Clear Aligners

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Abstract
Esthetics and orthodontics have always gone hand in hand. Though the concept of moving teeth using tooth positioners was introduced way back in 1945, the clear aligner therapy has gained momentum in the last two decades. Due to continuous advancements in computer technology, medical devices have become more easier to design and manufacture. The constant need for better esthetics and the increasing number of adults seeking orthodontic care has influenced the choice of appliance today. Clear aligners have become a value addition to the orthodontic armamentarium due to patient demand and also due to the range of malocclusions it can treat today.

Keywords: Clear aligners, Invisalign.

Introduction
The concept of moving teeth using removable appliances analogous to clear aligners to facilitate mild to moderate tooth movements has been a part of orthodontic practice since decades. It was first introduced by Dr. H.D. Kesling way back in 1945 as a Tooth positioning appliance. The Invisalign system introduced by Align Technology, Inc (San Jose, California), draws its inspiration from the principles of Kesling[1], Nahoum[2] and others and Raintree Essix.[3-4]Taking it a notch higher, Invisalign employs the Computer-Aided Design & Computer-Aided Manufacturing (CAD-CAM) technology, combined with advanced imaging and 3-D printing technology like stereolithography for fabricating a series of custom made appliances that are both esthetic and removable, that could affect various types of tooth movements.

According to Robert Keim, the editor of the Journal of Clinical Orthodontics, temporary anchorage devices and Invisalign were nominated as the two major advances in the last 15 years in orthodontics.[5] Invisalign, today offers patients with a viable alternative to fixed appliances especially for adult patients who seek orthodontic care and also for those who seek an esthetic alternative to the routine train-track braces as they are perceived to be. With the advancements of modern scanning technology like iTero scanner, digital 3D printing technology like stereolithography, an updated software program like the ClinCheck Pro (v4.1), newer and better biocompatible SmartTrack aligner material & latest SmartForce optimized attachments, the Invisalign system today is indeed a marvel of modern technology.

Generations of Clear Aligners[6]

First Generation
These were the systems that solely relied on the aligner alone to achieve the results. There were no auxillaries incorporated into the appliance.

Second Generation
Here they began using attachments to improve tooth movement. The practising clinician could request attachments like composite buttons to be placed on the teeth and inter-maxillary elastics were being used.

Third Generation
The manufacturer's software now places the various types of attachments automatically wherever derotations, extrusions and root movements are required. The most commonly used type of attachments are the ellipsoid, bevelled and rectangular attachments.

About Align Technology
History
Invisalign is manufactured by Align technology, a global medical-device company headquartered in San Jose, California. The Invisalign system is the most advanced clear aligner system in the world today. Backed by over two decades of innovative computer technology and advanced manufacturing processes - the hallmarks of the Invisalign system, is currently used to treat millions of people around the world.

Invisalign, was founded in 1997 by Zia Chishti and Kelsey Wirth in San Jose, California. Chishti was an adult orthodontic patient himself when he came up with the idea of Invisalign. Christi was having problems with a retainer as part of his own treatment, and realized that such an approach could probably be used for the entire orthodontic procedure. Teaming up with Wirth, the two began looking for developers. As students of Stanford University, it seemed sensible to look for partners in their own campus. They then found Apostolos Lerios and Brian Freyburger, and the four officially found Align Technology.

Align technology received FDA clearance to market the Invisalign system in 1998 and it was first marketed in 2000[7]. At first, even after FDA approval, orthodontists were skeptical about such a drastic shift — especially since none of the founders or partners had any orthodontic expertise.

However, demand from consumers forced orthodontists to adopt this revolutionary treatment option.

Indications for clear aligner treatment[8]

1. Class I spacing with minor/moderate crowding and existing good buccal occlusion.
2. Half-cusp Class II with minor crowding.
3. Class III with minimal overbite/overjet non-extraction cases.
4. Deep bite
5. Anterior open bite
6. Lower incisor extraction
7. Premolar extractions with minor crowding
8. Orthognathic surgery

Advantages of Clear aligners[9,10]

1. Better esthetics as it is a clear material and no metal show as seen in fixed appliances.
2. Since these are removable appliances, they are more comfortable and better maintenance of oral hygiene can be achieved and lesser white spot lesions during treatment.
3. Less chair side time for the orthodontist.
4. Technically it is more easier to fix/fabricate than the lingual appliances.
5. Patient compliance is higher if they are motivated well as they are almost invisible and can be worn throughout the day & removed only during eating.
6. Clear aligners being almost invisible, gives the patient the confidence to smile.
7. Treatment duration is more predictable as it can be calculated more precisely than braces.
8. The disarticulation of teeth may be advantageous for patients having TMJ problems.
9. Retreatment can be lot easier.
10. Since most clear aligner treatment involves interproximal reduction, extraction of premolars in minor to moderate crowding cases can be avoided.
11. Occlusal abrasion from parafunctional habits during treatment can decrease during the course of aligner therapy.
12. Better periodontal health and greater patient satisfaction during orthodontic treatment.[11]

Disadvantages of Clear aligners

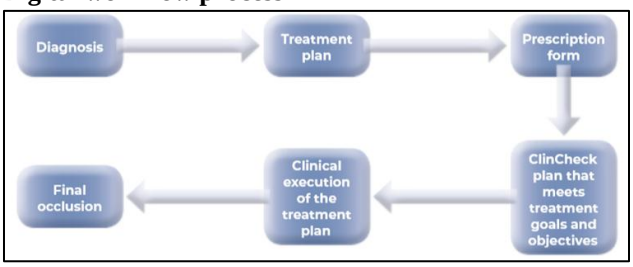
1. Since these are removable appliances, patient motivation to wear the appliance is very essential. Compliance can be an important limitation of the appliance.
2. Removability of the appliance gives the advantage to the patient but not to the clinician.
3. Long hours of wear for at least 22 hours a day makes effectiveness of the appliance patient dependent.
4. Since the patient has to remove the appliance while eating and drinking hot beverages, the chances of the appliance getting lost are high.
5. Expensive than fixed appliances.
6. Broken & lost appliances, not wearing the appliance for the recommended duration can prolong the treatment duration & therefore the cost as well.

Limitations of Invisalign

Though Invisalign can be used to treat a number of orthodontic problems, it cannot however fix certain complex orthodontic issues involving major tooth movement. They may not have the same forces and ability to move teeth as the traditional fixed appliance. The examples where Invisalign may not be the best option are:

1. The shape of the teeth can influence the choice of the appliance. Short, round or peg shaped teeth can influence the retention of the aligners.
2. Severely rotated teeth are difficult to correct
3. Large & multiple spacing between teeth
4. Intrusion & extrusive tooth movements
5. Prior prosthetic work like bridges can prevent the patient from wearing aligners.

Digital workflow process[8]



Invisalign vs fixed appliance[8]

Fixed appliances exerts a pull force on the teeth whereas clear aligners exerts a push force on the teeth. The archwire and bracket engagement depends on the gauge of the wire. The thicker the wires, the better the engagement whereas in clear aligners, the plastic material encapsulates the teeth. Therefore, more the plastic coverage around the teeth, better the engagement & better the retention. Also, anchorage follows the Newton's third law in fixed appliances whereas in clear aligners the anchorage segments can be planned & predetermined at the treatment planning stage.

In fixed appliances, single tooth extrusion is possible whereas in clear aligners anterior segment extrusion can be achieved with multi-tooth optimized extrusive attachments. Also, entire segments or selective intrusion can be achieved in clear aligners. Lingual root torque is achieved through power ridges. The root inclinations in fixed appliances are controlled by bracket positioning and archwire bends whereas in clear aligners, the optimized attachments and virtual gable bends achieve this objective.

In fixed appliances, there is a tendency for the incisors to procline on alignment whereas in clear aligners, one can control the incisor inclination. Overbite and overjet decreases as the incisors procline and align in fixed appliances whereas very good vertical control can be achieved with minimal overbite and overjet with clear

aligners. Also, predictable midline correction can be achieved with clear aligners whereas in fixed appliances it depends on elastic wear by the patient. The tooth size discrepancy can be accurately calculated using ClinCheck software in clear aligners, whereas in fixed appliances one has to calculate or adjust it midway through the treatment.

Invisalign vs lingual appliance

Lingual appliances are fixed onto the inside of the teeth, whereas Invisalign uses clear, removable aligners to guide teeth into their position. Both systems have their strengths as well as some weaknesses.

Advantages of the Lingual appliance[12]

1. Lingual appliances are virtually invisible. They are the most esthetic option available today to straighten teeth. On the other hand, clear aligners are discrete though not completely invisible.
2. The clinician has complete control over the various tooth movements and lingual appliances can tackle complex cases precisely.
3. Small adjustments towards the end of the treatment can be made in lingual appliances in order to get the best results.
4. Lingual appliances are fixed onto the teeth, therefore they don't need to be removed every time during meals and hence the chances of losing them doesn't arise.

Disadvantages of lingual appliances[12]

1. The most important drawback of the lingual appliance is the discomfort to the tongue. Also, difficulty in speech is often experienced by patients having these appliances. However, it usually improves after 2-3 weeks of appliance placement.
2. Lingual orthodontics needs special training and can reflect the skill of the orthodontist.
3. The technique sensitivity of the laboratory procedures and extended chair time needed for placement of these appliances makes the treatment very expensive and unaffordable for many patients.
4. Maintenance of oral hygiene is very crucial when it comes to lingual appliances over Invisalign. Since the appliance cannot be removed, it is very important to brush after every meal to prevent the teeth from decay.

Invisalign vs ceramic braces

1. Ceramic braces are similar to metal braces, but they are more esthetic as they use clear or tooth-coloured brackets.
2. They offer an esthetic alternative to patients who do not want the metal show of the conventional metallic brackets.
3. Each ceramic bracket can be shaded to match the tooth colour individually and hence allowing complete customization of the appliance.
4. Ceramic brackets tend to stain the teeth with time especially if the patient consumes a lot of coloured drinks like coffee or tea or smokes a lot.
5. Ceramic braces cannot always be fitted on to the mandibular teeth. The ceramic material being harder than tooth enamel can rub against the maxillary teeth and can wear them down.
6. Ceramic brackets can feel slightly bulkier than the conventional metal brackets and hence can cause more discomfort to the lips and cheeks. The clear aligners however are very comfortable to wear.
7. Ceramic brackets are brittle by nature, making them more susceptible to breaking or chipping whereas clear aligners are made up of flexible plastic material that prevents them from chipping or breaking.
8. Ceramic appliances can be used to bring about complex tooth movements similar to conventional metal braces and can be used to treat extensive cases whereas Invisalign has their limitations.

Other alternatives to Invisalign[13]

Aligners currently available can be broadly categorized as[13]:

Positioner and Guides

Orthodontics Positoner by TP Othodontics & AOA, Nine-Guide Occlus-o-guide, Orths-T, Preformed Positioner by Ortho-Tain & Myobrace from Myofunctional research company.

Aligners for minor tooth movement chiefly of the upper and lower anterior teeth

MTM clear aligner from Dentsply, Straight 'N' clear cosmetic correctors from GAC, Inman aligners & Clear Aligner (Spring aligner).

Aligners that manually reset teeth

Clear Image Aligners from Speciality Appliances, Red White Blue from Ormoc AOA, Triple Play from ortho organizers, MTM clear aligner from Dentsply International, Originator clear aligner system by TP Orthodontics, EZ-Align from Dynaflex, Dual laminate by TruTrain, Smart moves from Great Lakes Graham Orthodontic Aligner from Graham Tool Co.

Aligners that digitally reset teeth[13]

Table 26-4: Aligners currently available: Teeth Digitally Reset

S.No.	Product name	Manufacturer	Description	Use	Material
1	Invisalign Teen,Invisalign Assist, Invisalign Express 10, Invisalign Express 5	Align Technology, Inc.,	Number of aligners dependent on treatment;siimultaneous tooth movement of all teeth,SmartForce features (attachments, torque, bite	Range from minor anterior tooth movement to	SmartTrack multilayer polyurethane and

2	Insignia: Clearguide Express	Ormco AQA	Upto 10 aligners per arch. Move tooth upto 2.5 mm/tooth (0.25 mm/aligner)	Alignment of U/L anterior teeth	No information
3	Vivid Aligners	ODL	Sets of 3-5 aligners; move teeth upto 0.5 mm/tooth		Zendura: rigid polyurethane
4	Clear Correct	Clear Correct	Aligners created in phases; models included to fabricate replacement aligners	Range from minor anterior tooth movement to treatment of	Zendura: rigid polyurethane
5	Minor alignment correction	Digi3DWorks	Return model with teeth moved for aligner to be made in office; will make aligner if desired	Alignment of U/L anterior teeth	Raintree Essix ACE: copolyester proprietary
6	Clarus Clear Aligners	Clarus (Egypt)	Use attachments, buttons and elastics. Standard aligner: 4 aligners/month;each worn for 1 week, movement 0.5-0.7 mm/month. Smart aligner - 2 aligners/month each worn for 2 weeks, movement 1.0	Range from minor anterior tooth movement to treatment of all teeth	Standard clear aligner material unknown; Smart clear aligner
7	AIR Aligner	Nivol (Italy)	AIR One (one arch treatment); AIR Light (treatment of both arches <22 aligners); AIR Complete of (Treatment both arches >22 aligners)	Move all teeth	No information
8	TwinAlignerSystem	Orthocaps (Germany)	Two aligners: hardCAPS for day wear; softCAPS for night wear	Move all teeth	hardCAPS, softCAPS no information
9	InLine Clear Aligners	InLine Orthodontic UK Ltd	Twin layer laminate aligner; moves teeth upto 0.6 mm/aligner wear for 4-6 wks; IPR performed for anterior crowding	Minor to moderate U/L anterior crowding or spacing	No information
10	Clear Aligners	Nimro Dental Orthodontic solutions (UK)	Few aligners	Minor U/L anterior crowding	No information
11	Clear Path	Clear Path (India)		Mild to moderate	No information
12	Clear Aligners	3D Ortholine (UAE)		Move all	Raintree
13	iROK-CAT	Irok(China)	Alginers shipped in sets of four	Move all	No

AOA - Allesee Orthodontic Appliances; IPR - interproximal reduction; U/L - upper & lower; 3D - three dimensional

ClearCorrect[7]

ClearCorrect was started in 2006 and received FDA clearance in 2009. ClearCorrect aligners have more gingival coverage to cover the attached gingiva. This has been found to provide better aligner retention.

However, ClearCorrect aligners also use CAD CAM technology. The attachments are also available similar to Invisalign but these are presently limited to one shape only. Aligners similar to ClearCorrect are ClearPath, eCligner, K line and Orthocaps[7].

Among the other aligners available include Orthly, Simply fast smiles, six month smiles, snap correct, candid, byte & Smile direct club.

What is unique about Invisalign?

The most advanced clear aligner currently available is Invisalign. Invisalign offers the clinicians the option of either the impression or the scan. ClinCheck Pro (v4.1) software program gives a 3-D computerized treatment plan where a virtual setup is done by the orthodontist. SmartForce feature is also another patented unique design feature of the Invisalign system. These SmartForce enhancements provide the biomechanical forces for moving the teeth. Also, Invisalign uses a biocompatible thermoplastic material known as the SmartTrack introduced in 2013 which is polyurethane and a co-polyester which has showed to achieve higher amount of tooth movement than the previous aligner material Exceed-30[11]. Also available from Invisalign is the iTero scanner that uses parallel confocal imaging technology which can give high resolution pictures of the teeth.

The Align Corporate Fact Sheet Q2 2019 reveals the following statistics for Invisalign appliances[14]:

Invisalign cases shipped: 585 million plus

162,501 Invisalign-trained doctors

86,263 Active Invisalign doctors

433k+ aligners made per day (based on average of 2 quarters)
952 active patents (462 U.S., 490 Int'l)

Some studies related to Aligners

Patients treated with Invisalign® have a better periodontal health and greater satisfaction during orthodontic treatment than patients treated with Fixed Orthodontic Appliances.[11] According to a study by Fujiyama et al, Invisalign may offer less pain compared to the edgewise appliance during the initial stages of treatment.[15]

According to Buschang et al, study done to assess the predictability of actual end-of-treatment occlusion with aligner therapy showed that the ClinCheck models do not accurately reflect the patient's final occlusion as measured by the Objective grading system at the end of active treatment.[16]

Another study by Djeu et al to assess the treatment outcome of Invisalign and traditional orthodontic treatment objectively with ABO system shows that Invisalign did not treat malocclusions as good as the traditional braces. Invisalign was especially deficient in correcting large anteroposterior discrepancies. However, it could close spaces and correct anterior rotations and marginal ridge heights.[17]

A study done to assess the effectiveness and efficiency of Invisalign and fixed appliances using the Peer Assessment rating index by Gu et al, showed that Invisalign may not be as effective as fixed appliances in achieving great improvement in malocclusion.[18]

A study done to assess the effectiveness of the new SmartTrack material of Invisalign as compared to the previous material showed that the new material was rated better in terms of reduction in pain intensity, pain duration and pressure on insertion. Also, the patients reported overall comfort to be better with the new material[19].

Conclusion

There are a plethora of options available today if clear aligners is the desired treatment appliance. The choice of the appliance depends chiefly upon the severity of the malocclusion at hand, the proficiency of the clinician in influencing the treatment outcome, the ability of the orthodontist's clinical judgement & the patients' needs. Superior esthetics and comfort are the other patient dependent driving factors that could also influence the choice of the appliance. Therefore, the choice of clear aligner treatment should be based on sound clinical judgement & knowledge about the pros and cons of the appliance and the clinician should be able to make a sound assessment of the treatment systems available to them for potential clinical utility.

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