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Review Article

Aligners in Orthodontics: A Review Study

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ABSTRACT:

When we hear the word "orthodontics," what comes to mind is probably a young teenager whose teeth are covered by a latticework of metal. However, there now exists an increasingly popular alternative to traditional metal braces: Clear aligners. This article describes the aligner technique, the technology behind aligners, what it is, how it works, process, records which are essential for case submission, case selection and advantages of Aligners are highlighted. The aligner clinical technique, procedure, essential tips are described and cases treated with Aligners are presented. **Keywords:** Aligners, Invisible orthodontics, Clear aligners, Aesthetics, Malocclusion, Tooth movement.

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INTRODUCTION

Orthodontic treatment used to is correct malocclusions, caused by dentoalveolar and skeletal discrepancies. Orthodontic appliances have been found among Greek and Etruscan artifacts¹. However, removable and fixed orthodontic appliances were first introduced to a wider audience by Kingsley and Angle in the late 19th century². The first aligner treatment was introduced by Kesling in 1945 and consisted of a series of a rubber-based tooth positioner appliances intended to gradually correct misaligned teeth. Fixed appliances (FA) treatment with brackets and arch wires have been dominating over removable appliances treatment during the last decades. Due to computer aided design and computer aided manufacturing technique (CAD-CAM), removable clear aligner treatment has gained popularity in recent years³ and is considered as a more esthetical alternative to buccally placed fixed appliances⁴.

Before the introduction of CAD-CAM technique, the production of clear aligner was labor intensive. Clear thermoplastic appliance was manufactured on multiple series of plaster casts where the teeth were separated from the socket and progressively positioned into an ideal occlusion. A series of clear plastic aligners were fabricated on these casts for the patient to wear and gradually move irregular teeth into the desired position. Today the computerized production process (CAD-CAM) of clear aligner starts with chairside direct scanning of patient's teeth and alveolar ridges. The scanning of the jaws is sent to a laboratory together with a prescription plan made by a dentist or orthodontist. A computer aided design (CAD) software is used to create a series of virtual models, in which the teeth are progressively moved to the desired position in the final model^{5,6}. When the virtual models are approved by the referring dentist or orthodontist, a series of aligners are produced by using computer-aided manufacturing technique (CAM). The aligners follow the stages of the treatment plan, and each aligner is worn full-time for 2 weeks in general^{5,7}.

There are now several companies offering variations of clear aligner (CA) treatment. Invisalign® and Essix® are two companies using in office scanning technique and the aligners are checked at dental appointments by professionals. Invisalign Align Technology (Invisalign®) created the first sequence of aligners in late 1990s that could correct more complex malocclusions in adults, teens, and children⁸ and has dominated the market since⁵.

Byte®, Candid Co®, ALIGNERCO®, and Smileunion® are some companies providing so called "home aligners" where impressions of the teeth are taken by the patient, then mailed to the supplier, and reviewed by an orthodontic team. A series of clear

aligners are produced using CAD-CAM technique and are then delivered to the patient. Each set should be worn for one week and full-time^{9,10,11}. SmileDirectClub® is a home aligner company where scanning of the patient's teeth is made at "Smileshops"¹², and series of aligners are delivered to the customer.

Several recent studies on "in office clear aligner treatment" have claimed that clear aligners produce less white spot lesions (WSL) compared to fixed appliance treatment^{13,14,15}. Fang et al. have stated that root resorption cannot be avoided with clear aligner, however the incidence and severity is lower after clear aligner treatment compared to fixed appliance treatment¹⁶. Periodontal health variables and oral hygiene have also been shown to be better in patients undergoing clear aligner treatment compared to fixed appliance treatment¹⁷. Aligner users have also been reported to have less pain and discomfort compared to patients treated with fixed appliances¹⁸.

Due to the increased popularity of clear aligners, we wanted to gain more knowledge about potential adverse effects with this type of treatment. This article provides a comprehensive review about the various types of orthodontic aligners available today.

TYPES OF CLEAR ALIGNERS

Clear aligners can be categorized into four basic types.

- Type 1: Commonly known as positioners or guides which include Kesling's tooth positioner.
- Type 2: Thermoformed plastics like Essix retainers, spring aligners.
- Type 3: Aligners that are made from models cut out to correct position to align teeth when done in a series of models. They produce minor tooth movement using four or five aligners.
- Type 4: Aligners fabricated using digital technology that can treat minor to complex malocclusions including posterior and anterior segments. There is increased precise tooth movement with every change in the aligner²¹.

WHAT MATERIALS ARE ALIGNERS MADE OF?

Clear aligners are made up of various combination materials or thermoplastic materials. These materials include; polyurethane, polyvinyl chloride, polyethene terephthalate, polyethene terephthalate glycol. Set of aligners are made virtually by particular software designed specifically for aligners using initially taken plaster impression or by direct 3D intraoral scan of patient's dentition. 3D models are needed for each set of aligners which are printed using stereo lithography or 3D model printing. Then next set of aligners are fabricated using thermosetting material over 3D model of the patient's teeth by vacuum forming or thermoforming process, and trimming is done finallyG The plastic material used for making aligners are stains and cracks free because of which they remain clear even after use, which makes aligners more esthetic and are not easily noticeable in patients' mouth. Biodegradable or recyclable materials are used for aligner trays, which makes them eco-friendly when compared to conventional orthodontic braces¹⁹.

THE PRODUCTION PROCESS

Clear aligners are made up of different thermoplastic materials by a thermoforming process. Aligners can be produced using two methods manual set up and by CAD CAM technologies.

Manual set-up: Manual set-up is labour involving method fabricated in laboratory and is technique sensitive. In this method impressions are manually taken on the patient and casts are fabricated in laboratory which mimics the patient's jaw. Approach of this method is wax setting; tooth movement and retainers are made by using vacuum machine. It also facilitates orthodontists to make necessary changes at an earlier stage. Using polysiloxane material impressions are taken and a working cast is made on which cast further treatment is planned by adjusting the tooth movement and aligners are fabricated using vacuum machine or pressure moulding machine. After trimming 6inally 3D models are delivered to the patients. Aligners produced of various thicknesses provide more control over tooth movement and reduces pain caused from orthodontic forces. Two or three aligners of various thicknesses are given to the patient and are instructed to use each aligner for 14-15 days. Every time the patient visits new impression are taken for working models and new aligners are fabricated which allows the clinician to make treatment plan accordingly and follow the progression of tooth movement.

CAD-CAM technologies: One of the best known aligner companies Invisalign is the one which uses CAD-CAM technology. This technology is the most common clear aligner's technology available currently. Initially Invisalign system was introduced to treat mild malocclusion while nowadays it is even used to treat more complex cases such as cases with premolar extraction. Invisalign is most widely used nowadays because of its combination of stereo lithographic prototype technology and virtual computerized treatment planning. Using computer technology other aligner systems created are companies like clear correct, orthero, EON aligner, etc¹⁹.

TYPES OF MATERIAL USED

Clear aligner materials have evolved from a single layered or monophasic plastic to the 2nd generation polyurethane material, to the currently used 3rd generation multilayered polyurethane-like material that comprises of 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. Table 1 enlists popular clear aligner brands and the material used for aligner fabrication.²⁰

 Table 1: Clear aligner brands and the material used by them for aligner fabrication

Code	Thickness	Product name	Manufacture	Component (MSDS)
EVA	1.0 mm	Bioplast	Scheu-Dental, GmbH	Ethylene- vinyl acetate copolymer
PE	1.0 mm	Copyplast	Scheu-Dental, GmbH	Polyethylene
PETG	1.0 mm	Duran	Scheu-Dental, GmbH	Polyethylene terephthalate glycol
PP	0.8 mm	Hardcast	Scheu-Dental, GmbH	Polypropylene
PC	0.75 mm	Imprelon "S"	Scheu-Dental, GmbH	Polycarbonate
A+	0.040 in.	Essix A+	Raintree Essix, Inc.	Copolyester
C+	0.040 in.	Essix C+	Raintree Essix, Inc.	Polypropylene/ ethylene copolymer (>95%), stabilizers (<5%)
PUR	0.030 in.	Invisalign	Align Technology, Inc.	Polyurethane from methylene diphenyl diisocyanate and 1,6-hexanedial, Additives

Component as obtained from the manufactures' material safety data sheet

3D PRINTING OF ALIGNERS

3D is printing, also known as additive manufacturing, has been around since the 1980's and is now approaching a point of maturity where it is being used more frequently in dentistry and medical modelling. 3D printing, as opposed to traditional manufacturing methods such as machining, casting and subtractive procedures, allows for the layer by layer creation of objects. Acrylonitrile-butadiene-styrene plastic, stereo lithography materials (epoxy resins), polylactic acid, polyamide (nylon), glass billed polyamide, silver, titanium. photopolymers, steel. wax. and polycarbonate are now used for 3D printing in orthodontic. The usage of 3D printed models was the 6irst step in reducing faults and blunders (such as geometric imperfections) during impression gathering. It is preferable to use digital impression taking and 3D printing for improvement rather than error-prone plaster models that are scanned and modelled to produce multiple alignment phases. The use of a 3D printed transparent aligner for direct use can minimise the cumulative errors created by analogue impression taking and the thermoplastic workflow that follows. Direct printing has other advantages besides increased precision, such as shorter supply chains, shorter lead times, and reduced costs¹⁹.

AGING

Mechanical properties of the aligner material deteriorate with time. Microcracks, delaminated areas, calcified biofilm deposits, and loss of transparency were reported in Invisalign (Align Technology, Inc., Santa Clara, CA, USA) aligners worn for 2 weeks. The residual stresses decrease in the thermoplastic materials with time. A change in fit of the appliance and resultant orthodontic forces can be seen as a result of intraoral hygroscopic expansion. Water absorption of thermoplastic materials increases with time, with Invisalign (Align Technology, Inc., Santa Clara, CA, USA) showing the highest absorption followed by PET-G²⁰.

THERMAL PROPERTIES

All polymers have a glass-transition temperature (Tg) at which the rigid state converts to a rubbery state. When thermal properties of three clear aligners (Invisalign [Align Technology, Inc., Santa Clara, CA, USA), Simpli5 [Allesee Orthodontic Appliances, Sturtevant, WI, USA], and ClearCorrect [ClearCorrect, Round Rock, TX, USA]) were compared, all three aligner systems were found to have a Tg above the accepted oral maximum

temperature, with no significant difference seen before and after clinical use²⁰.

STAINING

The aligner material should be able to maintain its color stability and transparency. To avoid pigment adsorption, it is recommended to remove aligners during eating and while drinking colored drinks. Color changes in aligners have been reported on exposure to staining solutions such as coffee, black tea, and red wine. Invisalign (Align Technology, Inc., Santa Clara, CA, USA) was more prone to pigmentation when exposed to coffee or red wine²⁰.

INDICATIONS FOR ALIGNER THERAPY

Joffe suggested that the clear aligner is most successful for treating the following problems

- Malocclusion is caused by mild crowding and misalignment (1 –5 mm).
- Treatment that involves minor lateral and / or anteroposterior expansion, minor interproximal tooth reduction, or the extraction of a lower incisor.
- Spacing issues (between 1 and 5 mm).
- In deep overbite cases (Class II division 2 type malocclusions) where the overbite can be decreased by intrusion and advancement of incisors.
- Narrow arches where expansion can be done without tipping the teeth too much²¹.

CONTRAINDICATIONS FOR ALIGNER THERAPY

Conditions that can be difficult to treat with orthodontic clear aligner's altogether are as follows.

- Cases of crowding and spacing where the discrepancy is over 5 mm.
- Skeletal anterior-posterior discrepancies of more than 2 mm (as measured by discrepancies in cuspid relationships).
- Discrepancies of centric-relation and centricocclusion.
- Cases where rotation of teeth is severe (more than 20 degrees).
- Open bites cases (both anterior and posterior) that need to be closed.
- Cases where teeth need to be extruded.
- Cases where there is severe tipping of teeth. (More than 45 degrees).
- Teeth where clinical crown length is short.
- Arches where in multiple teeth are missing²¹.

BENEFITS AND LIMITATION BENEFITS

- Esthetics: A transparent, clear design that is discreet.
- Comfort: Free from brackets or wires and resultant cuts and ulcerations.

- Improved oral hygiene and periodontal health: Removable nature allows proper brushing and flossing.
- No food restrictions: Patients are free to eat or drink anything during clear aligner therapy (CAT).
- Predictable treatment time: Digital planning ensures a precise estimation of treatment time.
- Decreased dental office visits: Patients themselves change their subsequent aligners, requiring fewer office visits.
- Minimal emergencies: Significantly reduced emergency appointments with CAT as compared to fixed orthodontic treatment.
- Possible to include teeth with structural anomalies and difficult-to-bond surfaces²⁰.

LIMITATIONS

- Dependency on patient compliance: A wear time of 22 h/day is mandatory for therapy to be effective.
- Limited extent of tooth movements by aligners alone: For complex movements, auxiliaries are required as an adjunct to aligners.
- Higher cost.
- Initial slurring of speech: Subsides subsequently after 2–3 days of wear.
- Breakages: While wearing or removing if the patient applies excessive force.
- Chances of losing the aligners: Removable nature makes aligners prone to being misplaced.
- Inconvenience: Removing aligners every time one eats or drinks can be a burden.
- Manufacturing defects: Results in ill-fitting aligners²⁰.

GOLDEN RULES OF ALIGNER BIO-MECHANICS

Willy Dayan gave golden rules of invisalign biomechanics to approach treatment planning with clear aligners.

- 1. Think like Plastic and Feel like a Tooth: Invisalign is a removable appliance and thus cannot be glued to teeth to "pull" them; the aligner can only "push" on surfaces of the teeth or surfaces of attachments. When a force is placed upon a tooth, it will move according to the biomechanical principles that exist, no matter what the computer screen shows.
- 2. The ClinCheck Video is not Teeth Moving: The software that shows the virtual arrangement of teeth is not the actual movement of teeth. Think of the images as representing the anatomy of the "changing inner aligner surfaces", and then analyse the resulting forces the aligner will exert upon the teeth²¹.

CASE SELECTION

A thorough knowledge on biomechanics of orthodontic tooth movement with aligners is very important to achieve successful treatment planning with regard to staging and setups.

A common misconception is that the manufacturer of the aligners is what provides a good smile result. Rather, it is the orthodontist who works on the treatment through thorough diagnosis and treatment planning, staging clinical observation, and follow up with managing the tracking issues that provides a good result. In other words, all clear aligners can be effective in the hands of an experienced clinician.

Another misconception is that the orthodontist merely needs to dispense the aligners the manufacturer provides, however, treatments in which all of the aligners are made in advance rarely work out as planned showed to you in the virtual plan. Because biology of humans is complex and not as predictable as computer models. For this reason, the treating clinician needs to be involved throughout treatment in order to provide a correct diagnosis, treatment staging, and setup, as well as the necessary refinements and followup appointments to make sure the treatment is going as planned²².

BEFORE STARTING CLEAR ALIGNERS TREATMENT COMPREHENSIVELY INFORM THE PATIENTS ABOUT

- Self-Motivation. Because it is a removable appliance, the treatment outcome will be depending on how much the patient is motivated towards the appliance.
- Attachments. Discuss attachments with patients at the consultation. Inform patients about what they are, and where and when they will be placed. Attachments are small pieces of light-cured composite resins bonded temporarily on the tooth surface which helps in tooth movement and aligner retention. Initially, the technician designs a virtual resin which is transformed into a stereo lithographic model and an aligner called the template aligner is fabricated from the same, this is used to make the actual attachments in the patient's mouth.
- Inter proximal reduction (IPR). Educate patients about different space gaining methods and inform about what IPR is, and why it is necessary in their

treatment. IPR is not only for space gaining but used to remove tight contacts²².

DURING ROUTINE APPOINTMENTS PROCEDURE

- Carefully monitor the progress of treatment. Not all patients will follow the suggested progression of aligners because biology and physiology of patients are various and, at times, unpredictable.
- Advance carefully to the next aligner. Aligners must fit loosely before advancing to the next one. Advancing too rapidly is a common cause of tracking issues. If any tracking issue is detected should be corrected before advancing to the next set of aligners. If discrepancy is less (1mm) should be managed by making patient to wear for some more days. If discrepancy is more (greater than 1mm or if the issue doesn't corrected even after using for more days) detail pliers or auxiliary techniques should be used to correct the condition²².

ESSENTIAL TIPS TO BE INFORMED

- Patient should wear aligners for at least 20 -22 hours in a day except when the patient is eating, drinking, flossing to achieve desired outcome.
- Should take proper care of clear aligners. If any aligner lost or broken should not proceed to next aligner. Till the lost aligner comes from lab need to wear previous aligner.
- To prevent plaque or food remains to stick between teeth and aligners should have a tooth brush handy for proper cleaning of teeth every time after eating or drinking.
- While wearing aligners, except water should not take any other beverages such as tea, coffee, cola or wine as they will stain the aligners.
- For cleaning aligners don't use hot water because it can disfigure their shape and loose its properties. Avoid tooth paste for cleaning, instead, brush them with a moderate detergent or anti-bacterial wash.
- While taking out aligners should be careful. Do not take them out forcefully. Use light hands at inner surface and remove gently.
- It is very important to wear retainers after treatment to restrict newly positioned teeth from getting back to their original position²².

PHOTOS OF CASES TREATED WITH CLEAR BITE ALIGNERS²²



CROWDING





PRE TREATMENT











POST TREATMENT OPEN BITE









PRE TREATMENT











POST TREATMENT

CONCLUSION

Aligners are also one of orthodontic appliances which need Orthodontist diagnosis and treatment planning,

monitoring and corrections of tracking issues at regular appointments. So that only the results can be achieved properly.

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