Taiwanese Journal of Orthodontics

Volume 30 | Issue 3 Article 4

January 2018

Clinical Use of Contemporary Clear Aligner Therapy

Chun-Te Ho
Orthodontic Department, Chung Shan Medical University Hospital, Taichung, Taiwan; College of Oral Medicine, Chung Shan Medical University, Taichung, Taiwan

Chien-Wei Chao
Orthodontic Department, Chung Shan Medical University Hospital, Taichung, Taiwan; College of Oral Medicine, Chung Shan Medical University, Taichung, Taiwan

Chia-Tze Kao
Orthodontic Department, Chung Shan Medical University Hospital, Taichung, Taiwan; College of Oral Medicine, Chung Shan Medical University, Taichung, Taiwan

Recommended Citation

Ho, Chun-Te; Chao, Chien-Wei; and Kao, Chia-Tze (2018) "Clinical Use of Contemporary Clear Aligner Therapy," *Taiwanese Journal of Orthodontics*: Vol. 30: Iss. 3, Article 4.
DOI: 10.30036/TJO.201810_31(3).0004
Available at: https://www.tjo.org.tw/tjo/vol30/iss3/4

Clinical Use of Contemporary Clear Aligner Therapy

Abstract

Clear aligner therapy (CAT) is an increasing popular alternative to conventional bracket therapy. This review summarized contemporary data regarding the history of CAT. The information regarding the advantages and disadvantages of CAT, biomechanical force and biological considerations, controlling orthodontic tooth movement (OTM) would be discussed in this review. The CAT is well accepted for their esthetics, comfort, good care of oral hygiene and periodontal status and suitable for interdisciplinary dental treatment. However, CAT was also considered as difficult compliance for the patients, uneasy to be handled by clinicians, unprecise root movement, difficult for the postoperative fixation in cases receiving orthognathic surgery, and high cost. The essence of orthodontic treatment is the application of forces and force systems to change the position of the teeth. Although CAT could replace the conventional brackets treatment on correction of malocclusions in some cases, the problems of limitations in clinical use still presented. The information was provided to explore the clinical evidence of CAT use.

Keywords

clear aligner therapy (CAT); digital orthodontics; 3D printing; Invisalign; aligner orthodontics.

Review Article

Clinical Use of Contemporary Clear Aligner Therapy

Chun-Te Ho,[1,2] *Chien-Wei Chao,*[1,2] *Chia-Tze Kao*[1,2]

[1]*Orthodontic Department, Chung Shan Medical University Hospital, Taichung, Taiwan*

[2]*College of Oral Medicine, Chung Shan Medical University, Taichung, Taiwan*

Clear aligner therapy (CAT) is an increasing popular alternative to conventional bracket therapy. This review summarized contemporary data regarding the history of CAT. The information regarding the advantages and disadvantages of CAT, biomechanical force and biological considerations, controlling orthodontic tooth movement (OTM) would be discussed in this review. The CAT is well accepted for their esthetics, comfort, good care of oral hygiene and periodontal status and suitable for interdisciplinary dental treatment. However, CAT was also considered as difficult compliance for the patients, uneasy to be handled by clinicians, unprecise root movement, difficult for the postoperative fixation in cases receiving orthognathic surgery, and high cost.

The essence of orthodontic treatment is the application of forces and force systems to change the position of the teeth. Although CAT could replace the conventional brackets treatment on correction of malocclusions in some cases, the problems of limitations in clinical use still presented. The information was provided to explore the clinical evidence of CAT use. ***(Taiwanese Journal of Orthodontics. 30(3): 163-170, 2018)***

Keywords: clear aligner therapy (CAT); digital orthodontics; 3D printing; Invisalign; aligner orthodontics.

INTRODUCTION

In 1945, Kesling introduced the tooth positioner used in orthodontic treatment.[1] It might be the first aligner in the world. Prior to 1998, orthodontic clear aligner therapy (CAT) was used only for minor tooth movements, usually at the end of orthodontic treatment or minor relapse correction after orthodontic treatment. In 1998, Align Technology (San José, CA, USA) modified the concept of Kesling and developed orthodontic clear aligner. It used the digital technology to move teeth in a virtual model. With 3D printing technology, materials changing, and manufacturing efficiencies, this technology enables the aligner to be produced in large quantities and delivered in time. The initial aligner case was applied in a case with mild crowding or spacing.[2] CAT gradually progressed to expand the dental arch and/or correct the molar relationship. Due to the research and development of digital aligner orthodontics, manufacturing techniques, accessories and dental movements, clear aligner therapy is constantly evolving. There are many different types of aligner companies in the world and sold aligners to all clients (Figure 1). The aligners available today are very different from the aligners in the past. The changing of

Received: August 29, 2018 Revised: September 13, 2018 Accepted: September 15, 2018

Reprints and correspondence to: Dr. Chia-Tze Kao, No.110, Sec. 1, Jianguo N. Rd., South Dist., Taichung City 402, Taiwan

Tel: +886-4-24718668 Fax: +886-4-24759065 E-mail: ctk@csmu.edu.tw

DOI: 10.30036 / TJO.201810_31(3).0004

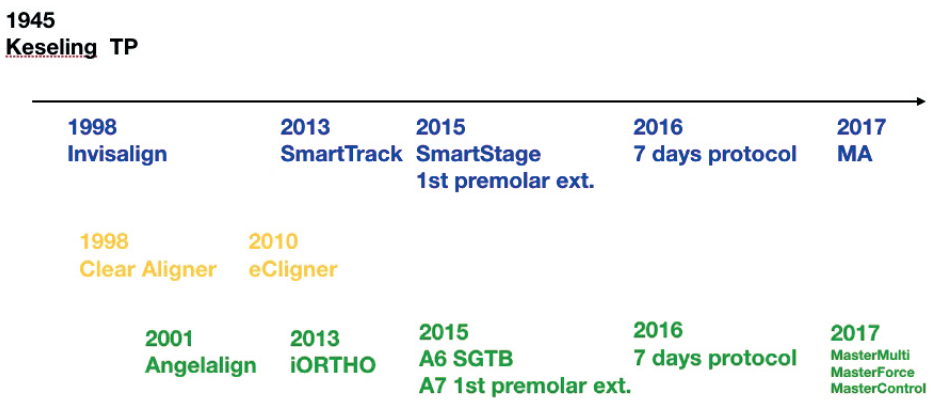

Figure 1. *Global aligners companies. (Invisalign, eCligner, Angelalign)*

the aligner is still on going. Since 2008, the improvements such as precision cutting, precision bite ramp, and smart force attachments have resulted in innovations in Invisalign G3, G4, and G5, allowing greater range of the tooth movement and more precisely. To reassess the effectiveness and efficiency of CAT is important. Therefore, well-designed clinical trials are needed to provide the evidence for the contemporary aligner therapy.

The aim of this review is to introduce the update CAT, discussed and provided the valuable information from the evidence base of CAT.

Why aligner was applied in orthodontics?

In the 1986 textbook Contemporary Orthodontics,[3] the characteristics of an ideal orthodontic appliance is described as follows; no matter what the type of orthodontic appliance, it must meet certain some basic design criteria, including (1) it should not interfere with function; (2) it should cause no harm to the oral tissues or interfere with the maintenance of good oral hygiene; (3) it should be as light and inconspicuous as possible, yet sufficiently strong to withstand masticatory forces and a reasonable amount of abuse; (4) it must be firmly retained in position; (5) it must be capable of exerting an appropriately controlled force in the correct direction and delivering this force for as long as possible between adjustment visits; and (6) it should allow control of anchorage so that tooth movements other than those intended are minimized. The CAT seems to satisfy most of these criteria.

As we review the CAT system, it has several advantages as follows: more esthetic, more comfortable, better oral hygiene and periodontal status, combined easily with interdisciplinary dental treatment. Patients prefer invisible orthodontic appliance treatment over conventional fixed appliances because of its better esthetics[4] and comfort.[5] A higher percentage of patients treated with fixed appliance were reported to have analgesics during the first week of tooth pain. On the contrary, the patients treated with the aligner were reported less analgesics and discomfort.[6]

Taiwanese Journal of Orthodontics. 2018, Vol. 30. No. 3
DOI: 10.30036/TJO.201810_31(3).0004

Marzieh Karkhanechi et al. reported treatment with fixed buccal orthodontic appliances is associated with increasing severity of periodontitis and accumulation of periodontopathic bacteria, when compared the treatment with removable aligners over the 12-month study duration.[7] Aditya et al. reported a prospective randomized clinical trial, they found that during a 9-months observation, the aligner group had better gingival index (GI) and probing on bleeding index (PBI) scores than the fixed appliance groups.[8]

However, the disadvantages of CAT are: the poor compliance of the patients, not easy to master by clinicians,[9] the root movement of the teeth is not easy,[10] the difficult in postoperative fixation in cases receiving the orthognathic surgery, and the cost is higher.[11]

Compliance is an important factor for the effective treatment with a removable orthodontic appliance.[12,13] Proffit has stated that the removable appliances by their nature produce simple tipping movements of teeth, making control of tooth position extremely difficult.[10] He concluded that using fixed appliances was the usual solution to this problem. Buschang et al. stated braces group required significantly more visits (approximately 4.0), a longer treatment duration (5.5 months), more emergency visits (1.0), greater emergency chair time (7.0 minutes), and greater total chair time (93.4 minutes) as compared with aligner therapy group (ALT).[11] However, the ALT group showed significantly greater total material costs and required significantly more total doctor time than the conventional braces group. The greater time efficiency of ALT compensate for the greater material costs and doctor time needs well-trained and experienced orthodontists.

Biomechanical force and biological considerations

Many companies developed various aligners and upgrade the function of aligner during these years. Such as Invisalign (Align Technology, San Jose, Calif) uses identical aligner material throughout treatment and a scalloped margin design. Clear-Aligner (Scheu Dental, Iserlohn, Germany) offers aligners in three different thicknesses (0.5 mm, 0.625 mm, and 0.75 mm) for each stage in treatment.[14] Similar to their construction material, this can affect the orthodontic biomechanical properties and therefore affected their tooth movement performance. The AngelAlign System provided two thickness (thin and thick) type of aligner materials for each stage since 2016. The thin and thick (soft and hard) aligners are to maintain constant force as they desired. Currently those materials on the market are different in their construction and clinical protocol. The first mass-marketed aligners, commercialized by the Align Technology (San Jose, Calif), were made of a single-layer rigid polyurethane obtained from methylene diphenyl diisocyanate and 1,6-hexanediol. Subsequent aligners were formed from Exceed-30 (Align Technology). In 2013, Align Technology started fabricating aligners with a new material-SmartTrack. SmartTrack is a highly elastic material and multi-layer aromatic thermoplastic polyurethane. SmartTrack achieved a higher mean OTM compared with the EX30 material over a 25-day period.[15,16] The major part of other aligner materials currently is polyethylene terephthalate glycol-modified (PET-G), but polypropylene, polycarbonate (PC), thermoplastic polyurethanes (TPU), ethylene vinyl acetate, and many other materials are also adopted.[17]

Clear aligner is viscoelastic, possessing intermediate properties between those of viscous and elastic materials.[18] This indicated that the loading behavior might vary considerably from wearing to removing the aligners.[19] Indeed, the deflection of a viscoelastic material increases over time (creep phenomenon) under constant loads and the load decreases (stress relaxation phenomenon) as the deflection is constant. Orthodontic aligner performance is strongly influenced by the material of their construction. Stress release, which may exceed 50% of the initial stress value in the early hours of wear, may cause significant changes in the behavior of the polymers at 24 hours then influence tooth movement.[20]

Recent studies showed that even forces as low as 18g is sufficient to produce bodily movement.[21] Because the force delivered with an aligner made from Exceed 30 is initially 200g and decays to essentially a constant level of 40g within approximately 48 hours, delivering adequate forces to the teeth to create desired movements should be no problem.[22] Controlling those forces in aligner subsequently becomes an important issue (Figure 2). It can be achieved by bonding attachments on tooth. Different attachment shapes have been designed (CA Power Grip, Invisalign attachments) to enhance retention and facilitate complex movements, such as rotation.[23] Increasing the number of attachments does not appear to enhance the rotational control.[24] The engineers and scientists designed materials in controlling tooth movement with various approaches; such as altering the shape of the aligner, applying attachments to modify the shape of the tooth, and the movement of the tooth is programmed sequentially (movement staging). Reitan confirmed the findings that during human orthodontic tooth movement, the periodontal ligament (PDL) is compressed in the direction of tooth movement.[25,26] Stretched PDL fibers occurred when the tooth was moved away from the bone. These histologic finding were explained to describe types of tooth movement— tipping or bodily tooth movement. Despite the mesial movement as they set in the aligner, early histologic changes in response to the clear plastic aligner were intrusion and distal tipping rather than mesial movement.[27] That aligner set is based on change of geometry shape, called "shape-driven". To achieve good outcome, the priority is to establish our orthodontic treatment goal of achievement, and then contemplate

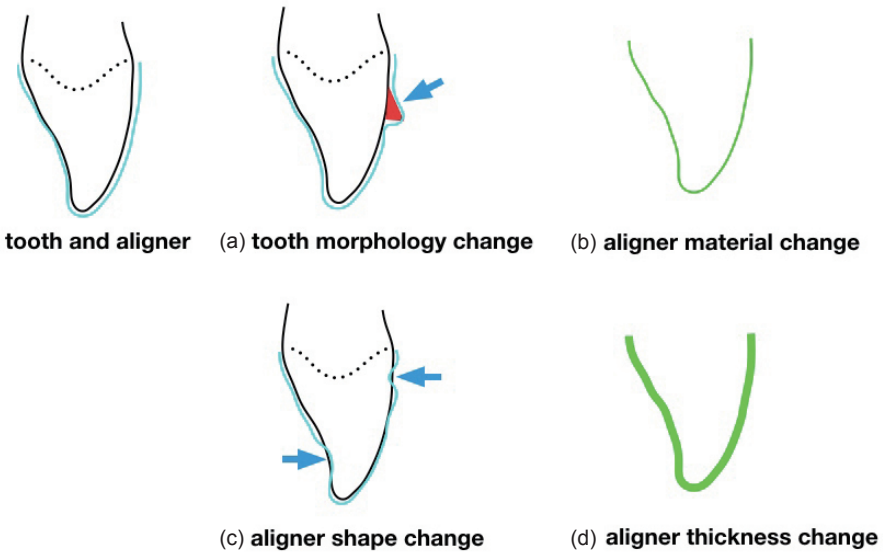

Figure 2. *Controlling force generated by interaction of tooth morphology (a) and aligners modifications (b, c, d) .*

Taiwanese Journal of Orthodontics. 2018, Vol. 30. No. 3
DOI: 10.30036/TJO.201810_31(3).0004

the force system that move teeth to final position. Often, that final shape of orthodontic appliance based on force-driven concept would not be identical to the ideal finish model. This can explain partly the virtual models do not accurately reflect the patients' final occlusion, as measured by the OGS (Orthodontic Grading System) at the end of active treatment.[28] Orthodontic treatment with Invisalign aligners was reported to induce root resorption (RR). However, the incidence is similar to that described for orthodontic light forces, with an average percentage of RR < 10% of the original root length.[29] The tendency of orthodontically induced external apical root resorption (OIEARR) was found to be similar by using either removable aligners (Invisalign) or fixed appliances.[30]

Controlling OTM with clear aligners

Gabriele et al. 2015 reported that the amount of mean intrusion of CAT was 0.72 mm.[31] Extrusion was the most difficult movement of CAT (30% of accuracy), followed by rotation. Upper molar distalization revealed the highest predictability (88%). In 2017, Gabriele et al. concluded that the mesio-distal tooth movement had the highest predictability; molar distalization up to 2.5 mm and space closure of 7 mm and predictable arch expansion up to 2 mm on the molars could be achieved.[32] Improvements in Littles and PAR Index were reported in mild to severe malocclusions.

When dentoalveolar expansion is planned with Invisalign, the mean accuracy for the maxilla is 72.8%, 82.9% at the cusp tips and 62.7% at the gingival margins.[33] The lower arch presented an overall accuracy of 87.7%, 98.9% for the cusp tips and 76.4% for the gingival margins. Careful planning with overcorrection and other auxiliary methods of expansion may keep in mind, especially in the posterior region of the maxilla. Extrusion of anterior teeth can be accomplished with attachments.[34,35,36] Attachment shape and location have been shown to affect retention of the aligners.[37,38] Hennessy et al. described the optimized attachments which developed by Invisalign including those for extrusion of anterior teeth, with pre-activated beveled shape.[39] The effectiveness of extrusive movement was reported only around 29.6% due to easy slippage of alginers occlusally.[40]

The effect of molar intrusion by using CAT facilitates the reduction closure of the anterior open bite.[41] Intrusion of posterior teeth may need a greater force than in other regions. In some instances, TADs have been used to reinforce the posterior teeth intrusion by aligner.[42,43] Deep bites are generally treated by anterior intrusion which can also be difficult with aligners application. To facilitate anterior intrusion, Invisalign uses attachments on the premolars for anchorage while an active intrusive force is placed on the incisors as well as building bite ramps on the lingual of the upper anterior teeth serving as a bite plane.[44]

CONCLUSIONS

The era of digital aligner orthodontic time is approaching. To know better to do better is always the truth. The following tips to familiar with CAT including:

1. Although CAT had replaced some of the conventional treatment technique, some treatment limitations is pending to overcome.
2. The biomechanical force design on aligner does not originate from orthodontics. It is based on physics, material science, biomechanics models, and computer science to achieve the treatment goals. In orthodontics, the force of aligner was applied mainly on periodontal membrane to cause bone resorption and bone remodeling. It is also interesting to know how the teeth move through the alveolar bone with the use of aligner.
3. It is understandable that the essence of orthodontic treatment is the application of forces and force systems to produce biological response and change the position of the teeth. The application of biomechanics would improve the quality of treatment and the efficiency of aligner treatment.

Since the technologies of aligner development have kept improving the aligner system. Oral scan combined with 3D printing instead, simulation of tooth movement in a virtual software, and improvements in aligner materials and attachments are used more often. We expect more solid evidence of CAT use to improve the esthetics, function and oral health.

REFERENCES

1. Kesling HD. Coordinating the predetermined pattern and tooth positioner with conventional treatment. Am J Orthod Oral Surg 1946;32: 285–293.
2. Boyd RL, Miller RJ, Vlaskalic V. The Invisalign system in adult orthodontics: mild crowding and space closure cases. J Clin Orthod. 2000; XXXIV:203–212.
3. Proffit WR. Adjunctive treatment for adults. In: Proffit WR, Fields HJ, eds. Contemporary Orthodontics. St. Louis: CV Mosby; 1986.
4. Walton DK, Fields HW, Johnston WM, Rosenstiel SF, Firestone AR, Christensen JC. Orthodontic appliance preferences of children and adolescents. Am J Orthod Dentofacial Orthop 2010;138: 698.e1-12: discussion, 698-9.
5. Fujiyama K, Honjo T, Suzuki M, Matsuoka S, Deguchi T. Analysis of pain level in cases treated with Invisalign aligner: comparison with fixed edgewise appliance therapy. Prog Orthod 2014;15:64.
6. David W. Discomfort associated with Invisalign and traditional brackets: A randomized, prospective trial. Angle Orthod.2017;87:801-808.
7. Karkhanechi M, Chow D, Sipkin J, Sherman D, Boylan RJ, Norman RG, Craig RG, George J. Cisneros GJ. Periodontal status of adult patients treated with fixed buccal appliances and removable aligners over one year of active orthodontic therapy. Angle Orthod. 2013;83:146–151.
8. Chhibber A, Agarwal S, Yadav S, Kuo CL, Upadhyay M. Which orthodontic appliance is best for oral hygiene? A randomized clinical trial. Am J Orthod Dentofacial Orthop 2018;153:175-83.
9. Lagravere MO, Flores-Mir C. The treatment effects of Invisalign® orthodontic aligners: a systematic review. J Am Dent Assoc. 2005;136(12): 1724–1729.
10. Proffit WR. Adjunctive treatment for adults. In: Proffit WR, Fields HJ, eds. Contemporary Orthodontics. St. Louis: CV Mosby; 1986.
11. Buschang PH, Shaw SG, Ross M, Crosby D, Campbell PM. Comparative time efficiency of aligner therapy and conventional edgewise braces. Angle Orthod. 2014;84:391– 396.
12. Brandao M, Pinho HS, Urias D. Clinical and quantitative assessment of headgear compliance: a pilot study. Am J Orthod Dentofacial Orthop. 2006;129:239–244.
13. Lee SJ, Ahn SJ, Kim TW. Patient compliance and locus of control in orthodontic treatment: a prospective study. Am J Orthod Dentofacial Orthop. 2008;133:354–358.
14. Echarri P, Chapter 1. In: Echrri P. Introduction. Madrid, Spain: Editorial Ripano, SA. 2013:13-20.
15. Wheeler T, Patel N, McGorray S. Effect of aligner material on orthodontic tooth movement. Journal of Aligner Orthodontics 2017;1(1):21–27.
16. Align Technology, Inc. INVISALIGN introduces Smart- Track. Available at: http://invisalign.com.au/doctor/doc/ brochures/SmartTrack_brochure.pdf.
17. Dupaix RB, Boyce MC. Finite strain behavior of poly (ethylene terephthalate) (PET) and poly (ethylene terephthalate)- glycol (PETG). Polymer 2005;46:4827–4838.
18. Fang D, Zhang N, Chen H, Bai Y. Dynamic stress relaxation of orthodontic thermoplastic materials in a simulated oral environment. Dent Mater J. 2013;32:946–951.
19. Kravitz ND, Kusnoto B, BeGole E, Obrez A, Agran B. 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.

DOI: 10.30036/TJO.201810_31(3).0004

20. Lombardo L, Martines E, Mazzanti V, Arreghini A, Mollica F, Siciliani G. Stress relaxation properties of four orthodontic aligner materials: A 24-hour in vitro study. Angle Orthod. 2017;87:11–18.
21. Iwasaki LR, Haack JE, Nickel JC, et al. Human tooth movement in response to continuous stress of low magnitude. Am J Orthod Dentofacial Orthop. 2000;117(2):175–183.
22. Graber, Lee W., editor. | Vanarsdall, Robert L., editor. | Vig, Katherine W. L., editor. | Huang, Greg J., editor. Current Principles and Techniques, 6th Editions, St. Louis, Missouri : Elsevier, [2017]
23. Simon M, Keilig L, Schwarze J, Jung BA, Bourauel C. Forces and moments generated by removable thermoplastic aligners: incisor torque, premolar derotation, and molar distalization. Am J Orthod Dentofacial Orthop. 2014;145(6):728–735.
24. Momtaz P, Mah J. The effect of attachment placement and location on rotational control of conical teeth using clear aligner therapy. J Aligner Orthodontics 2017;1(1):29–36.
25. Reitan K. The initial tissue reaction incident to orthodontic tooth movement as related to the influence of function; an experimental histologic study on animal and human material. Acta Odont Scand 1951;6(Suppl):1-240.
26. Reitan K. Tissue behavior during orthodontic tooth movement. Am J Orthod 1960;46:881-900.
27. Sombuntham NP, Songwattana S, Atthakorn P, Jungudomjaroen S, Panyarachun B. Early tooth movement with a clear plastic appliance in rats. Am J Orthod Dentofacial Orthop 2009;136:75-82.
28. Buschang PH, Ross M; Shaw SG; Crosby D, Campbell PM. Predicted and actual end-of-treatment occlusion produced with aligner therapy. Angle Orthod. 2015;85:723– 727.
29. Gay G, Ravera S, Castroflorio T, Garino F, Rossini G, Parrini S, Cugliari G, Deregibus A. Root resorption during orthodontic treatment with Invisalign®: a radiometric study. Progress in Orthodontics (2017) 18:12.
30. Iglesias-Linares A, Sonnenberg B, Solano B; Yan ẽ z-Vico RM, Solano E, Lindauer SJ, Flores-Mir C. Orthodontically induced external apical root resorption in patients treated with fixed appliances vs removable aligners. Angle Orthod. 2017;87:3–10.
31. Rossini G, Parrini S, Castroflorio T, Deregibus A, Debernardi CL. Efficacy of clear aligners in controlling orthodontic tooth movement: A systematic review Gabriele Angle Orthodontist, Vol 85, No 5, 2015.
32. Rossini G, Parrini S, Deregibus A, Castroflorio T. Controlling orthodontic tooth movement with clear aligners. An updated systematic review regarding efficacy and efficiency. J Aligner Orthodontics 2017;1(1):7–20.
33. Houle JP, Piedade L, Todescan Jr R, Fabio HSL. The predictability of transverse changes with Invisalign Pinheiro. Angle Orthod. 2017;87:19–24.
34. Boyd RL. Complex orthodontic treatment using a new protocol for the Invisalign appliance. J Clin Orthod. 2007; XLI:525–547.
35. Guarneri MP, Oliverio T, Silvestre I, Lombardo L, Siciliani G. Open bite treatment using clear aligners. Angle Orthod. 2013;83:913–919.
36. Schupp W, Haubrich J, Neumann I. Treatment of anterior open bite with the Invisalign system. J Clin Orthod. 2010;XLIV:501–508.
37. Dasy H, Dasy A, Asatrian G, Rozsa N, Lee HF, Kwak JH. Effects of variable attachment shapes and aligner material on aligner retention. Angle Orthod. 2015;2015:934–940.
38. Jones M, Mah J, O'Toole B. Retention of thermoformed aligners with attachments of various shapes and positions. J Clin Orthod. 2009;XLIII:113–117.
39. Hennessy J, Al-Awadhi EA. Clear aligners generations and orthodontic tooth movement. J Orthod. 2015;00:1–9.

DOI: 10.30036 / TJO.201810_31(3).0004

40. Kravitz ND, Kusnoto B, Begole E, Obrez A, Agran B. 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.
41. Boyd RL. Complex orthodontic treatment using a new protocol for the Invisalign appliance. J Clin Orthod. 2007; XLI:525–547.
42. Bowman SJ, Celenza F, Sparaga J, Papadopoulos M, Ojima K, Lin J. Creative adjuncts for clear aligners, part 2: intrusion, rotation, and extrusion. J Clin Orthod. 2015; XLIX:162–171.
43. Giancotti A, Germano F, Muzzi F, Greco M. A miniscrew- supported intrusion auxiliary for open-bite treatment with Invisalign. J Clin Orthod. 2014;XLVIII:348–358.
44. Timothy T. Wheeler. Orthodontic clear aligner treatment. Semin Orthod 2017; 23:83–89.
45. Lagravère MO, Flores-Mir C. The treatment effects of Invisalign orthodontic aligners: a systematic review. J Am Dent Assoc. 2005;136(12):1724–1729.
46. Buschang PH, Ross M, Shaw SG, Crosby D, Campbell PM. Predicted and actual end-of- treatment occlusion produced with aligner therapy. Angle Orthod. 2015;85 (5):723–727.

DOI: 10.30036/TJO.201810_31(3).0004