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BIOMECHANICAL INSIGHTS IN ARCH EXPANSION WITH CLEAR ALIGNERS: A LITERATURE REVIEW

Orthodontology

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ABSTRACT

Clear aligner therapy has rapidly gained popularity as an esthetic and patient-friendly alternative to fixed orthodontic appliances. Among the various movements claimed to be achievable with aligners, transverse arch expansion is one of the most debated. Expansion is clinically valuable for relieving crowding, correcting crossbites, and improving arch form; however, the biomechanical basis of expansion with aligners and its predictability remain controversial. This review explores the available literature on the biomechanics of aligner-mediated arch expansion, with emphasis on the nature of the forces delivered, the determinants that influence expansion, and the clinical outcomes reported in different age groups. Evidence from laboratory investigations, finite element modeling, and clinical studies suggests that expansion with clear aligners is primarily dentoalveolar in nature, produced predominantly through buccal tipping of posterior teeth rather than true skeletal expansion. Factors such as aligner thickness, trimline design, staging protocols, patient age, and bone quality affect the extent and quality of expansion. While limited skeletal change may occur in adolescents, adults typically demonstrate only dental tipping, raising concerns regarding periodontal side effects and long-term stability. Overall, aligners can achieve expansion in certain cases, especially where the transverse discrepancy is mild to moderate, but outcomes depend on proper application of biomechanical principles, and greater skeletal changes may still require supplementary approaches.

KEYWORDS

Clear Aligners, Arch Expansion, Transverse Correction, Skeletal Expansion, Dentoalveolar Effects

INTRODUCTION

Clear aligner therapy has seen rapid advances over the past two decades, evolving from a tool for minor tooth alignment into a system capable of addressing complex movements including arch expansion. The promise of aesthetics, removability, and patient comfort has driven aligners into mainstream orthodontics. However, expansion with aligners remains controversial due to debated biomechanics and clinical effectiveness [1–3].

Traditional expanders like RPE, MARPE, and SARPE use heavy orthopedic forces to separate the midpalatal suture and create skeletal expansion, whereas clear aligners apply crown-level forces through plastic shells, leading mainly to dentoalveolar tipping rather than true skeletal widening [4,5]. Finite element and in vitro studies show aligner forces concentrate at crown and cervical regions, causing tipping and limiting root movement [6]. CBCT evidence in adults confirms greater crown than skeletal change. Age also influences outcomes: younger patients may show minor skeletal response, while adults exhibit mainly dentoalveolar effects [7].Aligner thickness, trimline design, staging, and attachment geometry further affect force transmission and outcomes [8]. This review summarizes current evidence on the biomechanics of arch expansion with aligners, outlines the key factors influencing treatment outcomes, and discusses their clinical significance across different age groups.

Biomechanical Basis of Expansion With Clear Aligners

Clear aligners transmit forces through elastoplastic shells that engage primarily at the crowns, so the line of action is often coronal to the centre of resistance. This creates a tipping-biased moment, making buccal crown movement more likely than true bodily translation during arch expansion [9]. Finite element models consistently show higher stress at cervical/coronal PDL regions and comparatively less apical/root engagement, reinforcing the tendency toward dentoalveolar effects rather than skeletal widening [10, 11]. Material properties and thickness influence force delivery, with thicker single-layer sheets producing greater forces but subject to expansion rebound deformation (ERD), which reduces predictability. These viscoelastic and manufacturing effects explain why programmed bodily expansion often results in controlled tipping unless counter-moments are incorporated. Design features also affect mechanics. Attachment geometry (e.g., occlusally bevelled horizontal attachments) can generate counter-moments and, combined with buccal root torque, reduce uncontrolled buccal tipping of molars during planned expansion. Staging choices (smaller step sizes) and torque "pre-activation" can shift the movement pattern closer to translation but often with lower efficiency [12].

Determinants of Arch Expansion With Clear Aligners

The success of arch expansion with clear aligners depends on several factors. Anatomical features like cortical thickness, alveolar height, and periodontal biotype affect outcomes, with thin buccal bone raising the risk of dehiscence [13]. Attachment design and placement also matter; optimized or occlusally bevelled attachments can improve predictability and reduce uncontrolled molar tipping [14,15].

Planned expansion magnitude and staging increments further affect outcomes, with larger programmed expansions showing greater discrepancies between predicted and achieved results, and an average under-expansion of nearly 1 mm reported in permanent dentition cases. Age and suture patency additionally shape responses: younger patients may show minor skeletal adaptation, whereas adults experience almost entirely dentoalveolar changes. Finally, aligner material properties such as viscoelastic creep, plastic deformation, and rebound impact force delivery over time. Collectively, these determinants highlight that aligner expansion is strongly influenced by biological variability, appliance design, and treatment planning.

Clinical Considerations in Different Age Groups

Mixed dentition (6–10 years): Aligners are used in interceptive treatment to gain space for erupting teeth. Expansion is mainly dentoalveolar, with limited skeletal influence [16]. Adolescents (11–13 years): Partial suture patency may allow small skeletal adaptation, but CBCT studies show crown tipping remains the dominant pattern [17]. Adults (>14 years): Expansion is almost exclusively dentoalveolar. Risks include alveolar dehiscence and gingival recession. For skeletal deficiencies, adjunctive methods such as MARPE or SARPE are required [17].

Limitations and Side Effects

Expansion with clear aligners has limitations: studies show actual expansion is often less than predicted, with tipping exceeding translation and accuracy near 70% at cuspal levels [18]. This

underperformance, along with unpredictable force delivery, increases risks of dehiscence, gingival recession, and relapse—especially when overcorrection is not planned.

Clinical Implications

Given these constraints, aligner expansion is best reserved for mild to moderate transverse deficiencies; careful treatment planning, overcorrection, and monitoring of gingival health are essential. In cases needing substantial skeletal change, combining aligners with skeletal anchorage appliances or using hybrid protocols may yield safer and more stable results [19].

Future Directions

Future developments in clear aligner therapy aim to improve the predictability of expansion by refining material properties, reducing force decay, and incorporating torque control. Advances such as AI-driven staging, 3D-printed aligners, and digital workflows are expected to enhance expansion accuracy and long-term stability. These innovations may expand the role of aligners beyond mild to moderate cases, making them more effective for a wider spectrum of malocclusions [20].

CONCLUSION

Arch expansion with clear aligners remains one of the most debated aspects of modern orthodontics, as its biomechanics differ from traditional methods. Most expansion achieved is dentoalveolar, though careful design and staging can improve outcomes. Understanding biomechanical determinants helps clinicians distinguish between predictable tipping and limited skeletal change, guiding decisions on when aligners can be used alone and when adjunctive approaches are necessary. By focusing on biomechanics, this review highlights the balance between innovation, biological limits, and clinical application in aligner expansion.

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