International Journal of Current Science Research
www.drbgrpublications.in

Volume: 6; Issue: 10; October-2020; pp 2022-2039. ISSN: 2454-5422

Invisalign: A Review

Dr.P.Deenadayalan[1], Dr.R.Sathyapriya[2], Dr.Nidhi angrish[3], Dr.Dhivya Dilipkumar[4] and Dr.Sebastian Abraham[5]

[1]M.D.S Reader, SRM Dental College Kattankulathur, Potheri, Chengalpet (Dt.), India.

[2]Post Graduate Student, SRM Dental College Kattankulathur, Potheri, Chengalpet (Dt.), India.

[3]M.D.S Senior Lecturer, SRM Dental College Kattankulathur, Potheri, Chengalpet (Dt.), India.

[4]M.D.S Associate Professor, SRM Dental College Kattankulathur, Potheri, Chengalpet (Dt.), India.

[5]Post Graduate Student, SRM Dental College Kattankulathur, Potheri, Chengalpet (Dt.), India.

Corresponding author E-mail: priyasekaran21@gmail.com

Abstract

However, the field of orthodontics has been modernized according to the demands and needs of patients. Clear aligners are new age development in the field of orthodontics developed for patients who are more conscious about their appearance. Because of being comfortable and aesthetic, they have become treatment of choice for increasing number of adults seeking orthodontic treatment. With the use of CAD-CAM technology, ALIGN TECHNOLOGY (Santa Clara, calif, USA) introduced Invisalign. This Invisalign technology allows multiple tooth movements from a single impression. Invisalign at the beginning, was used to treat only simple tooth movements, but after subsequent years, the manufacturer began using attachments, and intermaxillary elastics to achieve different tooth movements. This article will discuss about the indications and contraindications of Invisalign and including its process and limitations; periodontal health, root resorption.

Keywords: Invisalign, Clear Aligner, Attachments

Introduction

Several developments have changed the field of orthodontics in the recent years. Digital imaging and computers have improved the diagnostic process. Many recent advances have improved the treatment efficiency and efficacy (Durong, 2006). However, the field of

orthodontics has been modernized according to the demands and needs of patients. Aesthetics is the one of the major concerns among patients who seek orthodontic treatment. Now a day's adult patients seeking orthodontic treatment demands a beautiful smile at the end and same time concerned about their appearances during the treatment. In recent times, many Patients reject wearing labial fixed steel appliances and are looking for more aesthetic treatment options, including ceramic brackets, lingual orthodontics and clear plastic appliances (Kesling, 1945). Clear aligners are new age development in the field of orthodontics developed for patients who are more conscious about their appearance.

History

Aligners are not new to dentistry it was described as early as 1945 by Dr H.D. Kesling who described the movement of teeth via a tooth positioner. Later Henry Nahoum (1950) developed the vacuum formed dental contour appliance similar to Invisalign. Pointz (1971) based on the kesling principle introduced removable plastic retainer and Sheridan *et al*., 1993 developed a technique by combining these retainers with interproximal reduction (IPR).

In April 1997, Zia Chishti and Kelsey Wirth, two students from Stanford University founded Align Technology. Based on the principles of Kesling and Nahoum and with the use of CAD-CAM technology, ALIGN TECHNOLOGY (Santa Clara, calif, USA) introduced Invisalign after approval from FDA.

How Does Clear Aligner Works?

With the combined use of CAD-CAM technology (computer-aided-technology and computer-aided-manufacturing) and with other laboratory technology, a complete treatment plan from the initial position to the final position is made from which a series of custom-made clear aligners are fabricated. Each aligner is designed to move the teeth a maximum of about 0.25 to 0.3 mm over a 2-week period, and is worn in a specific sequence (Joffe, 2003).

This Invisalign technology allows multiple tooth movements from a single impression. Invisalign at the beginning, was used to treat only simple tooth movements, but after subsequent years, the manufacturer began using attachments, and intermaxillary elastics to achieve different tooth movements.

Biomechanics

- With a typical fixed appliance, the wire is engaged in a bracket with the adhesive retaining the bracket on the tooth. The active archwire is elastically deformed and moves the tooth to a determined position as it returns to its original shape.
- With an aligner, the plastic encapsulates the tooth and in doing so must provide both retention and activation to move the teeth.
- In general, natural undercuts of the teeth provide the retention and the active component to move teeth by the elastic deformation of the aligner.
- The elastic deformation of the aligner should not be so great as to overcome the retention forces. There are certain directions in which aligner has a greater inherent ability to undergo elastic deformation. For instance, a faciolingual movement is fairly predictable because the entire body of the aligner can be distorted elastically and then returns to its original shape carrying the tooth with it.
- The total desired movement is then subdivided in such a way that the aligners remain within this range of elastic deformation and a sequence of aligners is made to accomplish the entire desired movement.

Indications for Invisalign

Invisalign Therapy usually performs well in following condition (Joffe, 2003; Murthy and Vijay, 2011):

- Crowding and spacing problems
- Rotations
- Extrusion of teeth
- Deep overbite (Class II div 2 cases)
- Absolute- intrusion (1 or 2 teeth)
- severe crowding cases requiring lower incisor extraction
- Molars requiring distal tipping
- Centric relation and centric occlusion discrepancies
- Relapse after fixed appliance therapy

It can also be used to correct dentoalveolar posterior cross bite (Garret Djeu and Clarence Shelton, 2005). With various approaches Invisalign is used to manage mild to moderate open bite (Roozbeh Khosravi and Bobby Cohanim, 2017; Shin, 2017).

Contraindications

Certain cases are difficult to handle (Joffe, 2003):

- presence of short clinical crown teeth.
- missing teeth-more than half of the arch
- severe skeletal discrepancies cannot be contemplated with Invisalign alone. Surgery or a pre-Invisalign functional phase would be necessary.

Advantages (Joffe, 2003; Duong and Derakhshan, 2006)

- Ideal aesthetics
- Ideal for retreatment
- Easier than lingual appliances, technically
- Ease of use for the patient: They are removable, this allows patient to maintain their current oral hygiene practices. patient can brush and floss normally.
- Comfort:
  They are comfortable and do not cause irritation to the cheeks or surrounding tissues, which is usual for wires or brackets.
- Bonding to enamel defects:
  Invisalign can be used with patients for whom conventional fixed appliances are contraindicated because of metal or nickel allergies or the inability to bond appliances to teeth, like amelogenesis imperfecta.
- Less discomfort and pain:
  Invisalign treatment is unique in that treating clinician can specify to slow down movements programmed into each aligner in patients who have lower pain threshold.
- Better oral hygiene:
  For aligners no special treatment is required. Simple brushing with a toothbrush and toothpaste is all that is needed. Maintenance of oral hygiene is easier with Invisalign in comparison to other fixed appliances, which leads to Healthier periodontal tissue.

- Numerous crowns:

  Treatment with Invisalign in cases of numerous restorations is ideal because the clinician can specify which teeth will not have attachments and therefore reduce or eliminate any risk.
- Speech:

  As the Invisalign appliance do not cover palate, it usually does not affect speech.
- CLIN check as a diagnostic tool:

  One significant advantage of this treatment is 3-dimensional visualization of the treatment plan provided through CLIN Check and provides the clinician to view the treatment from beginning to end before initiating treatment.

Disadvantages (Joffe, 2003):

- Limited control over root movement
- patient compliance and motivation are required to achieve desired results, to be effective it should be worn 22 hours a day.
- removed during meals and when taking hot drinks because the risk of deformation is higher
- poor patient compliance, broken appliance, poor oral hygiene, missed appointments can lengthen the treatment time
- increased cost
- over a time, they may undergo staining because they are made of transparent thermoplastic materials

Clinical Method: The diagnostic preparation for both Invisalign appliance and conventional fixed orthodontic appliances is similar, but clinician plays a very limited role during the treatment with Invisalign system.

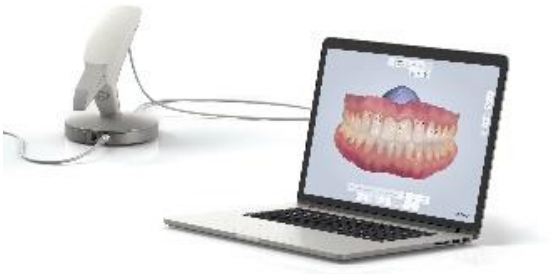
The Invisalign process involves several steps (Thukral and Gupta, 2015)

The initial assessments like intraoral and extraoral examination, diagnosis, treatment planning is done. The clinician submits a pair of polyvinyl siloxane impressions, a panoramic radiograph, a centric occlusion bite registration (Aljabaa, 2020; Jaiswal *et al*., 2014), a lateral cephalometric radiograph, and photographs to Align Technology. High precision impressions by polyvinyl material are important. Because impressions taken with Polyvinyl siloxane

provides the greatest degree of accuracy and stability and remain stable for weeks and allows multiple pours.

Align Technology produces a three-dimensional computer image from the impressions:

- Initially, Align Technology used a process called *destructive scanning* to produce the three-dimensional (3D) digital image of the patient's teeth. The impressions are poured up in dental plaster and then placed in a tray and encased with epoxy and urethane. The tray is placed into the destructive scanner and this the scanner's rotating blade makes numerous passes over the epoxy-encased models, removing a thin layer with each pass.
- 3-dimensional models are created by computer linked with the scanner which assembles the scanned information.
- Disadvantage of this technique were that it is expensive and time consuming and produced huge quantities of plaster dust. Now days, Impressions are scanned directly using computerized tomography and converts them directly into a virtual model.
- Currently intra oral scanners are used. This method has greatly increased the efficiency of the scanning process.



- The advantage of direct digital capture are - 1) the need for PVS impressions is eliminated and their inherent potential for clinical errors are avoided. (2) reducing the time needed to produce appliances because the image would be transmitted instantly to Align Technology via the Internet.

- After the bite has been established, the Invisalign virtual orthodontic technician (VOT) uses software to "cut" the virtual models and separate the teeth, allowing them to be moved individually and then a virtual gingiva is placed along the gingival line of the clinical crown to serve as the margin for the manufacturing of the aligners.

- The orthodontist's prescription is followed in positioning the teeth and the bite to proper alignment virtually on the computer with the company's Treat software (Align Technology, Santa Clara, Calif).

- After virtual treatment is done, it has to be approved by the clinician. To accomplish this, a new application called CLINCHECK (Nelson, 2005) was created. It will allow the practitioner to view the results of the treatment virtually and used to evaluate the need for extraction, IPR, distalization, expansion and proclination. The outcome may be visualized and compared with treatment using either extractions or interproximal reduction and provide the feed-back to the technician whether design process needs to be improved.

- Once orthodontist approves the treatment, with help of "Stereolithography" Align technology produces a set of clear aligners in which digital images are converted to physical models.
- Aligners are fabricated on a Biostar pressure moulding machine using these models. Engineers from align technology created a proprietary material for use in aligners.
- After fabrication, they are trimmed and laser etched with case number, patient's initials, aligner number, and arch (upper or lower).
- Then aligners are disinfected, packaged and shipped to the dentist's office.
- Clinician delivers them to the patient with instructions for use. They should be worn for one to two weeks before moving on to the next pair in the aligner series.
- The number of series of aligners depends on the number of stages required to complete the treatment per patient (Djeu, 2005; Kravitz, 2009; Boyd, 2000).

Accuracy and Clinical Management of Invisalign

The accuracy of clear aligner therapy was studied and reported by several authors. They evaluated whether any deviation present between the achieved and planned tooth movements. Their conclusion consists of sufficient accuracy to some inadequacies in treating some malocclusions. Their findings suggested that there is sufficient accuracy in treating anterior crowding (Krieger *et al.*, 2011 & 2012) and during distalization of maxillary molars and found some inconsistency in case of upper incisor root control (Simon, 2014; Castroflorio *et al.*, 2013) and some inadequacies in bodily expansion of maxillary posterior teeth (Solano-Mendoza *et al.*, 2017; Buschang *et al.*, 2015; Houle *et al.*, 2017) and found lack of accuracy in case of

rotational movements of canine (Kravitz, 2009; Kravitz, 2008) and premolars (Simon *et al.*, 2014), inadequacies during extrusion of maxillary incisors and during controlling overbite (Krieger *et al.*, 2011 & 2012). Vertical movement and derotation are difficult and IPR is recommended during such treatments (Galan-Lopez, *et al*., 2019).

Rossini *et al.*, suggested use of some auxiliaries, attachments and interdental elastics, interproximal reduction (IPR) along with Invisalign to improve tooth movement.

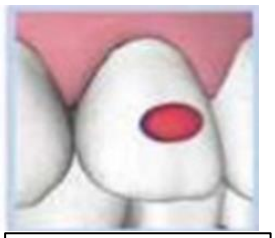
IPR

With the help of Clincheck set-ups, the need for IPR is evaluated. Based on predefined parameters, the reproximation form is created to show the clinician the interproximal contacts that will require IPR, the amount of IPR needed and the timing of the reproximation.

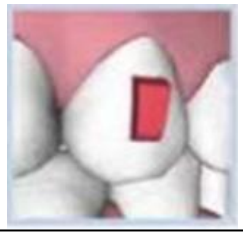
Attachments

- Attachment use is essential for the success of the Invisalign treatment. Since Attachments serve for the retention as well as help to achieve specific tooth movements, they form an essential part of the treatment with Invisalign system. In both Treat and Clincheck, the attachments are displayed as red shapes. Currently, ellipsoid and rectangular attachments are available. They can be placed manually or automatically, per the Invisalign attachment protocol.
- An alternative to attachments that help facilitate torque control is the power ridge. Power ridges are engineered corrugations placed at specific locations to enhance the undercut near the gingival margin of teeth undergoing torquing movements.
- The cylindrical teeth derotation presents a biomechanical challenge because of minimal availability of interproximal surface and undercuts available near the horizontal occlusal plane to the aligners. For improved tracking during tooth movements, the placement of buccal and lingual attachments creates aligner purchase points.
- Improving translation of root is a third clinical application for composite attachments. Rectangular attachments can be used in this circumstance because the sides of the attachment create additional surface contact with the aligner near the gingival third of the tooth.

- One method being used to overcome the extrusion problem with some promising results is to use the gingivally beveled attachment to provide a longer surface that can be elastically deformed and provide an extrusive force on the tooth.
- Attachments are placed to prevent the separation of the aligner from the posterior teeth; the aligner is able to deliver a vertical force to intrude the incisors.
- For large mesio-distal movements - Rectangular attachments are used (3, 4 or 5 mm high, 2 mm wide and 0.75 to 1 mm thick). It is proposed that these attachments will allow teeth to be moved bodily by allowing for a longer span for force application.



ELLIPSOID



RECTANGULAR

BEVELED

Use of Elastics

Class II and Class III elastics are frequently needed just as they are with fixed appliances. One can either attach the elastics directly to the aligner or attach elastics to buttons bonded to the teeth. If the elastics are directly attached to the aligner, then attachments are generally required to prevent displacement of the aligner. Toe nail clippers can be used to cut slits in the aligners for elastic placement. Hilliard thermopliers can be used to construct elastic attachment buttons on plastic. Two thermopliers are necessary to construct the elastic attachment button.

Use of Mini-Screws:_Mini-screws can also be used effectively with aligners in the same manner as they can with fixed appliances, either planned initially as part of the treatment or to help with movements that are not progressing as desired. They can be used with aligners alone or in combination with other auxiliaries to simplify the movements the aligners are required to accomplish. The two most common uses of mini-screws with aligners are for vertical and anteroposterior movements. One such example is the extrusion of an upper canine, a movement that would be virtually impossible with aligners alone. Another vertical movement that is easily enhanced with mini-screws is the intrusion of molars that have supraerupted into an edentulous space.

Variables that Influence Dental Movement

Chisari *et al*, (2014) identified sex and age as variables that may affect the movement of teeth with aligners. Drake *et al*, (2012) reported that, in addition to sex and age, bone quality, tooth length, location of the resistance centre, and systemic factors should be considered.

Limitations of Invisalign Treatment

- COMPLIANCE

The Invisalign appliance is removable, so patient motivation is important for achieving desired result. To be effective, it should be worn for at least 22 hours a day. They can remove it during meal time and when taking hot beverages that may cause warping or staining. The transparency of this appliance may increase the likelihood of its being misplaced when it is removed. In 1998 a study conducted by Lindauer and Shoff in which retainers like Hawleys and Essix are compared. They reported that about one sixth of their patients lost their Essix appliance, because of the appliances being clear and removable. Aligners have very similar properties to those of Essix appliances (Lindauer and Shoff, 1998).

- EXTRACTION CASES

  Premolar extraction cases are suitable for Invisalign treatment. Bollen *et al*, (2003) reported excessive tipping around premolar extraction sites. Miller *et al*. (2002) in their case study of lower-incisor extraction, found similar excessive tipping around extraction sites using panoramic radiographs.

- ANTERIOR - OPEN BITE

  Anterior-open bite cases are difficult to treat with Invisalign and some authors reported difficulty in achieving ideal occlusion during the treatment of anterior open bite.

Womack *et al.,* (2002) reported that anterior extrusion is difficult with Invisalign., Clements *et al.,* in 2003 conducted a randomized clinical trial in which he reported that there is no major improvement in anterior open bite cases.

- OVERBITE CASES

  In 2003 Joffe, suggested that Invisalign can be used to correct deep overbite cases. Others authors have provided evidence to the contrary. Kamatovic *et al.,* 2004, in his study, reported that the Invisalign did not correct overbite relationships. The peer assessment rating (PAR) index was below 40%.

- INTERMAXILLARY APPLIANCES

  The use of interarch mechanics (e.g., Class II and Class III elastics) in Invisalign system is difficult because it is removable and wraps around the teeth. One can either attach the elastics directly to the aligners or attach elastics to buttons bonded to the teeth.

- TOOTH MOVEMENT

  Being a removable appliance, Invisalign appliance will produce only limited tooth movements. A Study by Vlaskalic and Boyd *et al.,* (2002), concluded that conventional-fixed appliances could attain improved occlusal outcomes than the aligners.

- TIPPING MOVEMENTS

  Bollen *et al.,* (2003) indicated that the Invisalign appliance yielded the most expected results with tipping movements. Kravitz *et al.,* (2009) in their clinical study reported a 41% mean accuracy for mesiodistal tipping. Kassas *et al.,* (2013) showed a significant improvement of score (American board of orthodontics model grading system score) for buccolingual inclinations especially in posterior region. Buccal expansion, in the range of 2 to 4 mm, can be achieved with this appliance to provide space for crowded anterior teeth or to change arch form. Expansion is largely by tipping nature, however, if bodily expansion is required, this may be specified (usually as an overcorrection) as the goal for treatment into the computer plan initially. Djeu *et al.,* (2005) observed superior results in fixed appliances than CAT in relation to buccolingual tipping. A study Zhou and Guo, (2019) investigated the arch expansion during Invisalign® treatment in which records (digital models and cone-beam computed tomography [CBCT]) were used to evaluate. They concluded that clear Aligners might increase the width of the arch, but expansion was obtained by tipping movement.

- BODILY MOVEMENT

  Rectangular attachments are used when large mesio-distal movements are requested. It is proposed that these attachments will allow teeth to be moved bodily by allowing for a longer span of force application (Hennessy *et al*., 2015). There is a high predictability (88%) of distalization movement of upper molars (bodily movement) when the movement was supported by attachments (Simon *et al*., 2014).

- ROOT PARALLELISM

  An alternative to attachments that help facilitate torque control is the power ridge. Power ridges are engineered corrugations placed at specific locations to enhance the undercut near the gingival margin of teeth undergoing torquing movements. when root movements are attempted then Ellipsoid attachments are used in pairs (3 mm-high, 2 mm-wide and 0.75–1 mm -thick) and are available for incisors, canines and premolars. It allows production of moment of couple to upright roots (Hennessy *et al*., 2015).

- ROTATIONS

  Highest rotational accuracy is seen in canines that received inter-proximal reduction (IPR). The accuracy of maxillary canine movement having rotation greater than 15° was significantly reduced. When premolar rotation is greater than 15°, the accuracy of the correction was significantly reduced (Simon *et al*., 2014). However, with advent of the newer optimized attachments, the predictability of rotational movements has improved.

- EXTRUSION

  Extrusions can also present problems with aligners, because the aligner cannot stretch within the plastic itself so an elastic deformation in the direction needed for extrusion is not possible. Bevelled attachments are used most often when trying to extrude a tooth. They can be 3, 4 or 5 mm wide, 2 mm high and from 0.25 to 1.25 mm thick. They have an active border, just like fixed brackets, that should limit the slipping (or loss of tracking) that can occur between the aligner and the tooth (Hennessy *et al*., 2015). In some cases, a button bonded to the tooth together with an elastic will assist with the extrusion. Mini screws can also be used effectively with aligners for extrusion. A systematic review on Efficacy of clear aligners in controlling orthodontic tooth movement concluded that the amount of mean intrusion reported was 0.72 mm (Rossini

et al., 2015). Extrusion was the most difficult movement to control (30% of accuracy), followed by rotation.

Patient Comfort and Acceptance of Clear Aligner Therapy

Aesthetics were found to be the main concern for the adults seeking for Invisalign treatment. Miller *et al.*, (2007) compared the treatment impacts between Invisalign and fixed appliances, reporting that the aesthetics and removability of the Invisalign resulted in significant pain reduction and better functional and psychosocial differences as compared to patients treated with fixed appliances.

Periodontal Health

Several studies shown that Invisalign is the treatment of choice for adult patients at risk of periodontitis. The patients treated with clear aligner therapy had good periodontal status compared to those patients treated with fixed appliances (Karkhanechi *et al*., 2013; Levrini *et al*., 2015; Rossini *et al*., 2015). The plaque index is significantly lower in patients treated with Invisalign (Rainer-Reginald Mietheke and Silke Vogt, 2005).

Root Resorption

Treatment with Invisalign could lead to root resorption similar to those which occurs due to orthodontic lighter forces, with an average percentage of <10% of the original root length (Gay *et al*., 2017). Aman *et al.*, (2018) using CBCT investigated the root resorption of 160 orthodontic cases, who had been given comprehensive orthodontic treatment with CAT. They found that there was minimal root resorption in patients undergoing CAT and that the percentage of change in root length is affected mainly by gender, malocclusion, crowding, and post-treatment approximation to the cortical plates. Other study (Eissa *et al*., 2018), found that root resorption was lower in cases treated with CAT compared to fixed appliances. A systematic review on root resorption with CAT concluded that root resorption with CAT is comparable to that with light-force fixed appliances and better than that with heavy-force fixed appliances (Aldeeri *et al.*, 2018).

Retention and Stability

Retention and stability (2020) are the most challenging part of orthodontic treatment. Daniel Kuncio *et al.*, (2007) conducted a study in which dental casts and panoramic radiographs from that the post-retention treatment outcomes of cases treated with CAT were compared with

patients treated with regular, fixed-appliances. The results showed greater relapse in cases treated with CAT compared to patients treated with fixed appliances.

Conclusion

The Invisalign System is the treatment of choice for patients who may not want conventional fixed appliances or for whom traditional removable appliances may be unsuccessful. The Invisalign appliance can provide excellent aesthetic during treatment, ease of use, comfort of wear, and superior oral hygiene. The entire process of making the Invisalign aligners is a marvel of modern technology. In addition, to excellent aesthetic, there are certain limitations to this appliance in terms of cost, case selection, experience required for computer treatment planning and difficulty in obtaining certain tooth movements. Without the help of computers and advanced machinery, it is impossible to fabricate aligners with such great accuracy and in such large numbers. Patients should be well informed about the advantages and disadvantages of clear aligner therapy. This setup is not only a diagnostic aid, but it can also be used as an educational tool for the patient.

Reference

Aldeeri A, Alhammad L, Alduham A, Ghassan W, Shafshak S, Fatani E. Association of orthodontic clear aligners with root resorption using three-dimension measurements: A systematic review. *J. Contemp Dent Pract* 2018;19:1558-64.

Aljabaa AH. Clear aligner therapy—Narrative review. *J. Int. Oral Health* 2020;12: S1-4.

Aman C, Azevedo B, Bednar E, Chandiramami S, German D, Nicholson E, et al. Apical root resorption during orthodontic treatment with clear aligners: A retrospective study using cone- beam computed tomography. *Am. J. Orthod Dentofacial Orthop* 2018;153:842-51.

Bollen AM, Huang G, King G, Hujoel P, Ma T. Activation time and material stiffness of sequential removable orthodontic appliance. Part 1: Ability to complete treatment. *Am. J. Orthod Dentofacial Orthop* 2003; 124(5):496–501.8.

Boyd RL. “The invisalign system in adult orthodontics: mild crowding and space closure cases”. *JCO*. 2000;34(4).

Buschang PH, Ross M, Shaw SG, Crosby D, Campbell PM. Predicted and actual end-of-treatment occlusion produced with aligner therapy. *Angle Orthod*. 2015 Sep;85(5):723–7.

Cao H, Duong T. Applications of Mechanics with Invisalign. In: Tuncay OC (ed.). The Invisalign System, Quintessence publishing, 2006. p.153-162.

Castroflorio T, Garino F, Lazzaro A, Debernardi C. Upper-incisor root control with Invisalign appliances. *J. Clin Orthod*. 2013;47(6):346–51.

Chisari JR, McGorray SP, Nair M, Wheeler TT. Variables affecting orthodontic tooth movement with clear aligners. *Am. J. Orthod Dentofacial Orthop* 2014;145(4 Suppl): S82-91

Clements KM, Bollen AM, Huang G, King G, Hujoel P, Ma T. Activation time and material stiffness of sequential removable orthodontic appliance. Part 2: Dental improvements. *Am. J. Orthod Dentofacial Orthop* 2003; 124(5):502–8.11.

Clinical effectiveness of Invisalign® orthodontic treatment: a systematic review Aikaterini Papadimitriou, Sophia Mousoulea, Nikolaos Gkantidis and Dimitrios Kloukos progress in orthodontics 2018.

Djeu G. "Outcome assessment of invisalign and traditional orthodontic treatment compared with the American board of orthodontics objective grading system". *Am. J. Orthod Dentofacial Orthop*. 2005; 128:292-8.

Drake CT, McGorray SP, Dolce C, Nair M, Wheeler TT. Orthodontic tooth movement with clear aligners. *ISRN Dent* 2012:657973.

Duncan LO, Piedade L, Lekic M, Cunha RS, Wiltshire WA. Changes in mandibular incisor position and arch form resulting from Invisalign correction of crowded dentition treated nonextraction. *Angle Orthod* 2016;86:577-83

Duong T, Derakhshan M. Advantages of the Invisalign System In: Tuncay OC (ed.) The Invisalign System, Quintessence Publishing. 2006. p.47-54

Durong T; History and overview of the Invisalign System. In: Tuncay OC, Editor: The Invisalign System, Quintessence Publishing. 2006. p.25-34.

Eissa O, Carlyle T, El-Bialy T. Evaluation of root length following treatment with clear aligners and two different fixed orthodontic appliances: A pilot study. *J. Orthod Sci* 2018;7:11.

Galan-Lopez L, Barcia-Gonzalez J, Plasencia E. A systematic review of the accuracy and efficiency of dental movements with Invisalign®. *Korean J. Orthod* 2019; 49:140-9.

Garret Djeu, Clarence Shelton. Outcome assessment of Invisalign and traditional orthodontic treatment compared with the American Board of Orthodontics objective grading system. *Am. J. Orthod DEntofacial Orthop*. 2005;128(3):292-8. discussion 298.

Gay G, Ravera S, Castroflorio T, Garino F, Rossini G, Parrini S, et al. Root resorption during orthodontic treatment with Invisalign®: A radiometric study. *Prog Orthod* 2017;18:12.

Hennessy J, A Ebrahim, Awadhi A. Clear Aligners generation and orthodontic tooth movement. *JO* 2015;00:1-9

Houle JP, Piedade L, Todescan R Jr, Pinheiro FH. The predictability of transverse changes with Invisalign. *Angle Orthod*. 2017;87(1):19–24.

Invisalign A to Z Benson H. Wong, DDS *Am J. Orthod dentofacial orthop* 2002

Jaiswal RK, Bhagchandani J, Agarwal S, Mehrotra R, Chaudhari A. Invisible Orthodontics. *J. dentofacial Sciences*. 2014; 3(3): 47-53.

Joffe L. Invisalign: early experiences. *J. Orthod* 2003; 30(4):348–52.6.

Kamatovic M. A retrospective evaluation of the effectiveness of the Invisalign appliance using the PAR and irregularity indices. Toronto (Ont.): University of Toronto; 2004. 12.

Kamlesh G. "Invisalign - A new vista in orthodontics". *JPAHER* 2010;2(2):1161-75.

Karkhanechi M, Chow D, Sipkin J, Sherman D, Boylan RJ, Norman RG, et al. Periodontal status of adult patients treated with fixed buccal appliances and removable aligners over one year of active orthodontic therapy. *Angle Orthod* 2013;83:146-51.

Kassas W, AI-JewairT, Preston CB, Tabbaa S. Assessment of Invisalign treatment outcomes using ABO model grading system. *J. world FedOrthod*. 2013

Kesling HD; The philosophy of tooth positioning appliance. *Am. J. Orthod*. 1945; 31:297-304.

Kravitz ND, Kusnoto B, Agran B, Viana G. Influence of attachments and interproximal reduction on the accuracy of canine rotation with Invisalign®. A prospective clinical study. *Angle Orthod*. 2008;78(4):682–7.

Kravitz ND. "How well does invisalign work? A prospective clinical study evaluating the efficacy of tooth movement with invisalign". *Am. J. Orthod Dentofacial Orthop*. 2009; 135:27-35

Krieger E, Seiferth J, Marinello I, Jung BA, Wriedt S, Jacobs C, et al. Invisalign® treatment in the anterior region were the predicted tooth movements achieved? *J. Orofac Orthop*. 2012;73(5):365–76.

Krieger E, Seiferth J, Saric I, Jung BA, Wehrbein H. Accuracy of Invisalign® treatments in the anterior tooth region. First results. *J. Orofac Orthop*. 2011; 72(2):141–9.

Kumar K, Bhardwaj S, Garg V. Invisalign: A Transparent Braces. *J. Adv. Med. Dent Scie Res* 2018;6(7):144-147.

Kuncio D, Maganzini A, Shelton C, Freeman K. Invisalign and traditional orthodontic treatment postretention outcomes compared using the American Board of Orthodontics Objective Grading System. *Angle Orthod* 2007;77:864-9.

Levrini L, Mangano A, Montanari P, Margherini S, Caprioglio A, Abbate GM. Periodontal health status in patients treated with the Invisalign® system and fixed orthodontic appliances: A 3 months clinical and microbiological evaluation. *Eur J. Dent.* 2015;9:404-10. 24.

Lindauer SJ, Shoff RC. Comparison of Essix and Hawley retainers. *J. Clin. Orthod*. 1998; 32(2):95–7.

Miller RJ, Duong TT, Derackhshan M. Lower incisor extraction treatment with the Invisalign system. *J. Clin. Orthod* 2002; 36(2):95–102.9.

Miller KB, McGorray SP, Womack R, Quintero JC, Perelmuter M, Gibson J, et al. A comparison of treatment impacts between Invisalign aligner and fixed appliance therapy during the first week of treatment. *Am. J. Orthod Dentofacial Orthop* 2007;131:302. e1–9.

Murthy VS, Vijay. Orthodontics Without Braces and Wires!! A New Paradigm. *Indian J. Dental Advancements* 2011;3(2):508-11.

Nahoum HE; The Vacuum Formed Dental Contour Appliance; NY State Dent J. 1964; 30:9:385-90.

Nelson G, Invisalign Summit 2005, Part II, Pacific Coast Society of Orthodontists Bulletin Summer 2006

Ponitz RJ; Invisible retainers. *Am. J. Orthod*. 1971; 59:3:266-72.

Rainer-Reginald Mietheke, Silke Vogt – a comparison of the periodontal health of patients during treatment with Invisalign system and fixed orthodontic appliance. *J. Orofacial orthopedics* 2005.

Roozbeh Khosravi, Bobby Cohanim. Management of overbite with the Invisalign appliance. *Am. J. Orthod Dentofacial Orthop*. 2017; 151:691-99

Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review. *Angle Orthod* 2015;85:881-9.

Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Periodontal health during clear aligners treatment: A systematic review. *Eur. J. Orthod* 2015;37:539-43.

Sheridan JJ, Ledoux W, Mcminn R; Essix Retainers: Fabrication and Supervision for Permanent Retention. *JCO* 1993;27:37-45.

Shin K. The Insialign Appliance Could Be an Effective Modality for Treating Overbite Malocclusions Within a Mild to Moderate Range. *J. Evid Dent Pract*. 2017;17(3):278-80.

Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Treatment outcome and efficacy of an aligner technique—regarding incisor torque, premolar derotation and molar distalization. *BMC Oral Health*. 2014;14:68.

Solano-Mendoza B, Sonnemberg B, Solano-Reina E, Iglesias-Linares A. How effective is the Invisalign® system in expansion movement with Ex30' aligners? *Clin Oral Investig*. 2017;21(5):1475–84.

The Invisalign: review, Ezaz Ahmad, amit kalra, Kanish Bansal – Int. J. preventive and clinical dental research

Thukral R, Gupta A. Invisalign: Invisible Orthodontic Treatment- A Review. *J. Advanced Medical and Dental Sciences Res*. 2015;3(5): S42-S44.

Vlaskalic V, Boyd R. Orthodontic treatment of a mildly crowded malocclusion using Invisalign system. *Aust Orthod J*. 2002; 17(1):41–6.14.

Womack WR, Ahn JH, Ammari Z, Castillo A. A new approach to correction of crowding. *Am. J. Orthod Dentofacial Orthop* 2002; 122(3):310–6.10.

Zhou N, Guo J. Efficiency of upper arch expansion with the Invisalign system. *Angle Orthod* 2019. doi: 10.2319/022719-151.1.