The Era of Clear Aligners- Computerized dentistry providing aesthetic orthodontic treatment.”

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ABSTRACT
Patient demands for aesthetic orthodontic treatment outcomes have grown to include aesthetic appliances during treatment. Contemporary orthodontists have begun to focus on the patient’s perspective of treatment and how much value he or she places on quality of care and quality of life issues. Since the introduction of the Tooth Positioner (TP Orthodontics) in 1944, removable appliances analogous to clear aligners have been employed for mild to moderate orthodontic tooth movements. Orthodontic treatment with clear aligners is a quickly growing sector of orthodontic treatment. Use of computerized programs have allowed for easier visualization and treatment planning of orthodontic malocclusions. Both the increase in awareness of aesthetics and the increase in orthodontic treatment demand from adults has fuelled the demand for a more aesthetic orthodontic treatment technique. The present paper will highlight the increasing popularity of clear aligner appliances, as well as the clinical scope and the limitations of aligner therapy in general. Further, the paper will outline the differences between the various types of clear aligner products currently available.

KEYWORDS: Aligners, Aesthetic orthodontics, 3-D planning, CAD/CAM, Virtual set up

INTRODUCTION
The demand for aesthetic treatment options are rising in the field of orthodontics. Efforts are being continuously made to meet this demand for aesthetic treatment options. Stainless steel bands got replaced by tubes that could be directly bonded on the tooth surface. Tooth coloured brackets made of ceramic and plastic came next to meet the aesthetic goals of
orthodontic treatment. Wires with coating which closely mimic the tooth colour were used along with the ceramic brackets to improve the aesthetics. The first description of tooth movement caused without the use of traditional wires was reported by Dr H.D. Kesling in 1945 who used a flexible tooth positioner appliance. Nahoum and many others later reported on the different types of overlay appliances like the invisible retainer.1

In today’s market there are a variety of clear aligner options available from all over the world. Even though research is being done in the area of clear aligners, the aim of the early studies was to show that scope of aligner treatment is limited to minor spacing or crowding cases. Majority of literature on clear aligners comprises case reports.2

CLASSIFICATION OF DIFFERENT ALIGNER SYSTEM: 3

1. ON THE BASIS OF CLINICAL APPLICATION
   - Retention Appliances
   - Active tooth moving appliances

2. ON THE BASIS OF METHOD OF THERMOPLASTICIZING
   - Vacuum Formed- Invisalign, Orhtoclear,3D Ortholine, Clear aligner Intl, Essix
   - Positive pressure – Essix, Biostar (Scheu-Dental, Iserlohn, Germany)

3. ON THE BASIS OF MANUFACTURING PROCEDURE
   - CAD/CAM or commercial systems based on virtual set up
   - Fabrication with manual set up, controlled by the clinician or laboratory

4. ON THE BASIS OF FREQUENCY OF FABRICATION
   - Serial aligners (Lab/Company governed). i.e.Invisalign,Orthoclear, 3 D Ortholine
   - Step-wise gradual fabrication (Clinician governed)

INDICATIONS OF ALIGNER THERAPY: 4-7

- Minor crowding cases (<4mm).
- Open bite, deep bite, cross bite and mild to moderate expansion.
- Control of rotation, intrusion, and extrusion are better managed with the help of attachments.
The aligners can also be used simultaneously for tooth bleaching, if a bleaching gel is placed inside the tray.
Clear aligners can also be used as active and passive retainers.

CONTRA INDICATIONS FOR CLEAR ALIGNERS:

- Cases with spacing and crowding of more than 5mm.
- Skeletal sagittal discrepancy of greater than 2mm.
- Centric-relation and centric-occlusion discrepancies.
- Severe rotation of teeth.
- Severe open bite.
- Extrusion cases.
- Severe tipping of teeth.
- Short clinical crowns.
- Multiple missing teeth.

ORTHODONTIC FORCE DELIVERY SYSTEMS OF ALIGNERS:

Orthodontic tooth movement is based on the force delivery system of the appliance. The following components in aligners are involved in force application.³

1) ELASTIC PROPERTY OF THE ALIGNER
Different systems have different brand names for the polyurethane material used to fabricate the aligners. Material studies clearly indicate using a thicker polyurethane material causes more control of tooth movement. 0.75mm and 0.50mm thickness of aligners have better stiffness and clinical efficacy compared to 0.25mm of aligner thickness. It is generally accepted that an aligner tray generates 50 gms of force upon initial placement. Hard and soft materials performed equally well.⁸ Material fatigue determines the force constancy of a particular aligner and studies generally recommend an aligner change every week or two weeks depending on the system being used. Two-week activation times led to a higher degree of success than 1-week activation times.

2) OCCLUSAL FORCES
The chewing forces or masticatory apparatus is responsible for a better seating of the aligner for it to exert the appropriate force and anchorage control, causing desired tooth movement.

3) THE USE OF ADJUNCTS, AUXILIARIES, AND ATTACHMENTS
Proffitt states “it can be difficult to maintain removable appliances in place against the displacing effects of a pair of springs with heavy activation. The usual orthodontic solution is a fixed attachment on the tooth, constructed so that forces can be applied at two points”⁹. The tooth geometry and position are important determinants of where the points should be located.
Aligner therapeutics has always employed adjuncts, attachments and auxiliaries. They can be classified as:

- Those that augment appliance retention.
- Those that provide or support auxiliary functions.
- Those that assist movements.

Or based on whether they are attached to the tooth, or formed in the appliance.

**CLINICAL PROTOCOLS AND EVALUATION OF DIFFERENT ALIGNER SYSTEM**

A successful aligner therapy involves a proper diagnosis, case Selection and treatment plan. There might be some variation in the laboratory technique and method of fabrication, the management of clear aligners clinically is almost similar.

**A) GNATHOLOGIC CLEAR PLASTIC POSITIONER**

Lloyd Cottingham introduced a positioner appliance made of clear plastic gnathologically made to supplement the active phase orthodontic treatment. A mechanical means for the improvement of tooth positions is provided by the positioners after the culmination of appliance treatment before starting the retention protocol. A high degree of finish can be achieved in some cases using positioners. Gross treatment changes cannot be brought about by their use.

Material used for the gnathologic clear plastic positioner is Impark material that was produced by the Vernon Benshoff Company in Philadelphia.

Positioner effects:
- Small amount of mesiodistal correction can be achieved with the help of positioners.
- For correcting non-coincident midlines in simple cases.
- Correcting abnormal second molar relations on the balancing side.

**B) ESSIX SYSTEM**

Essix retainers were introduced in 1993 as an aesthetic, comfortable and inexpensive alternative to traditional fixed and removable orthodontic retainer.

Essix tooth movement is a unique biomechanical system involving the use of a removable plastic appliance.

**FABRICATION OF ESSIX RETAINERS AND ALIGNERS**

The Essix appliance is a light weight, transparent, removable device that fits snugly over the dentition. It’s mainly used as a retention device. Essix appliance is made up of two types of plastic materials:
1) Type A+: It is highly resilient and hence the material of choice for bite planes and occlusal splints. It is also used in cases that require long-term retention.

2) Type C+: It has high wear resistance and has more of a natural appearance on the teeth.\(^{12}\) Raintree Essix has recommended the use of PVS (polyvinyl siloxane) impression system.\(^{13}\)

Thermoforming: Raintree Essix has recommended the use of a vacuum thermoforming machine.\(^{13}\)

CONTRAINDICATIONS AND LIMITATIONS OF ESSIX APPLIANCES
- Poor oral hygiene
- Non-compliant patients
- In cases of severe pre-treatment rotations of the anterior teeth.

CLEANING
The use of toothpaste can cause dullness of the appliance. Soap and water at room temperature should be used to clean the appliance. Essix Retainer Brite® #RB-TP can also be used.

ALIGNER FABRICATION
Fabrication of Essix aligners is done in a step-wise manner. Dental casts are fabricated after taking the patient impression. The teeth the aligned on the model by altering their position as desired. This can be achieved in two ways:
- a) Dental model teeth are cut and ideally repositioned on a wax setup.
- b) By artistically “shaving” (modify) the side of the model that requires force application and then blocking out (void) the opposite side where tooth movement is desired.
Finally an Essix aligner is fabricated on the modified model.

MINOR TOOTH MOVEMENTS WITH WINDOWS AND DIVOTS
Essix retainers are retained, without the help of clasps. The appliance is retained with the help of the natural undercuts present gingival to the anterior contact points. These retainers are fabricated from .030” Essix plastic sheet, which gets reduced to .015” during thermoforming.\(^{14}\) The superior flex memory of this material makes minor tooth movements possible. Therefore, Essix retainers can be used for retreating a minor relapse of anterior teeth or for detailing a finished case when alignment discrepancies become apparent after debonding.
By the process of thermosealing, two sheets of plastic are thermally bonded and a rigid composite is sealed between them. This modification expands Essix applications to include habit breaking appliances, posterior stabilization appliances, space maintainers, and bite planes, while maintaining the advantages of less anterior bulk (less than 0.5mm), invisibility and low cost.\(^{15}\)

CLINICAL EVALUATION OF THE ESSIX SYSTEM
The appliance has been used for retentive devices and brings about active tooth movement also. It has also been reported for retentive bridges, habit appliances, molar uprighting and distalization, space maintenance and for replacing missing teeth. Alternatively, it can be used to fabricate bite guards and bleaching trays. Essix bite planes are extremely clinician friendly
without requiring posterior extensions. Force amplified retention for treated Anterior open bites have also been demonstrated using elastic wear. Armbruster and Sheridan\textsuperscript{16} have described tipping, torquing, rotation, intrusion, space closure, and Class II & Class III elastic applications with the system. Tooth movement has been induced with the ESSIX appliances by using two primary systems. The first with the use of the Hilliard thermo pliers to alter the plastic by spot thermoforming it and the second by mounding which involves placement of small mounds of composite to the surface of the tooth.

C) INVISALIGN
Align technology, Inc[Santa Clara, Calif], Invisalign system was introduced in 1997 as a new orthodontic tool. Invisalign takes the principles of KESLING, NAHOUM and RAINTREE ESSIX forward. With the help of CAD-CAM technology in combination with laboratory procedures a series of aesthetic, removable, custom appliances are fabricated that can bring about tooth movement.\textsuperscript{17} Apart from aesthetics, these appliances have other advantages such as ease of use, comfortable to wear, simplicity of care and better maintenance of oral hygiene.\textsuperscript{18}

UNDERSTANDING THE INVISALIGN SYSTEM
Laser scanning, imaging and production of high precision casts is the revolutionary aspect of Invisalign\textsuperscript{®}. The patient’s dentition can be replicated on a screen and viewed as a 3-D model. Virtual corrections can be made in them by the orthodontist and translated by Invisalign\textsuperscript{®} using sophisticated propriety software.\textsuperscript{19} The clinician is able to assess the ‘virtual’ models from malocclusion to the final correction, movement by movement, through an online program called ‘ClinCheck\textsuperscript{®}’. Once the changes made by the program are approved by the clinician, the aligners are fabricated and sent.\textsuperscript{19}

TECHNIQUE AND TECHNOLOGY
The Invisalign\textsuperscript{®} technology involves the following procedures:

A) Collecting high quality pre-treatment records
It is important to obtain high quality pre-treatment records which includes study models, orthopantomograms and cephalometric radiographs, along with photographs. Polyvinyl silicone material is the material of choice to take the impressions since high quality and proper recording of the dental and adjacent tissues is essential. Apart from the study models rest of the records are sent to Align Technology.

B) Interactive treatment planning with Align Technology
Within about 10-14 days of sending the records, the patient’s ‘virtual models’ are ready where the treatment plan has been translated into tooth movements and the ‘virtual correction’ can be viewed stage by stage and from any angle. to the treatment plan are unlimited. Once the changes made by the program are approved by the clinician, the aligners are fabricated and sent.

C) Aligner application
The entire set of aligners gets delivered to the orthodontist within a month’s time including all the aligners from the beginning to the end of treatment. The package is also accompanied by a
patient start-up and care kit. On the first visit, fitting of the initial aligners, are checked for fit and comfort. Depending on the schedule by Align Technology, the decision of starting IPR is made. All the required instructions regarding the wear and cleaning of the aligners is given to the patient. Patient is recalled after 2-3 weeks.

At the second visit the patient’s comfort checked in wearing the aligners on a full-time basis. IPR is checked using floss and continued if needed. The second aligner is fitted and aligner 3 given to the patient so they can replace aligner 2 after two weeks use. Thus, the patient is seen every 4 weeks.

A typical Invisalign® treatment will take around 25 aligners and 50 weeks of treatment, but can vary from 10 to 50 aligners, depending on the severity of the problem.

EVALUATING TREATMENT EFFECTS WITH INVISALIGN

Studies done by Bollen and Clements showed that the use of this appliance is successful for various types of tooth movements like tipping, incisors rotations and space closure. More complicated movements, such as bodily movement for closing extraction spaces, were less successful.20,21

Djeu22 conducted a cross sectional study where fifty cases treated by clear aligner cases were compared with fifty matched cases treated with fixed appliances. Using the American Board of Orthodontics grading criteria, the results indicated that the finishing with fixed appliance were generally better. Kunico et al23 evaluated post treatment retention outcomes with traditional orthodontics and the Invisalign system using the ABO objective grading system and noticed a significant change in alignment scores after at least one year of retention with the Invisalign system compared to traditional orthodontics.

Boyd et al.21,24 conducted a study where he compared the discomfort levels in patients who underwent clear aligner therapy to patients who had received fixed appliance treatment. It was observed that aligners caused much less discomfort and the incidence of mucosal irritation, and soreness of the teeth was also lower in the aligner group when compared to the fixed appliance group.

RECENT PROTOCOL IMPROVEMENTS IN CAD-CAM ALIGNERS ADOPTED BY 3D ORTHOLINE AND INVISALIGN

In 2003, a Clinical Advisory Board (CAB) was formed by Align Technology which consisted of 13 orthodontists with extensive experience in aligner therapy. After the successful treatment results achieved by protocol followed by CAB, Align Technology adopted majority of its elements in “Best Practices Protocol”, which was recommended for all treatment performed after Jan 1, 2007.

These changes can be categorized in the following:25

1) Corrections in the antero-posterior dimensions

   • The designing of the virtual setup is done in order to enable better visualization of the desired treatment objectives. Inter-arch elastics are incorporated in the planning. Placement of buttons and elastics are planned to achieve individual tooth movements.
• The simulation of the effect of elastics is done and the anterior-posterior correction to be achieved at the end of treatment can be viewed and the final arch coordination and occlusion can be verified.

2) Stages for Interproximal Reduction
• Automatic staging of the timing of IPR is done when the access to interproximal contacts is better.
• Staging of IPR will be done when the overlap between teeth is not much.
• Saving necessary IPR is needed in some cases for Bolton’s discrepancies.

3) Staging for Tooth Movements
• The minimum number of stages required is determined by the tooth that has to be moved the maximum distance. The remaining teeth will be moved at a slower pace compared to the lead tooth.
• Movement of teeth happen throughout the period of treatment.

4) Attachments
• The position of the attachments have been shifted from 2 mm from the gingival margin to the centre of the crown.
• Teeth with small rotations receive attachments.
• Long clinical crowns receive a longer rotational attachment.
• In case of round teeth and canines the attachments used are 1 mm in thickness and rectangular in shape. Similar attachments are used for bodily movement of teeth when they are being moved through extraction spaces.
• For retention of aligners, horizontal beveled attachments of 1 mm thickness and rectangular shape are used on the premolar teeth. Similar attachments are used for tooth movements like intrusion. Curve of spee correction, extrusion and torque control.
• 3D Ortholine uses attachments only for a specified period of treatment and indicates removal after that specific tooth movements is achieved, making treatment more acceptable to patient.

5) Staging of Tooth Movements
• Separate tracking of both rotational and linear velocities of the teeth are done.
• The tooth that is moved the most determines the staging of the tooth movement.
• Slower rotations are staged in treatment
• Movements of all teeth are simultaneous.
• 0.05 mm of visible spacing is provided between tooth movements.
• Expanding the arches is preferred as a means of gaining space to correct crowding instead of proximal stripping.

CONCLUSION:
Though the patient’s demands may necessitate the use of inconspicuous methods to correct malocclusions a lot is still to be about the biomechanical aspects and effectiveness of the clear aligner systems.
Certain limitations in terms of pricing, clinical experience and the type of cases that can be treated with aligners exist. Expertise is required in the area of 3-D planning and the softwares related to them. Aligners may not give the best results in cases involving certain tooth movements or mixed dentition and impaction cases. These limitations should be understood the orthodontist and they should accordingly choose aligners as the treatment of choice. The scope of aligner treatment is ever expanding. With new technological advancements happening every day the current limitations of this treatment modality might be reduced. It is not a question of whether invisible retainers or aligners will move teeth (they will), but rather for which cases this technology is appropriate.

REFERENCES: