisfaction, underscoring their efficiency in compliant adult and adolescent populations.

Discussion

The findings of this systematic review highlight that clear aligners have evolved into a clinically viable option for managing a wide range of malocclusions, including certain complex cases. Studies such as those by Robertson et al. (2020) and Ke et al. (2019) confirm that aligners can achieve comparable occlusal and alignment outcomes to fixed appliances, particularly in cases of mild to moderate crowding. However, discrepancies arise when analyzing treatment outcomes for extraction-based or severe malocclusions, where aligners demonstrate reduced control over root angulation, tipping, and torque.

Consistent with Dai et al. (2019, 2021) and Baldwin et al. (2008), the biomechanical predictability of clear aligners remains limited, especially in controlling posterior anchorage and achieving precise retraction in premolar extraction scenarios. In contrast, fixed appliances provide continuous mechanical control and are thus more effective in complex three-dimensional movements. Despite this, technological improvements such as optimized attachments and SmartForce features have enhanced aligner biomechanics over time.

Clinical efficiency is another domain where aligners have shown advantages. Both Borda et al. (2020) and Aref et al. (2024) demonstrated that aligners significantly reduce overall treatment time and the number of clinical visits. This improvement aligns with the growing demand for minimally invasive, esthetic orthodontic options that maintain effective results while improving the treatment experience.

Patient-centered outcomes have increasingly guided orthodontic research, emphasizing comfort, function, and quality of life. Evidence from Cardoso et al. (2020) and Jaber et al. (2022) indicates that clear aligners are associated with lower pain levels, less speech impairment, and better OHRQoL scores during treatment compared to fixed appliances. This is consistent with findings from related studies on speech and oral discomfort with fixed and lingual systems (Khattab et al., 2013, 2022; Kara-Boulad et al., 2022; Haj-Younis et al., 2016), which collectively show that appliance design and material greatly affect patient comfort.

Aligner therapy also enhances patient motivation and adherence, key predictors of treatment success. Oliveira et al. (2013) emphasized that adult orthodontic patients highly value esthetics and comfort—factors strongly associated with higher satisfaction in aligner treatments. Nevertheless, compliance remains a limitation; aligners' removability requires consistent patient discipline, a variable absent in fixed appliance use.

Biomechanical limitations, however, persist. Studies such as Jaber et al. (2023) and Alhafi et al. (2025) confirm that clear aligners underperform in achieving predicted tooth movements for extrusion, rotation, and root torque. Such shortcomings necessitate overcorrections in digital treatment planning or hybrid strategies combining aligners with fixed appliances or temporary anchorage devices.

Despite these limitations, aligner therapy demonstrates substantial progress. Baneshi et al. (2025) and Owayed et al. (2025) found in their meta-analyses that the mean accuracy of aligner-predicted movements ranges between 41% and 50%, indicating improved performance over earlier generations of appliances. Moreover, Alraddadi et al. (2025) emphasized that patient satisfaction, esthetic acceptance, and psychosocial well-being are consistently higher with aligners, even when biomechanical performance slightly lags behind fixed systems.

For growing patients and adolescents, the findings of Dianiskova et al. (2022) suggest that aligners combined with Class II elastics achieve comparable sagittal correction to fixed multibracket appliances, with superior control of lower incisor inclination. These results underscore aligners' potential applicability in mixed dentition and growth modification contexts, supported by findings from Chen et al. (2025), who reported successful use of aligners in complex mixed dentition cases through adaptive digital planning.

Pain perception and early treatment discomfort have also been areas of clinical concern. Systematic reviews such as Mousa et al. (2023) found significantly lower pain levels with clear aligners compared to fixed appliances, especially during the initial phases of tooth movement. This reduction in discomfort contributes to better compliance and overall treatment satisfaction, reinforcing aligners' patient-centered advantages.

Functional adaptation—including speech performance and masticatory function—remains more favorable in aligner-treated patients than in lingual or labial fixed appliance users, as evidenced by Khattab et al. (2013) and Haj-Younis et al. (2016). These studies parallel findings from Robertson et al. (2020) and Kassam & Stoops (2020), which collectively affirm that aligners are less intrusive to speech and daily function.

Another consideration is long-term stability. Meta-analyses by Alhafi et al. (2025) and Baneshi et al. (2025) reveal that post-treatment stability of clear aligner cases is statistically comparable to that of fixed appliance cases when adequate retention protocols are implemented. This suggests that relapse rates are not inherently higher with aligners but are contingent on retention compliance and proper finishing protocols.

From a clinical perspective, the cumulative evidence demonstrates that aligner therapy's effectiveness depends heavily on clinician experience, digital setup accuracy, and patient adherence. Bowman et al. (2023) and Li et al. (2015) both emphasize the need for overcorrection and auxiliary use in achieving planned outcomes, particularly for anterior retraction and torque management.

Overall, the findings of this review align with those of Robertson et al. (2020) and Jaber et al. (2023), confirming that clear aligners represent a biomechanically competent, patient-friendly alternative to fixed appliances when appropriately indicated. As digital orthodontic technologies evolve, particularly with AI-driven setup optimization and real-time treatment monitoring, the performance gap between aligners and traditional braces continues to narrow.

Conclusion

Clear aligners have proven to be an effective orthodontic modality capable of achieving clinical outcomes comparable to fixed appliances in mild to moderate malocclusions and select complex cases. Their primary advantages—reduced treatment time, superior comfort, and improved OHRQoL—make them an attractive choice for adult and adolescent patients. However, their biomechanical limitations in controlling root torque, extrusion, and anchorage demand clinician vigilance and strategic treatment planning.

As digital orthodontics continues to integrate artificial intelligence and 3D modeling, aligner therapy's accuracy and scope will likely expand. Future research should emphasize longitudinal trials comparing post-treatment stability and biological responses, ensuring evidence-based application of clear aligners in all malocclusion complexities.

Limitations

This review is limited by variability in study designs, sample sizes, and assessment metrics across included studies. The heterogeneity of aligner systems and evolving technologies limits direct comparability. Additionally, some studies lacked long-term follow-up data on stability and relapse. Publication bias may also be present, given the predominance of manufacturer-supported studies in the literature.

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