ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 12| Issue: 8| August 2026|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2026: 8.753 || ISI Value: 1.188

CLEAR ALIGNER THERAPY IN CONTEMPORARY ORTHODONTICS: A COMPREHENSIVE REVIEW

Prashant Balyan [1], Tarun Kumar[2], Santosh Kumar [3], Namrata Dogra [4], Ashi Bakshi [5]

[1]3rd Year Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, 122505.

[2]Professor & Head, Department of Orthodontics and Dentofacial Orthopaedics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, 122505.

[3]Professor, Department of Orthodontics and Dentofacial Orthopaedics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, 122505.

[4]Professor, Department of Orthodontics and Dentofacial Orthopaedics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, 122505.

[5]2nd Year Post Graduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, 122505.

Address for Correspondence- Dr.Tarun Kumar,Professor& Head, Department of Orthodontics and Dentofacial Orthopaedics, Faculty of Dental Sciences, SGT University, Gurugram, Haryana, 122505.

INTRODUCTION

Orthodontic treatment has traditionally relied on fixed appliance therapy to achieve precise and controlled tooth movement. Although fixed appliances remain the gold standard for managing complex malocclusions, increasing patient demand for esthetic, comfortable, and minimally invasive treatment options has driven the evolution of alternative orthodontic modalities. Among these, clear aligner therapy has gained remarkable popularity over the past two decades and has emerged as a significant component of contemporary orthodontic practice.

Clear aligners are removable, transparent orthodontic appliances fabricated using digital technology to deliver programmed tooth movements through a series of sequential aligners. Their appeal lies primarily in superior esthetics, improved patient comfort, and the ability to maintain oral hygiene more effectively when compared to conventional fixed appliances. Initially, the use of aligners was restricted to minor tooth movements such as mild crowding, spacing, and relapse correction. However, rapid advancements in material science, digital treatment planning, and auxiliary biomechanics have considerably expanded their clinical applications.

The integration of three-dimensional imaging, computer-aided design and manufacturing (CAD-CAM), and virtual treatment simulations has transformed aligner therapy from a simple removable appliance into a sophisticated biomechanical system. Modern aligner systems incorporate features such as optimized attachments, interproximal reduction protocols, staged tooth movement, and the use of auxiliaries including elastics and temporary anchorage devices. These innovations have enhanced the predictability of tooth movement and allowed aligners to be used in increasingly complex orthodontic cases.

Despite their growing acceptance, clear aligners differ fundamentally from fixed appliances in terms of force delivery, control of tooth movement, and reliance on patient compliance. Certain orthodontic movements—such as bodily movement, torque control, extrusion, and correction of severe malocclusions—remain challenging and require careful case selection and meticulous treatment planning. Consequently, a thorough understanding of aligner biomechanics, material properties, indications, and limitations is essential for achieving successful clinical outcomes.

Given the expanding role of clear aligner therapy and the variability in reported treatment effectiveness, a critical evaluation of existing evidence is necessary. This review aims to present a comprehensive overview of the evolution of clear aligner therapy, focusing on its biomechanical principles, clinical applications, advantages, limitations, and future prospects in modern orthodontics.

History

The concept of using removable appliances to achieve orthodontic tooth movement predates modern clear aligner systems. Early attempts at sequential tooth movement can be traced to the use of positioners and removable plates, where incremental adjustments were made to guide teeth toward desired positions. These early appliances demonstrated that controlled tooth movement could be achieved without fixed brackets and wires, laying the foundation for the development of clear aligner therapy.

The modern era of clear aligner therapy began in the late 1990s with the integration of digital technology into orthodontics. In 1999, Align Technology introduced the first commercially viable clear aligner system, marking a significant milestone in orthodontic treatment. This innovation combined computer-aided design with mass customization, enabling the fabrication of a series of transparent aligners programmed to deliver planned tooth movements. Regulatory approval in the early 2000s further facilitated widespread clinical adoption and increased patient acceptance due to improved esthetics and comfort.

Early clear aligner systems were primarily indicated for simple orthodontic corrections such as mild crowding, spacing,

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 12| Issue: 8| August 2026|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2026: 8.753 || ISI Value: 1.188

and relapse cases. These systems relied on thermoplastic materials and staged tooth movement, with each aligner worn for a limited period before progressing to the next. Digital treatment planning allowed clinicians to visualize the entire course of treatment in advance, which represented a paradigm shift from conventional appliance-based orthodontics.

As clinical experience grew, limitations in controlling complex tooth movements became evident. In response, manufacturers introduced refinements such as optimized aligner materials, attachment auxiliaries, and improved software algorithms. These developments enhanced force delivery, aligner retention, and predictability of movement, gradually expanding the range of treatable malocclusions. During this period, competing aligner systems entered the market, further accelerating innovation and diversification of aligner design and biomechanics.

In recent years, advances in intraoral scanning, three-dimensional imaging, and digital workflow integration have further transformed clear aligner therapy. The incorporation of artificial intelligence–assisted treatment planning, hybrid approaches combining aligners with auxiliaries, and in-house aligner fabrication has broadened clinical applications beyond their original scope. Today, clear aligner therapy is widely recognized as a mainstream orthodontic treatment modality, with ongoing research aimed at improving accuracy, efficiency, and long-term stability.

Biomechanics of Clear Aligner

Orthodontic tooth movement is a biologic response to the application of controlled mechanical forces that induce remodeling of the periodontal ligament and surrounding alveolar bone. Clear aligner therapy applies this fundamental principle using a series of custom-fabricated removable appliances designed to deliver pre-programmed forces to the dentition. Unlike fixed appliances, where forces are generated through continuous archwires, aligners rely on material elasticity, appliance geometry, and staged activation to achieve desired tooth movement.

Clear aligners are manufactured from thermoplastic materials with viscoelastic properties, allowing them to deform upon insertion and exert force as they attempt to return to their original shape. Each aligner is designed to move teeth incrementally, typically by a small fraction of a millimeter per stage. This incremental activation minimizes excessive force levels and promotes biologically favorable tooth movement. The magnitude, direction, and duration of force delivery are influenced by aligner thickness, material composition, and the extent of programmed tooth displacement.

Force generation in clear aligner therapy occurs primarily through intimate contact between the aligner surface and the tooth crown. When an aligner is seated, elastic deformation results in the transmission of forces to the teeth along the planned vector of movement. However, because aligners engage the crowns rather than the brackets or archwires used in fixed appliances, the line of action of force often does not pass through the center of resistance of the tooth. This inherent limitation predisposes aligner therapy to tipping movements unless additional biomechanical control is incorporated.

To overcome this challenge, auxiliary features such as composite attachments are routinely employed. Attachments increase the surface area for force application, improve aligner retention, and facilitate the delivery of moments necessary for bodily movement, rotation, intrusion, or torque control. The shape, size, and positioning of attachments are critical in determining the quality of force expression and the predictability of tooth movement. Optimized attachment designs allow better control of complex movements that would otherwise be difficult to achieve with aligners alone.

Another distinctive feature of aligner biomechanics is the predominance of intermittent force application. Because aligners are removable, force delivery depends heavily on patient compliance. When worn as prescribed, aligners deliver relatively constant low-magnitude forces; however, removal of the appliance interrupts force application, potentially affecting the rate and predictability of tooth movement. This contrasts with fixed appliances, which provide continuous force independent of patient behavior.

Digital treatment planning plays a central role in aligner biomechanics. Three-dimensional virtual models allow clinicians to simulate tooth movement, estimate force systems, and sequence movements strategically to reduce unwanted side effects. The accuracy of these simulations, however, may not always translate perfectly to clinical outcomes due to variations in material behavior, biological response, and patient compliance.

Overall, the biomechanics of clear aligner therapy represent a complex interaction between appliance design, material properties, auxiliary features, and biologic tissue response. While aligners are effective for many orthodontic movements, their biomechanical limitations necessitate careful case selection and meticulous treatment planning to achieve predictable results.

Clinical Implications of Clear Aligner Therapy

Clear aligner therapy has significantly influenced contemporary orthodontic practice by offering an esthetic and patient-friendly alternative to conventional fixed appliances. However, its successful clinical application depends on a thorough understanding of its capabilities, limitations, and the need for appropriate case selection. Clinicians must recognize that aligners are not merely removable appliances but biomechanically driven systems that require careful planning and close monitoring.

One of the most important clinical implications of aligner therapy is the critical role of treatment planning. Digital setups and virtual simulations allow clinicians to visualize the entire treatment sequence; however, the practitioner must retain full control over the treatment plan rather than relying solely on automated software predictions. Over-ambitious tooth movements or inadequate staging may lead to poor tracking, increased refinements, or the need for adjunctive appliances.

Case selection remains central to predictable outcomes. Clear aligners demonstrate high clinical effectiveness in mild to moderate malocclusions, relapse cases, and patients with good compliance. More complex movements—such as significant intrusion, extrusion, bodily space closure, and correction of severe sagittal discrepancies—often require auxiliaries including attachments, interarch elastics, temporary anchorage

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 12| Issue: 8| August 2026|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2026: 8.753 || ISI Value: 1.188

devices, or hybrid approaches involving fixed appliances. Understanding when to combine aligners with these adjuncts is essential for clinical success.

Aligners have important implications in the vertical dimension. Their full-coverage design may produce a posterior intrusive effect, which can be advantageous in managing anterior open bites or borderline vertical discrepancies. Conversely, achieving controlled anterior intrusion or extrusion can be unpredictable and may necessitate optimized attachments, bite ramps, or skeletal anchorage. Clinicians must therefore carefully evaluate vertical skeletal patterns before selecting aligner therapy.

From a patient management perspective, aligners offer improved comfort, esthetics, and oral hygiene, which can enhance patient acceptance and satisfaction. However, their removable nature introduces a strong dependence on patient compliance. Inadequate wear time is a common cause of treatment delay and loss of aligner tracking, emphasizing the need for patient education and regular follow-up.

Finally, clinicians must be prepared for treatment modifications. Refinements are frequently required to compensate for biologic variability and differences between predicted and achieved tooth movement. Recognizing aligner limitations early and transitioning to alternative or adjunctive treatment modalities when necessary is crucial to achieving stable and functional outcomes.

Overall, clear aligner therapy is a versatile and effective orthodontic tool when applied judiciously. Its clinical success relies not on the appliance alone, but on the orthodontist's diagnostic skill, biomechanical understanding, and ability to adapt treatment strategies to individual patient needs.

Limitations

Despite the increasing popularity of clear aligner therapy and its advantages in terms of esthetics and patient comfort, several limitations restrict its universal application in orthodontic practice. A clear understanding of these constraints is essential for appropriate case selection and realistic treatment planning.

One of the primary limitations of clear aligner therapy is its restricted effectiveness in complex orthodontic cases. Severe crowding or spacing that requires multiple extractions, significant sagittal discrepancies, and pronounced skeletal malocclusions are often beyond the biomechanical capabilities of aligners alone. In such situations, fixed appliances or combined orthodontic–orthognathic approaches provide superior control and predictability.

Another major concern is the difficulty in achieving certain tooth movements. Movements such as true bodily translation, controlled torque expression, significant intrusion or extrusion, and correction of complex vertical discrepancies are less predictable with aligners. Although attachments and auxiliaries can improve control, outcomes may still fall short of those achieved with conventional fixed appliances, particularly in cases requiring three-dimensional precision.

Patient compliance represents a critical limitation unique to aligner therapy. Because aligners are removable, their effectiveness depends heavily on consistent wear, typically 22–23 hours per day. Inadequate compliance can lead to prolonged treatment duration, loss of aligner tracking, increased need for refinements, and compromised results. This makes aligners less suitable for patients who are unwilling or unable to adhere strictly to wear protocols.

From a biologic and periodontal perspective, aligner therapy may be contraindicated in patients with active periodontal disease, uncontrolled caries, or poor oral hygiene. Although aligners facilitate easier oral hygiene compared to fixed appliances, improper maintenance of aligners can still contribute to plaque accumulation, gingival inflammation, and enamel demineralization.

Clear aligner therapy also presents economic limitations. The overall cost is often higher than that of conventional fixed appliances, particularly in complex cases requiring multiple refinements or extended treatment duration. Limited insurance coverage and restricted availability in public healthcare systems may further reduce accessibility for certain patient populations.

Finally, aligner therapy may not always be ideal for growing patients or individuals with developmental abnormalities, as it may not provide sufficient control over skeletal growth modification or occlusal development. In such cases, traditional orthopedic or fixed orthodontic appliances remain more appropriate.

In summary, while clear aligner therapy is an effective and patient-friendly treatment modality for selected cases, its limitations necessitate careful diagnosis, realistic treatment objectives, and, when required, the use of adjunctive or alternative orthodontic approaches.

Effectiveness of Clear Aligner Therapy

Clear aligner therapy has been shown to be an effective orthodontic treatment modality for selected tooth movements, particularly in cases involving mild to moderate malocclusions. Its effectiveness is primarily attributed to the application of controlled, low-magnitude forces delivered through a series of custom-designed aligners that progressively guide teeth toward their planned positions.

Clinical evidence suggests that clear aligners are highly effective in managing mild to moderate crowding and spacing, where gradual alignment can be achieved with good predictability. By sequentially applying programmed tooth movements, aligners can successfully reposition anterior teeth, improve arch form, and enhance smile esthetics. Correction of rotated or tipped teeth has also demonstrated favorable outcomes, especially when supported by appropriately designed attachments and optimized staging protocols.

Clear aligner therapy is particularly effective in anterior tooth alignment, an area of high esthetic importance for patients. Alignment of the maxillary and mandibular incisors often results in significant improvements in facial appearance and patient satisfaction. Gap closure in cases of mild spacing can also be achieved efficiently, reducing the risk of food impaction and improving periodontal health when proper oral hygiene is maintained.

The reported success rate of clear aligner therapy for mild to moderate orthodontic movements ranges between 80% and 90%, although outcomes vary depending on case complexity, biological response, and patient compliance. Treatment predictability improves significantly when aligner therapy is planned and executed by experienced clinicians who

ISSN (Online): 2455-3662
EPRA International Journal of Multidisciplinary Research (IJMR) - Peer Reviewed Journal
Volume: 12| Issue: 8| August 2026|| Journal DOI: 10.36713/epra2013 || SJIF Impact Factor 2026: 8.753 || ISI Value: 1.188

understand its biomechanical limitations and incorporate necessary auxiliaries.

However, the effectiveness of aligner therapy diminishes as treatment complexity increases. Severe crowding, significant vertical discrepancies, complex sagittal corrections, and skeletal malocclusions often require fixed appliances or combined treatment approaches to achieve optimal results. In such cases, aligners may be used as part of a hybrid strategy rather than as a standalone treatment.

Overall, clear aligner therapy is an effective orthodontic option for appropriately selected cases. When combined with accurate digital planning, adjunctive mechanics, and high patient compliance, aligners can deliver predictable and clinically satisfactory outcomes comparable to conventional fixed appliances in mild to moderate orthodontic corrections.

CONCLUSION

Clear aligner therapy has evolved from a limited orthodontic modality used primarily for minor tooth movements into a widely accepted treatment option supported by advances in digital technology, material science, and biomechanical understanding. The incorporation of three-dimensional treatment planning, improved thermoplastic materials, optimized attachment designs, and auxiliary mechanics has significantly expanded the scope of malocclusions that can be managed with aligners.

From a biomechanical perspective, clear aligners are capable of delivering controlled, biologically favorable forces when tooth movements are carefully staged and supported by appropriate auxiliaries. Their effectiveness has been demonstrated most consistently in mild to moderate malocclusions, particularly for alignment, spacing correction, and selected sagittal and vertical adjustments. However, predictability decreases as treatment complexity increases, emphasizing the need for sound clinical judgment and realistic treatment objectives.

Clinically, clear aligner therapy offers substantial advantages in terms of esthetics, patient comfort, and oral hygiene maintenance, which contribute to high levels of patient acceptance and satisfaction. At the same time, its dependence on patient compliance, limitations in achieving certain complex movements, and higher cost compared to conventional fixed appliances remain important considerations. These factors underscore the importance of careful case selection, patient education, and the judicious use of hybrid treatment approaches when indicated.

In summary, clear aligner therapy should not be viewed as a replacement for conventional orthodontic appliances, but rather as a complementary treatment modality within the orthodontist's armamentarium. When applied with a thorough understanding of its biomechanical principles, clinical indications, and limitations, clear aligner therapy can produce predictable, efficient, and esthetically pleasing outcomes. Ongoing research and technological advancements are expected to further refine aligner systems and enhance their role in contemporary orthodontic practice.

REFERENCES

1. *Tiantong L, Mair A. An historical overview of clear aligner therapy the evolution of clear aligners. 2020.*
2. *Zheng, M.; Liu, R.; Ni, Z.; Yu, Z. Efficiency, effectiveness and treatment stability of clear aligners: A systematic review and meta-analysis. Orthod. Craniofac. Res. 2017, 20, 127–133.*
3. *Rossini, G.; Parrini, S.; Castroflorio, T.; Deregibus, A.; Debernardi, C.L. Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review. Angle Orthod. 2015, 85, 881–889.*
4. *Rinchuse, D.J.; Cozzani, M. Effectiveness and efficiency in clinical orthodontic practice. Int. Orthod. 2015, 13, 507–524.*
5. *Jindal, P.; Juneja, M.; Siena, F.L.; Bajaj, D.; Breedon, P. Mechanical and geometric properties of thermoformed and 3D printed clear dental aligners. Am. J. Orthod. Dentofac. Orthop. 2019, 156, 694–701.*
6. *Kalia S, Reginald M, Birte M. Clear aligners and their role in orthodontics. Adult Orthodontics. Wiley; 2022. p. 379-91.*
7. *Varshini GN, Kannan MS. Clear aligner therapy-a review. Eur J Mol Clin Med 2020;7:1689-93.*
8. *Kudagi V, Shivakumar S, VM N, Nitin P. Aligners in orthodontics: A review. Int J Appl Dent Sci 2021;7:187-9.*
9. *Arango JPG. Current biomechanical rationale concerning composite attachments in aligner orthodontics. In: Nandra R, Castroflorio T, Garino F, Ojima K, editors. Principles and Biomechanics of Aligner Treatment. 2021. p. 13-29.*
10. *Upadhyay M, Arqub SA. Biomechanics of clear aligners: Hidden truths & first principles. J World Fed Orthod 2022;11:12-21.*
11. *Johal A, Bondemark L. Clear aligner orthodontic treatment: Angle Society of Europe consensus viewpoint. J Orthod 2021;48:300-4. Weir T. Clear aligners in orthodontic treatment. Aust Dent J 2017;62:58-62.*
12. *Kundal S, Shokeen T. Aligners: The science of clear orthodontics. Int J Dent Med Spe 2020;7:38-42.*
13. *Lagravère MO, Flores-Mir C. The treatment effects of Invisalign orthodontic aligners: A systematic review. J Am Dent Assoc 2005;136:1724-9.*
14. *Gogna N, Irving M, Nandhra K. Aligner orthodontics: A literature review. Orthod Update 2023;16:33-8.*