ALIGNERS IN ORTHODONTICS

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Abstract : Clear aligner therapy (CAT) has revolutionized orthodontic treatment by offering an aesthetic, comfortable, and removable alternative to conventional fixed appliances. Originally limited to minor tooth movements, advances in materials, digital planning, biomechanics, and artificial intelligence have broadened their applicability to more complex malocclusions. This review explores the history, types, materials, clinical considerations, advantages, limitations, recent innovations, and environmental impact of aligners in modern orthodontics.

Keywords: Clear aligners, Invisible orthodontics, Aesthetic orthodontic appliances

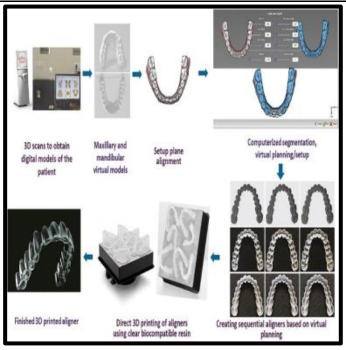
1. Introduction

Clear aligners have emerged as a discreet and patient-friendly orthodontic option addressing both aesthetic and functional concerns. Their removability facilitates oral hygiene and dietary freedom, while digital technology ensures personalized, precise treatment planning. However, their effectiveness is dependent on patient compliance and case selection. Despite limitations in managing certain complex cases, clear aligners have become a cornerstone in contemporary orthodontic care due to continuous innovation in materials and design.

2. Historical Perspective

The concept of clear aligners originated in the 20th century with early appliances like Kesling's tooth positioners. In 1999, Align Technology launched Invisalign®, marking a turning point in orthodontic treatment. Using thermoplastic aligners and CAD/CAM-generated treatment simulations, Invisalign offered a novel, patient-friendly alternative to braces [1,2]. Over time, enhancements in software and materials—such as SmartTrack®—extended its indications to include mild to moderate crowding, spacing, and malocclusions [3,4].

3. Types of Clear Aligners [5]

• **Type 1: Tooth Positioners or Guides: (Fig 1)** These are the earliest form of aligners, commonly represented by *Kesling's tooth positioner*. They are primarily used for minor final adjustments following fixed orthodontic treatment.	 **Fig 1 : Tooth Positioners or Guides**
• **Type 2: Thermoformed Plastic Aligners (Fig 2)** This category includes appliances like *Essix retainers* and *spring aligners*. These are typically used for minor tooth movements and post-treatment retention.	 ***Fig 2 : Thermoformed Plastic Aligners***
• **Type 3: Manual Setup-Based Aligners** These aligners are created from a series of dental models that are manually cut and reset to simulate progressive tooth movement. Each stage involves a new aligner, generally used for limited corrections over four to five stages.	
• **Type 4: Digitally Fabricated Aligners (Fig 3)** Utilizing advanced digital technology, these aligners such as Invisalign and other contemporary systems can address a wide range of malocclusions, from mild to complex. They offer enhanced precision in tooth movement with each successive aligner.	 **Fig 3 : Digitally Fabricated Aligners**

4. Material Composition and Properties

Aligner materials must be biocompatible, transparent, durable, and responsive to intraoral conditions. Common materials include:

• Polyethylene Terephthalate Glycol (PET-G): Known for strength, clarity, and processability. **(Fig 4)**

- Thermoplastic Polyurethane (TPU): Offers elasticity and wear resistance. **(Fig 5)** [6]

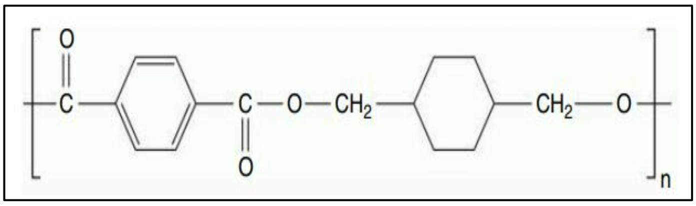


Fig 4: Chemical structure of polyethylene terephthalate glycol material (pet-g)

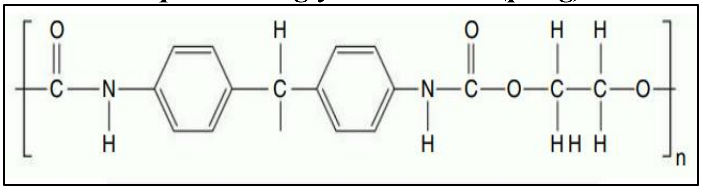


Fig 5: Chemical structure of polyurethane material (TPU)

Aligners typically fall under thermoplastics, which soften upon heating and can be reshaped. Polymer characteristics such as molecular weight, chain flexibility, and crystallinity significantly impact aligner performance [7].

5. 3D Printing in Aligner Fabrication

3D printing has optimized the aligner production process by enabling:

- Digital impression and virtual treatment planning.
- Precise model generation and aligner thermo forming.
- Direct aligner printing (emerging technology) [8].

Materials used include SLA resins, PLA, ABS, and photopolymers. Direct 3D printing enhances precision, reduces waste, and enables spatial control of aligner thickness.

6. Intraoral Effects on Material Properties

Aligner materials are subject to intraoral factors such as:

- Optical degradation: Staining from food and beverages, UV exposure, and poor hygiene can reduce transparency [9,10].
- Mechanical wear: Occlusal forces and temperature fluctuations can lead to stress, strain, and deformation.

Aligners are worn 20–22 hours/day and changed every 7–14 days, and their performance may vary depending on usage and compliance.

7. Clinical Considerations

7.1 Diagnosis and Records

- Extraoral: Profile, symmetry, smile analysis.
- Intraoral: Occlusion, dental alignment, gingival health.
- Diagnostics: Photographs, cephalograms, CBCT, intraoral scans, occlusal models

7.2 Indications and Contraindications

INDICATIONS	CONTRAINDICATIONS
Mild dental crowding or misalignment, typically within a 1–5 mm range.	Crowding or spacing exceeding 5 mm.
Minor dental arch expansions both anteroposterior and transverse, including cases requiring limited interproximal reduction or extraction of a single lower incisor.	Skeletal discrepancies greater than 2 mm in the anteroposterior dimension, particularly those observed in canine relationships.
Spacing issues involving gaps between teeth measuring 1–5 mm.	Significant discrepancies between centric relation and centric occlusion.
Deep bite cases, such as Class II Division 2 malocclusions, where correction is possible through incisor intrusion and advancement.	Severe tooth rotations, typically over 20 degrees.
Narrow dental arches that can be broadened without excessive tipping of teeth.	Anterior or posterior open bites requiring closure.
	Cases that involve extrusion of teeth.
	Severe tipping of teeth (over 45 degrees).
	Short clinical crown lengths, which hinder aligner retention.
	Arches with multiple missing teeth, affecting anchorage and aligner fit.

8. Advantages and Limitations

ADVANTAGES	DISADVANTAGES
Aesthetic appeal: Transparent design makes them nearly invisible.	**Patient compliance is crucial:** Aligners must be worn for at least 22 hours daily to be effective.
Enhanced comfort: Absence of brackets and wires minimizes irritation and ulceration.	**Restricted to certain tooth movements:** Complex movements often require additional appliances or auxiliaries.
Improved oral hygiene: Being removable, they allow for easy brushing and flossing.	**Higher treatment cost:** Aligner therapy can be more expensive than conventional braces.
No dietary restrictions: Patients can eat and drink without limitations during treatment.	**Speech disturbances:** Initial lisping or slurring is common but typically resolves within a few days.
Predictable treatment	**Risk of damage:** Aligners

timeline: Digital planning ensures accurate forecasting of treatment duration.	may break if excessive force is applied during insertion or removal.
Fewer clinic visits: Patients switch aligners at home, reducing the need for frequent appointments.	**Loss or misplacement:** Their removable nature makes them easy to lose.
Fewer emergencies: Compared to fixed appliances, aligners are less likely to cause urgent issues.	**Inconvenience during meals:** Aligners must be removed before eating or drinking anything other than water.
Adaptability: Suitable even for teeth with structural anomalies or difficult-to-bond surfaces.	**Manufacturing issues:** Defective aligners can lead to poor fit and reduced effectiveness.

9. Treatment Planning & Monitoring

Success with CAT depends on accurate case selection, proper staging, and ongoing clinical supervision—not merely dispensing aligners [11]. Tracking issues (poor aligner fit) should be monitored; minor discrepancies may be managed by prolonged wear, while major ones require auxiliaries or refinement aligners.

Patient Education

- Importance of compliance
- Purpose of attachments
- IPR (Interproximal Reduction)
- Potential limitations and duration

10. Aligner Manufacturing Workflow

1) Image Acquisition: Intraoral scans or digitized impressions
2) Treatment Planning: CAD-based simulation of tooth movement.
3) Model Fabrication: 3D printing of sequential stages.
4) Aligner Fabrication: Thermoforming, trimming, polishing.
5) (Emerging): Direct aligner 3D printing, bypassing physical models [8]

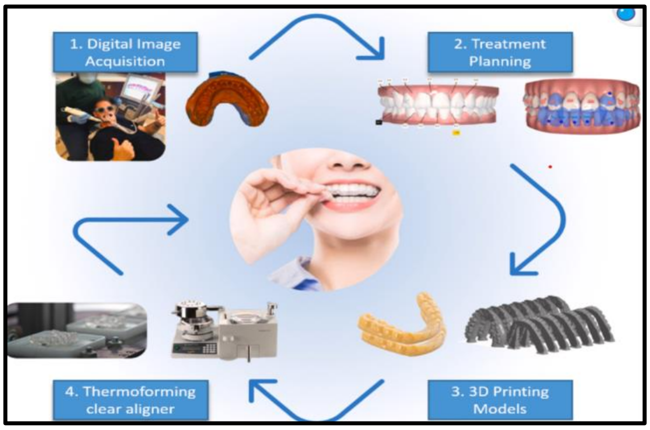


Fig 6 :Workflow of fabrication of clear aligners by the thermoforming process.

11. Innovations in Aligner Materials

11.1 Shape Memory Polymers (SMPs)

SMPs respond to temperature changes and recover their original shape, generating force for tooth movement. They allow for increased precision and may reduce the number of aligners needed [8].

11.2 Bioactive Materials

Incorporation of fluoride-releasing nanoparticles (e.g., hydroxyapatite, S-PRG) provides anti-caries benefits and supports remineralization.

12. Environmental Considerations

Each patient uses dozens of aligners—typically non-recyclable PET-G or TPU—which contribute to global plastic waste. With less than 9% of plastic effectively recycled worldwide, there is an urgent need for eco-conscious aligner systems and recycling programs [8].

13. Conclusion

Clear aligners represent a patient-centric, technology-driven evolution in orthodontics. However, their success is contingent upon accurate diagnosis, material science, biomechanical understanding, and patient compliance. While advancements like SMPs and direct 3D printing expand their potential, clear aligners should be prescribed judiciously, with close professional oversight to ensure effective and sustainable outcomes.

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