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# TRANSFORMING SMILES WITH CLEAR ALIGNERS:AN EVOLUTION IN ORTHODONTICS

Dentistry

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## ABSTRACT

Researchers have developed a number of alternatives to traditional braces to satisfy the increased cosmetic demand, including ceramic or composite braces, lingual orthodontics, and clear aligners. A set of transparent dental appliances that are specifically designed to suit a patient's teeth are used in the clear aligner therapy. Over the decades, clear aligners have become incredibly popular as an aesthetic and comfortable orthodontic treatment option.

## KEYWORDS

clear aligners, aesthetics, retainers, orthodontic treatment

## INTRODUCTION

Clear aligner-based treatment has drawn a lot of interest from the orthodontic community over the past 20 years, particularly from general practitioners. The desire for aesthetic and comfortable alternatives to traditional fixed appliances has increased as a result of the rise in adult orthodontic patients. Clear aligners provide an esthethic and comfortable treatment experience, facilitate oral hygiene, cause less pain as compared to fixed orthodontic appliances, reduce the number and duration of appointments, require less emergency visits. When Kesling unveiled "the positioner to refine the final stages of orthodontic treatment" in 1940, the idea for clear aligners began to take shape. Ponitz RJ[1] introduced "the invisible retainer" in 1971, inspired by Kesling's positioner. McNamara and Sheridan[2] thereafter developed similar devices. Rapid prototyping (RP) and computer-aided design (CAD) techniques enabled for the industrial planning of orthodontic therapy as well as the production of polymeric aligners. In 1998, Align Technology (Santa Clara, CA) introduced Invisalign, a series of removable polyurethane aligners, as an aesthetically appealing alternative to fixed labial braces. This system allowed for movement of multiple teeth simultaneously, to fix various malocclusions. With the advent of auxiliaries, attachments, and better fabrication materials, the system has recently seen a remarkable evolution that enables aligners to generate a wider range of movement in less time.

### View From The Past

It started with Harold D. Kesling,[3] who developed the first non-metal removable appliance for straightening teeth in 1945. Made of rubber, the "Tooth Positioning Appliance" enclosed both teeth quadrants. This appliance made mild tooth corrections and served as a finishing effect for braces to speed up the treatment time. In addition, the Positioner served as a retainer after removing braces. Kesling anticipated that with a series of positioners, major tooth movements could be achieved by slightly altering the teeth on the setup as therapy advances.

In 1964, Henry Nahoum[4] improved Kesling's method by creating a vacuum-based device that demonstrated strong adaptation to a patient's cast. Using a fissure bur or a goldsmith's saw, rotated anterior teeth were sectioned off of the cast using this procedure, and were then rearranged with wax on the cast to get the desired results. A variety of thermoplastic materials, including acetates, vinyl styrene, polyethylene, and butyrate sheets could then be vacuum-formed over the designed cast to fabricate a dental contour appliance that could move teeth.

In order to introduce an "Invisible retainer" in 1971, Ponitz[1] used Biocryl (polymethyl methacrylate), a material consisting of cellulose acetate butyrate, polyurethane (PU), polyvinyl acetate-polyethylene polymer, polycarbonate-cycolac and latex. This vacuum-formed transparent plastic appliance was initially created for the purpose of finishing and maintaining orthodontic cases using base plate wax on the prepositioned cast. It could achieve limited orthodontic tooth motions, primarily by tipping crowns, and it could be utilised for continued retention.In 1985, McNamara[5] modified Ponitz's technique and used 1 mm thick Biocryl™ polymers with a Biostar vacuum forming machine to fabricate invisible retainers for retention and final detailing.

Finally, Jack Sheridan[2] 1993 created the term "Essix appliance" to describe an aesthetic method for the alignment of anterior teeth by combining clear appliances with interproximal teeth reduction. He did this by using polypropylene, a 0.030" sheet of thermoplastic copolyester from Raintree Products. Additionally, he advised employing McNamara's positive air pressure thermoforming technique to almost halve the thickness of the sheet after manufacturing.

Despite these developments, the fundamental idea of inducing slight tooth movements with individual transparent appliances remained the same. The process of fabricating appliances involved taking impressions, pouring casts, sectioning individual teeth, aligning them properly to create a final cast, and repeating this procedure at each clinical appointment. The solution to which arrived in the form of a clear aligner system named Invisalign, that involved a series of removable polyurethane aligners created digitally by two Stanford graduates – Zia Chishti and Kelsey Wirth, launched in 1998 by Align Technology (Santa Clara, CA). This was the first orthodontic appliance to be fabricated using transparent and thermoplastic polymeric materials, with the aid of modern CAD/ CAM technology.[6] This system involved a multiple-step process, beginning with the three-dimensional (3D) reconstruction of patients' dentition, obtained either from an intra-oral scan or digital scanning of the study models, followed by segmentation of the individual crown with the help of a computer algorithm, and the development of treatment plans presented visually as a sequence of incremental tooth movement by a predetermined amount using the software. The following step involved employing fast prototyping to create the physical models for each stage of tooth movement.[7,8] In the end, a thermoforming procedure was used to create the custom aligners, and they were then cut to their final shapes.Table 1 enlists the four basic categories of clear aligners.

**Table1: Categories Of Clear Aligners**

| CATEGORY | EXAMPLES |
|---|---|
| 1. Positioners or guides | Orthodontics Positioner,Nite-Guide,Myobrace i-3,Occlus-o-guide,Preformed positioner |
| 2. Thermoformed Appliances | MTM Clear Aligners,Inman aligners,Straight 'N' Clear cosmetic corrector |
| 3. Teeth manually reset | Clear image aligners,Dual Laminate,Red White Blue Simpli |
| 4. Teeth digitally reset | Invisalign Full, Invisalign Teen, Invisalign Express, Invisalign Assist, Vivid Aligner, Clear correct |

Activation of tooth movement in CAT is by changing to a new set of CA which are provided by the manufacturer. The total number of trays hence used depend on the severity of the malocclusion. These plastic

trays are placed in the mouth, which is a hostile environment wherein the tray will be subjected to various kinds of thermal, mechanical and chemical injuries for a span of 2 weeks. Hence, degradation of these trays might occur in the long run. When such damage occurs leaching of toxic chemicals is another possible event. Several toxins like methylene diphenyl di isocyanate (MID), 1,6-hexanediol di acrylate (HD), benzene, 1,3-bis(1,1-dimethylethyl), phenol, and various metals were reported to leach from these plastic trays.[9,10] These thermoplastic materials were found to induce cytotoxic and localized allergic responses which could be attributed to these released toxins.One such chemical leakage which happened to raise a huge concern among the dental professionals was BPA- which is a xenoestrogen. When further narrowing down the effect of BPA in terms of age and orthodontic relevance, studies have raised apprehension based on the impact of BPA in the teenage orthodontic population which form one of the major orthodontic treatment group.[11] As new aligner materials are being born into the market annually, safety of these materials should be checked. New thermoplastic materials which were marketed as BPA free, have shown the release of BPA even though in small quantities in various studies.

It was reported by Martina S et al[12] that the cytotoxic effect was more among the thermoformed aligners than non-thermoformed aligner materials, because thermoforming might accelerate the liberation of toxic chemicals. In-vitro studies by Katras S et al,[13] Kotyk MW & Wiltshire Wa[11] and an in vivo study by Raghavan AS et al[14] have shown the potential release of BPA within 24 hour of plastic tray wear.

**Indications**

1. Mildly crowded areas. Treatment that can be accomplished with lateral and/or antero-posterior expansion, minor interproximal tooth reduction, or removal of a lower incisor.
2. Problems with spacing (1–5 mm).
3. Class II division 2 type malocclusions associated with deepbite where the overbite can be addressed by incisor intrusion and advancement.
4. Narrow arches that may be extended without tipping the teeth.
5. Cases of relapse after fixed orthodontic treatment.
6. Minor rotations.

**Contra-indications**

1. Crowding and spacing greater than 5 mm.
2. Discrepancies between Centric-relation and centric occlusion.
3. Teeth that have been severely rotated (greater than 20 degrees).
4. Anterior and posterior open bites that must be closed.
5. Teeth extrusion.
6. Teeth that are tipped more than 45 degrees.
7. Teeth with clinical crowns that are too short.
8. Arches with many missing teeth.

**Biomechanics Of Cat**

The mechanism of tooth movement with clear aligners is centered around two systems:[15,16]

1. Displacement-driven system: Controls tipping and minor rotations. The tooth continues to move until the aligner becomes passive; aligners are made in accordance with the subsequent staged position. Root movement was not elicited.
2. Force-driven system: The software determines the mechanical principles required to achieve the movement needed for each individual tooth, the type of movement needed, and the shape of the aligner. The forces necessary for intended movements are applied via pressure points and attachments built into aligners.

**Generations Of Clear Aligners**

**First-generation Aligners**

No auxiliary elements were incorporated. The first case report utilising first generation Invisalign to treat cases of mild crowding and space closure was published in 2000.[17] Clinicians experienced various challenges and restrictions when using these clear aligners.

**Second-generation Aligners**

With improvements in aligner systems, manufacturers included the use of attachments to better control the intended tooth movement. Other features, including SmartForce™ attachments, Power Ridge™, Velocity Optimization, and interproximal reduction (IPR) became universal in the Invisalign system.

**Third-generation Aligners**

The third-generation aligners introduced in 2010 included Smart Force™ features like optimised attachments designed and placed automatically by commercial software as well as Power Ridge indentations in the polyurethane plastic that increased pressure on specific points on the crown to produce a couple moment and root torque. Additionally, the clinician may advise non-precision attachments to be affixed to the teeth wherever they are needed to enhance movements like derotation and extrusion. For Class II and Class III interarch elastics, new precision cuts have been made available.

**Fourth-generation Aligners**

In order to improve clinical outcomes in open bite instances with numerous teeth having improved, optimised extrusion attachments, G4 attachments were released in 2011. For upper laterals, new multi-plane movement capabilities were offered to improve crown tipping, rotation, and/or extrusion. For better mesiodistal root control of canines and central incisors, optimised root control attachments were introduced.

**Fifth-generation Aligners**

In late 2013, fifth-generation improved the predictability of deep bite correction by introducing pressure areas on the lingual of the upper and lower anterior teeth, precision bite ramps on the lingual of the upper incisors, and bevelled dome-shaped retention attachments on the premolars. However, a recent study by Blundell et al.[18] found that the use of precision bite ramps does not appear to significantly improve the ability of SmartTrack™ material to predictably open the bite compared with EX30 materials.

**Sixth-generation Aligners**

Late in 2014, the sixth generation clinical innovation for first premolar extraction orthodontic treatment was unveiled. This innovation uses new Smart Stage™ technology and Smart Force™ features to provide vertical control and root parallelism that optimise the progression of tooth movements for extraction treatment planned for maximum anchorage.

**Seventh-generation Aligners**

Invisalign G7, a set of features created to provide better treatment outcomes and greater control over tooth movements, was released in 2016, especially for young patients. It sought to provide improved root control and characteristics to address the prevention of posterior open bites, as well as better upper lateral incisor control.

**Eight -generation Aligners**

The eighth-generation advancements, which use Smart Force™ aligners activated for anterior intrusion and changes to the Clin Check virtual proprietary software setup to level the Curve of Spee, were made around the end of 2020. They were designed to further increase the predictability of deep-bite correction. G8 also minimizes unwanted crown tipping during posterior arch expansion with optimized expansion support and rotation attachments to reduce the potential for buccal crown tipping.

**Materials Used**

The materials used in clear aligners have changed over time, from a single layer or monophasic plastic to a second-generation polyurethane material to the third-generation, multilayered polyurethane-like material that is currently in use and contains both hard and soft layers. While the soft layer imparts the property of elastic deformation allowing smooth seating of the aligner, the hard layer ensures strength and durability. Polyethylene terephthalate glycol modified (PET-G) remains the commonly used material. Other materials include polypropylene, polycarbonate, thermoplastic polyurethanes, and ethylene vinyl acetate.

**Duration Of Aligner Use**

To ensure that the aligner prescription is expressed to its fullest extent, wearing an aligner for 22 hours each day for two weeks is required.[19]

**Treatment with Clear Aligners: Scope and Its Limitations**

There are many different types of malocclusions that cannot be corrected with clear aligners, despite the fact that the quantity and complexity of cases treated with them are both growing. In cases of lower incisor extraction, mild to moderate crowding or diastema, posterior expansion intrusion of one or two teeth, and distal tipping of molars, clear aligners are practical. Extrusion, severe rotation correction, molar uprighting, and extraction space closure are movements that are known to be more difficult to achieve using

aligners. However, using attachments with the Invisalign system, incisor extrusion, molar transition, and closure of extraction areas are all achievable.

### Future of Aligners

Patients often receive several plastic aligners, each of which is worn for one to two weeks before being discarded with little chance of recycling. The Environmental impact of transparent aligners has grown to be a significant problem. The current orthodontic market does not appear to indicate a decrease in the usage of clear aligners, and it does not appear realistic for aligner manufacturers to develop substitutes for plastic in clear aligner production. According to Elshazly et al[20] shape memory polymers may make it possible to create a single shape-changing aligner that might perhaps replace up to three successive conventional aligners. As a result, it would be possible to utilise fewer aligners during orthodontic treatment, which would lower overall fabrication costs and reduce plastic use. In addition to being thoroughly studied in tissue engineering and regenerative medicine, biodegradable materials have also demonstrated a plausible potential in waste management. It is still worthwhile to investigate the practical application of the bioactive surface coating on biodegradable thermoplastic materials or direct 3D printing materials in treating malocclusion even though biodegradable plastics are only seen as a portion of the solution to lessen the environmental burden.

## CONCLUSION

Clear aligner therapy is now an accepted mainstay of orthodontic treatment and among the multiple parameters that affect the clinical performance of clear aligners, the material employed for the aligner fabrication plays an all-important role. In patients wearing clear aligners, achieving periodontal health is simpler, and less white spot lesions form during the course of treatment. Clear aligners can be utilised in cases of mild to moderate crowding, but care must be used in more complicated cases. The risk of root resorption persists even after aligner treatments. Long-term stability studies are required in this field.

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