Introduction to Invisalign® Smart Technology: Attachments Design, and Recall-Checks

Abstract

Modern clear aligners are engineered to expand the boundaries for the utilization of removable appliances to treat a wide variety of malocclusions. Innovation is continually evolving to provide orthodontists with greater control of tooth movement to achieve desired outcomes. Three current technologies are SmartTrack, SmartForce, and SmartStage. Attachment design is an important aspect of ClinCheck. There are 5 questions that provide guide lines for choosing attachments. Two examples are presented to demonstrate the design of dental attachments to facilitate tooth movement. Invisalign G6 is a method for treating patients with extractions, particularly first premolars. It provides vertical and second order (root parallelism) control for predictable outcomes with maximum or moderate anchorage. Efficient management of space closure is an important aspect for aligner therapy because enamel stripping and extractions are common approaches for managing crowding and protrusion. At every appointment it is important to check aligner adaptation (fit), attachment positions, and anchorage preparation. This article reviews clinical procedures for numerous applications and also addresses clinical problems. (J Digital Orthod 2019;54:80-95)

Key words:

Invisalign clear aligners, ClinCheck software, SmartForce features, SmartTrack material, SmartStage, Attachment design, Invisalign G6, Aligner fit, TADs, CII elastics

Introduction

Over the past 15 years Align Technology has invested heavily in clear aligner research and development (*R&D*) to expand the clinical scope and predictability for management of a broad range of malocclusions in a global market of about 5 million patients. Innovations include SmartTrack, SmartForce, and SmartStage (*Fig. 1*). From interdental spacing to challenging Class III corrections, treatment options are available for treating a large range of malocclusions.

SmartTrack

SmartTrack is a materials innovation that evolved from 8 years of R&D investigating over 260 candidate materials with both biomechanics and materials science expertise.[1] Modern aligner materials are composed of polyurethane derived from methylene diphenyl diisocyanate and 1,6-hexanediol. This is a medical grade polymer with supplemental additives to adjust material properties to produce a product that is clear, strong, thin and flexible. In addition it is hypo-allergic, inert and biologically stable.[2] There are

Dr. Ming-Jen Chang,
Lecturer, Beethoven Orthodontic Course, Taiwan
Editor, Journal of Digital Orthodontics (Upper left)

Dr. Chun Hung Chen,
Lecturer, Journal of Digital Orthodontics (Upper middle)

Dr. Chien-Yu Chang,
Lecturer, Journal of Digital Orthodontics (Upper right)

Dr. Joshua, Shih-Yung Lin,
Lecturer, Beethoven Orthodontic Course, Taiwan
Editor, Journal of Digital Orthodontics (Lower left)

Dr. Chris H. Chang,
Founder, Beethoven Orthodontic Center
Publisher, Journal of Digital Orthodontics (Lower middle)

Dr. W. Eugene Roberts,
Editor-in-chief, Journal of Digital Orthodontics (Lower right)

three different varieties: 1. LD30 (*0.75mm*) for Invisalign® aligners, 2. EX40 (*1.02mm*) for Vivera® and Invisalign® retainers, and 3. EX15 (*<0.75mm*) for Invisalign® templates.

SmartTrack Features

1) Improved Control

Align Technology reports proprietary data from a pilot study of 1015 patients at 5 months follow-up. Compared to the original aligner material, SmartTrack delivers optimal loads over the two-week period of aligner wear designed to improve tracking and control of tooth movement. No data are presented but the company claims the results were highly significant ($p<0.001$) at a 99.9% confidence level (*Fig. 2*).[1]

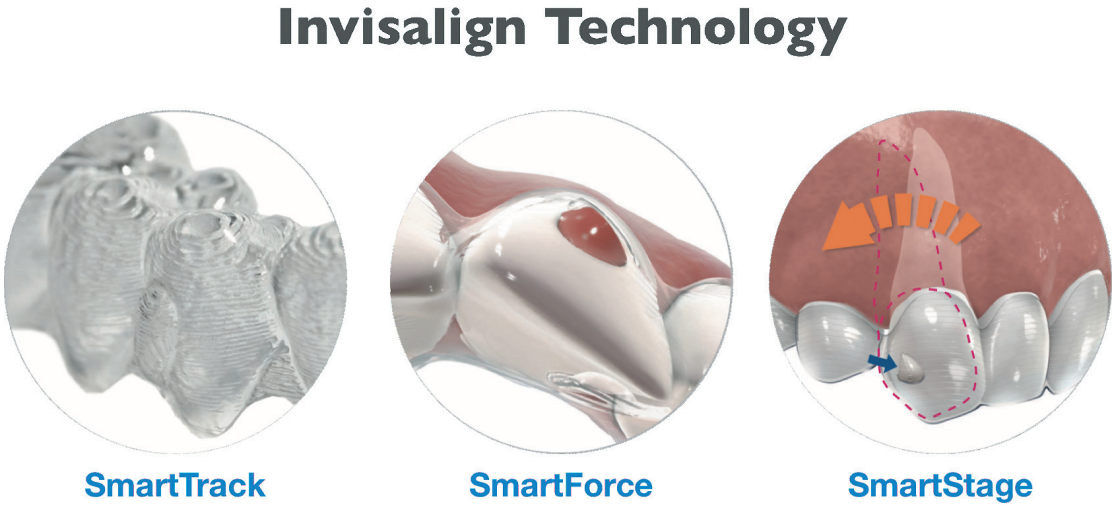


Fig. 1: The 3 innovations of Align Technology.
SmartTrack: Aligner material to supply gentle and content force.
SmartForce: Precise 3D control of tooth movement.
SmartStage: Optimizes the progression of tooth movement.

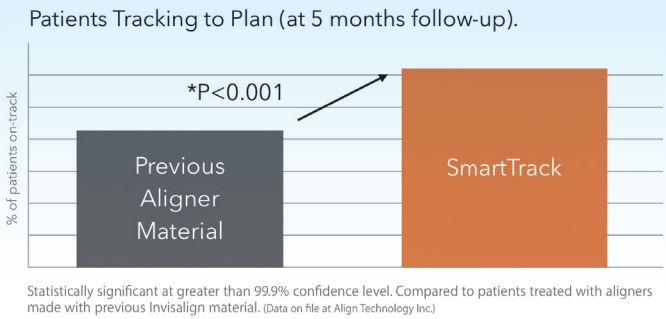


Fig. 2:
The percentage of patients remaining on track with Invisalign treatment was significantly higher at a 5-month review appointment (p< 0.001). See text for details.

2) Improved Constant and Gentle Force

The applied force for the original aligner material decayed rapidly over the first few days of wear, but decreased at a much slower rate for the last 10-12d of the two-week period. In comparison the SmartTrack material delivered a lower initial load, that decayed rapidly for the first couple of days and then delivered a relatively constant load for the next 12d (*Fig. 3*).[3] It is concluded that SmartTrack produces a more constant and gentle load over the entire two week period. Furthermore, there is a significantly lower initial insertion load for each new aligner, which improves patient comfort. The comparative curves, based on vitro measurements in a simulated oral environment, appear to be consistent with the conclusions, but "*Material Stress Relaxation*" is unclear because stress is typically measured in Pascals not Force. A more complete report or literature reference to the actual data for Fig. 3 would be helpful.

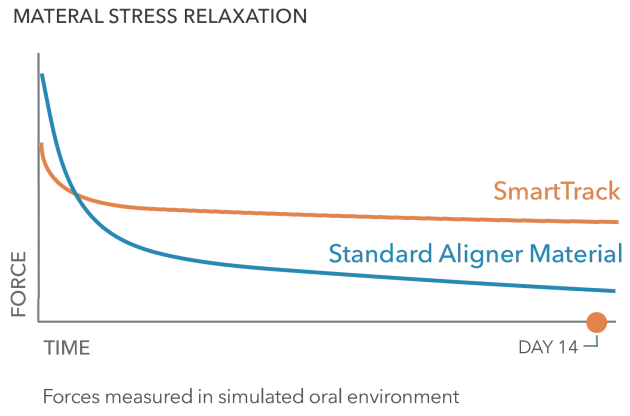


Fig. 3:
Invisalign SmartTrack has a more constant and gentle force to achieve tooth movement. The standard aligner material requires a high insertion force and the load quickly decays over the two week aligner wear period. See text for details.

3) Higher Elasticity

SmartTrack aligners are composed of a more pliable material (*Fig. 3*) that is more easily stretched over a dental arch, and less likely to crack (*Fig. 4*). The aligner then returns more completely to its programmed shape (*memory*). The decreased permanent distortion illustrated helps facilitate precise tooth movement (*Fig. 5*). Reportedly the SmartTrack material is more comfortable to wear than previous aligners made with the EX30 material.[3]

4) More Precise Aligner Fit

The comparative fit (*adaptation*) of the more flexible material is tested with relatively opaque blue gel, that is added to the aligner before it is fitted on the arch. The overall less intense blue color of SmartTrack indicates it conforms more closely to the dental anatomy. Improved adaptation (*Fig. 6*) and the

Fig. 4:
The more elastic material is much less likely to crack when stretched over a patients' teeth.

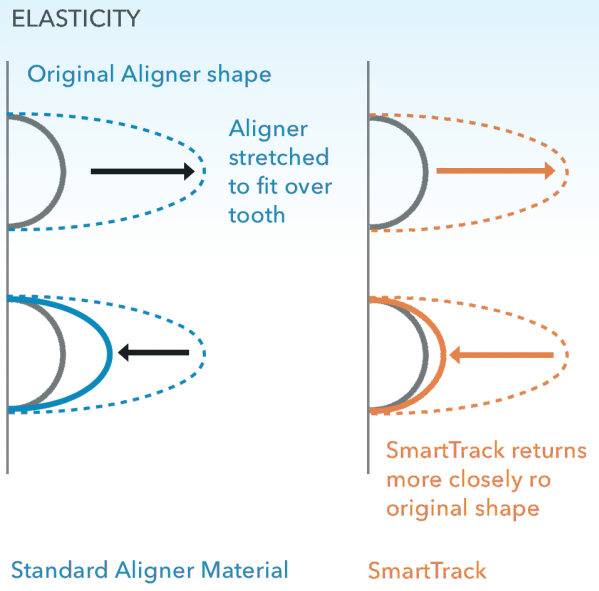


Fig. 5:
When deformed, the highly elastic SmartTrack returns more closely to the programmed aligner shape. See text for details.

tendency for less permanent distortion (*Fig. 5*) are expected to translate into improved control of tooth movement, particularly for finishing.[4]

5) Enhanced Patient Comfort

SmartTrack aligners are reportedly more comfortable to wear and easier to take in and out, which is an important feature if bonded attachments are present.[5] Despite the improved performance, the current aligners have good clarity, esthetics and transparency, so they are an almost invisible removable appliance.[6] In addition, SmartTrack has resulted in improved control of tooth movement, by applying a more gentle and relatively constant force (*Fig. 3*). These characteristics reportedly decrease treatment time up to 50%, and tooth movement is 75% more predictable[7] because of the improved conformity to the arch (*Fig. 6*) and less distortion (*Fig. 5*).

SmartForce

SmartForce was proposed for extrusion of teeth in 2009. Later a beveled surface was added on the occlusal surface of the attachment to enhance the delivery of extrusive force (*Fig. 7*).[4] When a load is transferred to the gingival surface of the attachment, the bevel allows the tooth to move occlusally (*extrude*). Similar force vectors were developed for attachments designed for rotational control,

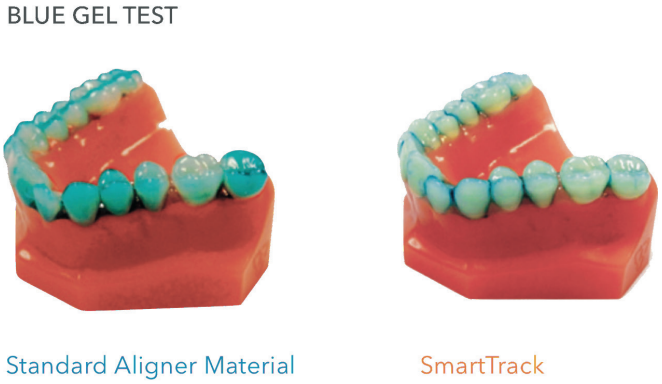


Fig. 6:
Aligners are filled with blue gel and seated on a typodont. White areas indicate direct aligner contact, and blue areas indicate a gap between the aligner and the teeth. SmartTrack demonstrates superior adaptation (fit), particularly in interproximal and attachment areas.

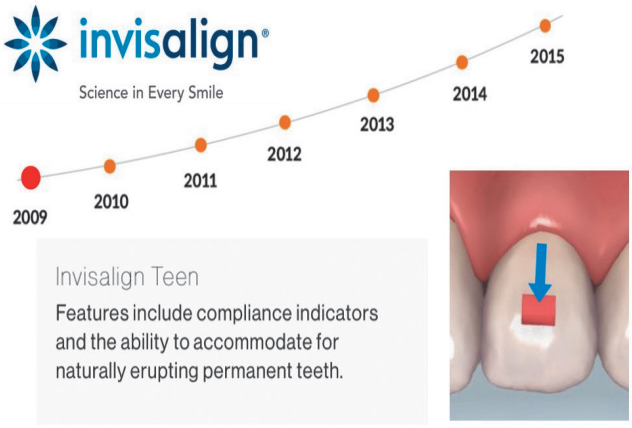


Fig. 7:
Invisalign® proposed the concept of SmartForce in 2009. A gingival rectangular beveled attachment was designed to extrude the tooth efficiently.

application of torque (*3rd order correction*), and intrusion. The G4-G7 concepts were developed later.

SmartForce Features

To understand SmartForce capabilities, it is important to carefully consider the attachment concept. Depending on the design of the attachment relative to the seating (*full engagement*) of an aligner, force and couples to generate moments can be applied to move teeth. In mechanics, a couple is two parallel forces that are equal in magnitude, opposite in direction (*sense*), and do not share a common line of action. When the treatment plan calls for anything other than tipping a tooth, an attachment(*s*) are necessary. It is essential to carefully evaluate the couple generated by a loaded attachment, relative to the force applied. The moment to force ratio (*M:F*) is directly related to the type of tooth movement: tipping (*low*), translation (*medium*) and root torque (*high*). Another important consideration is the equal and opposite effect of the force system on the anchorage unit. Bodily tooth movement (*translation*) and particularly root torque tax anchorage far more than tipping movements.

Fundamentally, a surface attachment is much like a handle to move a sliding door (*Fig. 8*). Prior to SmartForce, the principal attachments were ellipsoid, rectangular, and rectangular beveled (*Fig. 9*). Except for the latter, an aligner passively fitting an attachment only provides retention. The beveled attachments are worthwhile for aligning the dentition to achieve limited orthodontic correction, but they are not compatible with the complex movement required for comprehensive

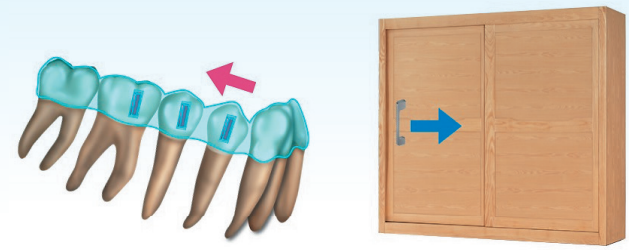


Fig. 8:
An attachment on an aligner is analogous to a handle on a wardrobe or cabinet. The attachment (handle) provides retention for an aligner.

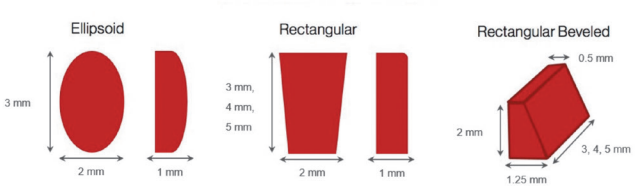


Fig. 9:
Three types of conventional attachments are shown. The ellipsoid is seldom used now because of poor retention. The rectangular attachment is effective for additional retention and can be used to apply a couple (moment) to the teeth. The beveled attachment is still a good choice for extrusion although the newer optimized attachments are now more common.

orthodontics. The G3 concept[5] for attachment-mediated tooth movement was aimed at more comprehensive applications such as rotations and torque control.[5,7] The principal difference for G3 was power ridges[6] built into the aligner, and a direction-oriented active surface on optimized attachments (*Fig. 10*).[7] With the improved elasticity of SmartTrack (*Fig. 3*) a force applied to an active surface can be used to effectively move a tooth in any direction. However, anchorage must be carefully considered particularly if the goal to move teeth bodily (*translate*). There is a tendency to tip teeth with an active surface unless there is an adequate moment for bodily movement. If it is desirable to retract a tooth,

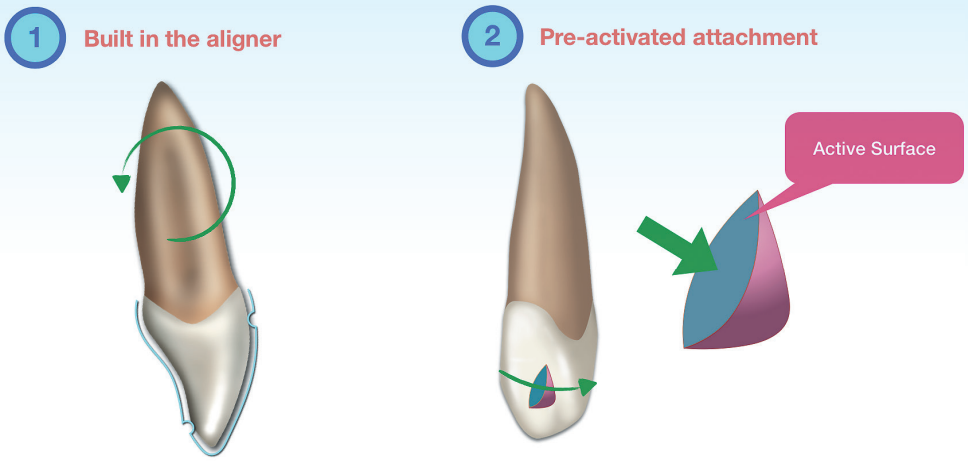


Fig. 10:
SmartForce is effective in two ways: 1. Built into the aligner, such as power ridges designed to control torque. 2. Active surface on an optimized attachment to control tooth movement precisely.

such as a lower third molar, the active surface will face mesially (*Figs. 11, 12*). The force developed to bodily move any tooth must be carefully balanced with an appropriate moment or the tooth will tip. The type of tooth movement depends on the M:F associated with the applied load.

There are many applications for SmartForce, depending on the design of the mechanics. The five basic movements for a tooth are rotation, extrusion, intrusion, torque control of the crown, and root control. If multiple types of movement are desired, there is a hierarchy for applicable attachments that is based on the Invisalign data base. Every optimized attachment comes with a set of rules based on the longterm experience of the manufacturer. Doctors can assess treatment progress, but changing optimized attachments is not an option. However, during a refinement (*reboot*) procedure, optimized attachments can be replaced with conventional ones if desired.[8]

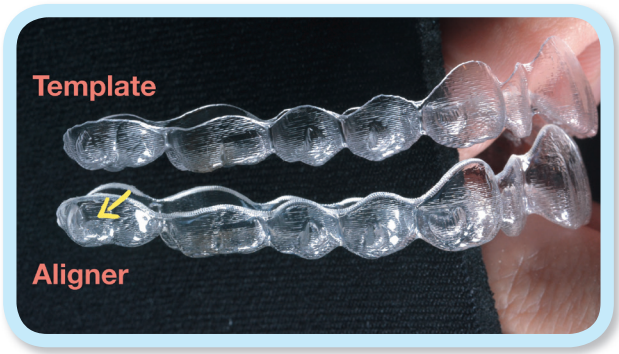


Fig. 11 :
In this stage, retraction ("distalization") of LR8 (#17) is planned. The shape of the #17 attachment on the aligner is a little different from the one on the template. This configuration produces a force that pushes on the attachment of #17.

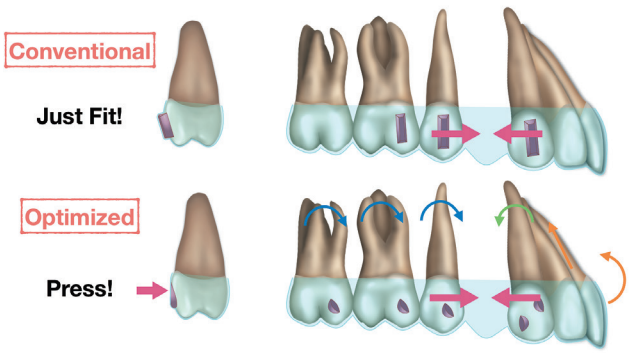


Fig. 12:
The active surface on an optimized attachment produces a couple that is designed as an anti-tip moment during space closure.

SmartStage

In 2015, Invisalign released G6 along with SmartStage to improve aligner performance for first premolar extraction treatment.[9] SmartStage is engineered to optimize tooth movement progression, but it is an abstract concept in mechanics that is challenging for many clinicians. The first application is to modify the shape of an aligner, and the other is to adjust the sequence of tooth movement. Combining SmartForce with SmartStage can enhance the predictability of clinical outcomes. A careful application of the method controls unwanted tipping and anterior extrusion of incisors during retraction.[10]

SmartStage Features

1) Optimaized Aligner Shape

Distal incisor tipping (*anterior torque loss*) and buccal segment mesial tipping (*posterior torque loss*) are common side effects when closing first premolar extraction spaces.[11] With fixed appliances, clinicians can reduce these side effects with archwire adjustments such as a curve of Spee adjustment, gable bends or selecting a full-size rectangular archwire.[12] Clear aligners can simulate these effects if they are designed to change form or modify in shape. These aligner activations work together with optimized attachments to effectively close extraction space. These mechanics require precise engineering to control both the moment to force ratio on each segment, and the equilibrium of the entire force system (*Fig. 13*).

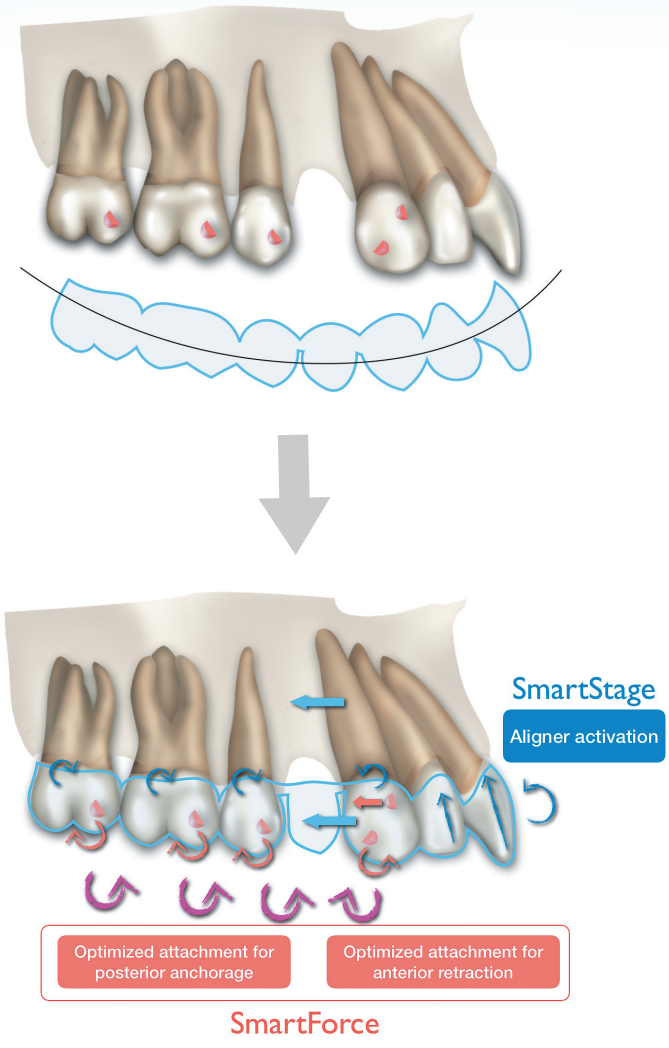
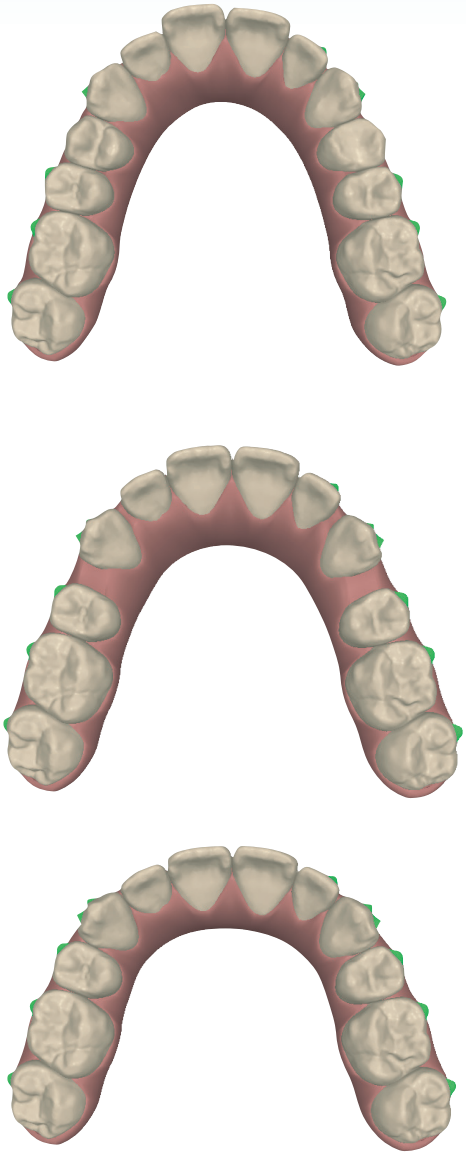


Fig. 13:
Aligner activation (SmartStage) compliments optimized attachments (SmartForce) to eliminate undesirable tipping extrusion during retraction. Magenta curved arrows are tipping moments when closing first premolar space. Red curved arrows are counter moments resulting from the aligner applying active force on optimized attachments. Dark blue curved and straight arrows show the direction of root control in addition to preventing anterior extrusion.

2) Optimized Tooth Movement Sequence

SmartStage technology is designed to optimize aligner shape and tooth movement progress to achieve more predictable clinical outcomes. To preserve posterior anchorage, a two-step anterior retraction method is proposed instead of en-mass space closure;[13] however, this tends to be an unattractive approach because it opens maxillary anterior spaces. Aligners can utilize this approach without an appreciable esthetic deficit because aligner material fills the space during the retraction process. Canines are retracted about 1/3 of the extraction space and then all six anteriors are retracted later, utilizing posterior arch anchorage (*Fig. 14*).[9] SmartStage adapted this modified two-step anterior retraction process, although not all clinicians accept this approach as effective and efficient.[14,15] Mini-screw anchorage for en-mass retraction with aligners is another option.



■ *Fig. 14:*
SmartStage can be programmed to optimize tooth movement sequence. Invisalign G6 is designed to retract canines first for about 1/3 of the predicted space closure movement. The six-anteriors are then retracted. This approach increases treatment time but may help preserve posterior anchorage. See text for details.

Attachments Design

Are attachments necessary to move teeth with aligners?

Aligners can accomplish many types of tooth movement without attachments because loads are applied to the teeth by the surrounding material. Tipping the crowns of teeth and incisor rotation rarely require any attachments. Complex tooth movement and rotation of most teeth is difficult to accomplish without attachments. Attempting to correct major malocclusions without attachments is

likely to be frustrating for both the patient and the clinician. Attachment design is an important aspect of diagnosis and treatment planning.

Tooth movement requiring attachments?

1) Rotation

Premolars have a small contact surface and relatively round shape, so they usually require attachments for rotation (*Fig. 15*).

2) Extrusion

Aligners use other teeth as anchorage to develop extrusive force, but the mechanics are ineffective unless the aligner has a firm attachment to the surface of the crown to be extruded. It is very difficult if not impossible to effectively extrude most teeth without attachments.

3) Translation

Bodily movement (*translation*) requires a relatively high moment to force ratio and substantial anchorage. Aligners are effective for delivering forces, but applying a significant moment to the crown of a tooth requires a couple, which depends on the active surface of an attachment. Optimized or vertical attachments can translate teeth by increasing the moment to force ratio (*M:F*) of the applied load. For pure translation, the M:F must approximate the equivalent force system, meaning the moment must be adequate to simulate a force passing through the center of resistance of the root. An inadequate moment results in tipping of a tooth while an excessive moment produces root movement without changing the relative position of the tooth.

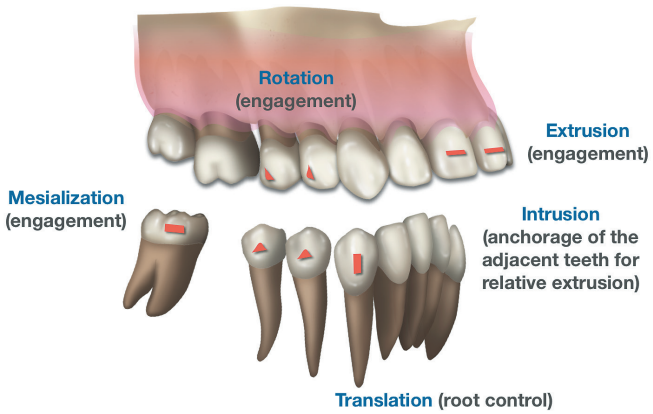


Fig. 15:
Attachments are required for tooth rotation, extrusion, translation, protraction ("mesialization"), and intrusion.

4) Mesial Tooth Movement

Anterior translation of posterior teeth such as a second molar is very difficult because the crown height is limited. Thus attachments are not effective for generating a large moment. With aligners the mesial force on the molar must be relatively low to avoid overcoming the limited moment generated by the attachment to prevent tipping the molar anteriorly. When substantial movement of molars is required, aligners may not be the optimal approach. Fixed appliance are much more effective in achieving substantial mesial translation of molars.[16]

5) Intrusion

When intrusion is prescribed, attachments are unnecessary because the aligner can easily develop intrusive force. However, there may be an undesirable extrusion of anchorage teeth. Like translation of a tooth, intrusion can easily compromise anchorage because it is much easier to extrude a tooth than to intrude it. Attachments are

usually required, for stabilization of anchorage teeth into segments, to resist extrusion.

5 Questions for Attachments Design

Clinicians are often confused by attachments. There are 5 questions to help define and design appropriate auxiliaries.

1. What is the planned direction of tooth movement? Mesial, distal, extrusion or intrusion?
2. What is the function of the attachment? Anchorage or delivering an active load?
3. Which is the active surface of an attachment? This calculation is critical for estimating the amount of force and the couple generated by programmed recoil of the aligner. The M:F, plane of force system, and underlying root structure dictate the path of tooth movement. Like archwires, aligners tie the arch together which is helpful for keeping tooth movement under control as the active surface of attachments move individual teeth.
4. Is it feasible for an active load from an aligner to produce the desired tooth movement? For instance, severely crowded teeth may require extraction, arch expansion and/or enamel stripping to avoid undesirable lip protrusion.
5. Is the active force parallel to the direction of tooth movement? If so, surface attachments are a wise choice.

Deep-bite Attachments

The solutions for a deep-bite are upper incisor intrusion, lower incisor intrusion, or buccal segment extrusion. Attachments are not required for incisors intrusion (*Fig. 16*), but the premolars serving as anchorage, do require them (*Fig. 17*). The attachments can be conventional (*for retention*) or optimized (*for extrusion and retention*).

Molar-Intrusion Attachments

The intruded molars do not need any attachments because the occlusal surfaces are adequate for delivering the axial load. However, the adjacent premolars do need attachments to resist the

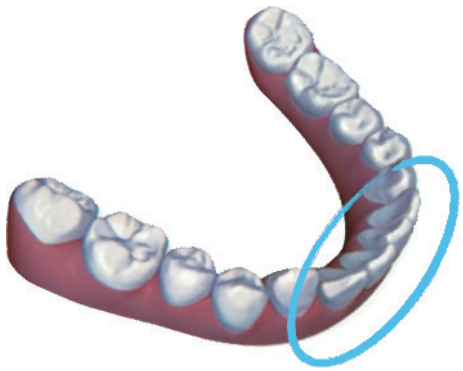


Fig. 16:
The blue circle indicate there is adequate surface area on each tooth for the aligner to apply the intrusive forces.

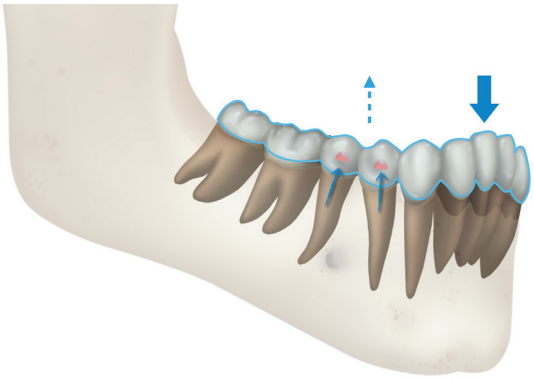


Fig. 17:
Attachments designed for managing deep-bite. The solid broad arrow indicates intrusive force. The dotted arrow is the resulting (counter) extrusive force.

resulting extrusive loads (*Fig. 18*). Again, attachments on the premolars can be conventional for retention, or optimized for extrusion and retention.

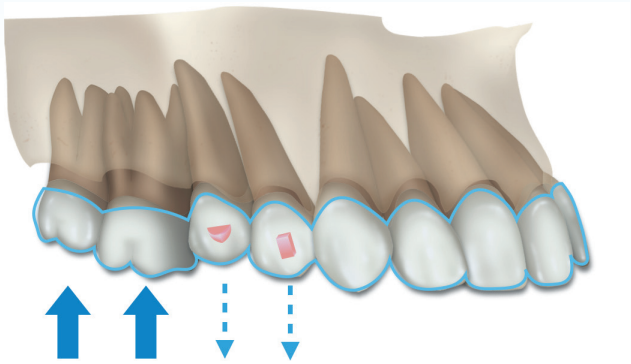


Fig. 18:
Attachments are designed for molar intrusion (solid broad arrows) and dotted arrows show the counter extrusive forces.

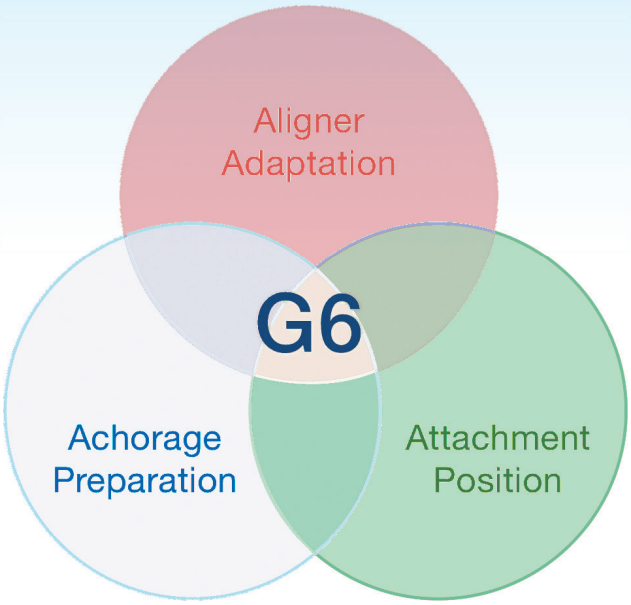


Fig. 19:
These 3 key points allow us to monitor our treatment result effectively at every appointment.

3 Key Points for Invisalign G6 Recall-Check

The Invisalign G6 is well designed to support first premolar extraction cases. It combines the three innovations of Smart Technology, to provide more predictable and efficient root alignment. The mechanics depend on carefully monitoring three key points: 1. aligner adaptation (*fit*), 2. attachment positions, and 3. anchorage preparation (*Fig. 19*).

Aligner Adaptation (Fit)

Teeth not fitting well into an aligner is deemed off-tracking, which is the most common problem with Invisalign aligners (*Fig. 20*). The first sign of off-tracking is a gap between the aligner and the incisal edges or cusps of the teeth. This may occur for two reasons. The first is extrusion of anterior teeth was programmed into the aligner, or a canine is moving distally. Initially there will be a small space between the incisal edge or cusp of the tooth and the aligner.

Fig. 20: Teeth are not fitting into the aligner (off-tracking).

This is normal when the aligners are changed, but it should not be allowed to increase as an aligner is worn. For example, the patient (*Fig. 21*) should be advised to bite on aligner "*chewies*" especially in the off-tracked area. The second reason for off tracking may be that aligners are changed too frequently, before the teeth have moved to the planned position for the next stage of treatment. The patient

may be trying to speed up treatment by changing aligners at 7-day intervals or less. The most common correction is for the patient to wear the problem aligner 3-5 days longer to determine if adaptation is self-correcting (*Fig. 22*).

Fig. 21:
Patient was advised to bite on the "chewies" to seat the aligner into an appropriate position for better adaptation.

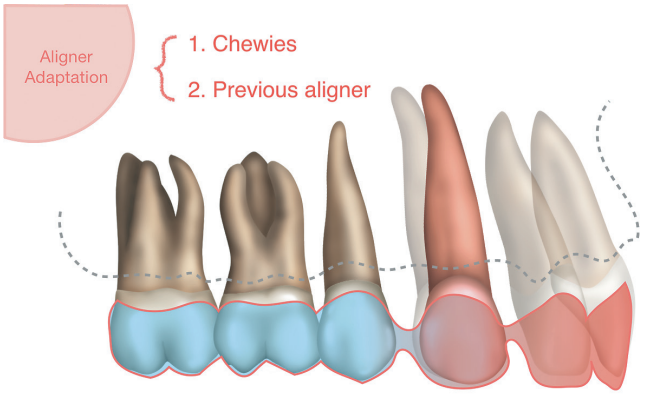


Fig. 22: Aligner adaptation problems and the relative solutions.

Attachment Position

G6 SmartForce features an Optimized Retraction Attachment that is designed to work with SmartStage technology to achieve effective bodily movement during canine retraction. The multi-tooth unit and staging of the G6 system is a complex system that is not adjustable. It is an all or none option (*Figs. 23 and 24*).

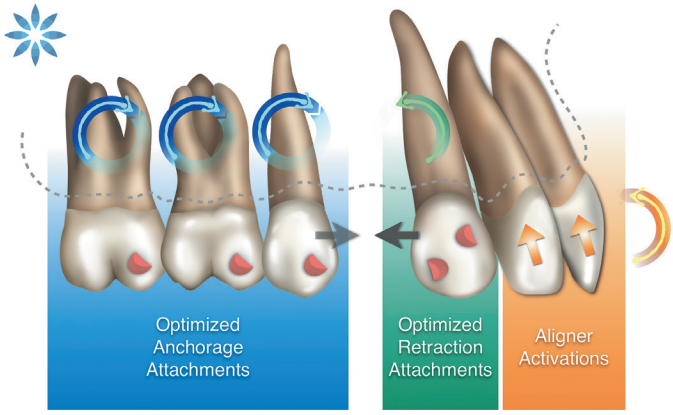


Fig. 23: The G6 features and biomechanics for space closure.

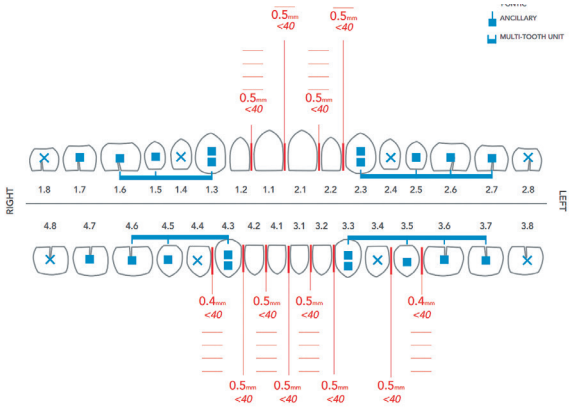


Fig. 24:
In the Invisalign treatment sheet, the blue horizontal bar means the multi-tooth unit that belongs to the same group and should be maintained. The red notation indicates tooth movement desired with aligner treatment.

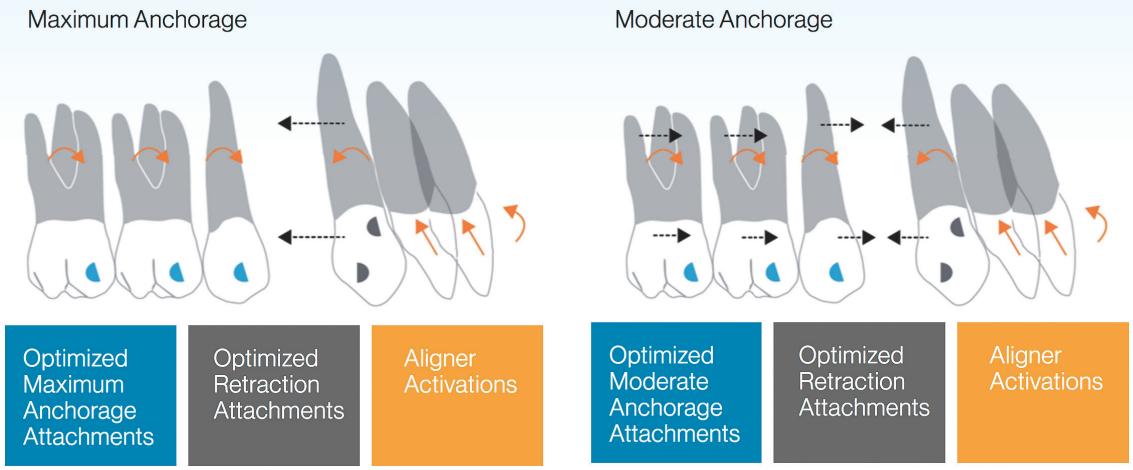


Fig. 25: Illustrations are shown for maximum anchorage and moderate anchorage in the G6 system.

The doctor's responsibility is to carefully check every attachment at each appointment. Any missing attachment must be replaced quickly with the template supplied. A full compliment of attachments is critical for space closure mechanics, so the patient is also asked to check the tooth surfaces with a finger every time they take out the aligner. If an attachment is lost, an appointment with the doctor is required within 7 days to repair the problem.

Anchorage Preparation

The G6 system can be programmed with SmartStage technology to provide maximum anchorage. Molar stability is programmed to hold the A-P position for achieving maximum retraction of the anterior segment. Moderate posterior anchorage permits <5mm of molar mesial movement (*Fig. 25*). These anchorage options are programmed with the ClinCheck system and must be carefully examined by the doctor prior to approval. In order to accomplish an ideal result, anchorage preparation can be supplemented with Class II elastics or temporary anchorage devices (*TADs*) (*Fig. 26*).

Integrating Aligners and Fixed Appliances

Achieving precise tooth movement to resolve malocclusion is the primary goal for orthodontics. Aligner therapy is popular with patients, who do not want to wear braces, but success with these removable appliance is dependent on both the

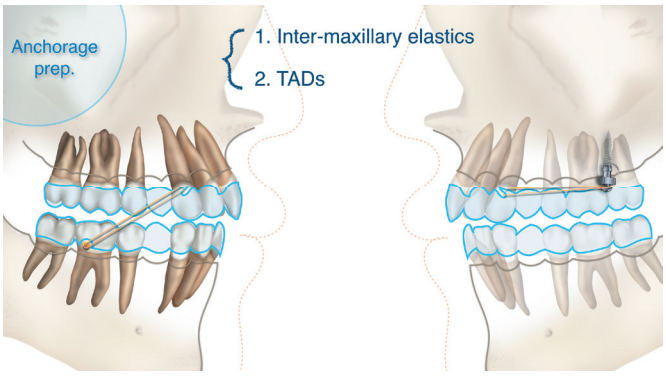


Fig. 26:
The intermaxillary elastics and TADs can be used as anchorage for a better treatment outcome.

doctor and patient following instructions precisely. The principles for applied mechanics and anchorage are the same for all tooth movement, but the clinical course for each approach is distinct. Both archwires and aligners are indeterminate mechanics[17] so periodontal ligament stress throughout the arch is unknown so the precise response to applied loads are variable. The same risks apply to aligners and archwires: uncertain course of tooth movement, relatively long treatment times, and root resorption.

The Insignia™ technology for fixed appliance treatment was the first patent in orthodontics for computer-aided design (*CAD*) and computer-aided manufacturing (*CAM*). However, Align Technology (*Invisalign®*) was the first company to actually market CAD/CAM appliances to move teeth. Invisalign has a long history of aligner innovations and clinical monitoring to improve outcomes. A trial and error approach is appropriate for indeterminate mechanics because the path and course for tooth movement cannot be calculated. Most teeth do not move precisely along the direction of the force, so considerable R&D is required to define how teeth will move in response to a given force system. The Invisalign team have monitored many outcomes to define the treatment scenarios available to manage complex malocclusions. Consequently, aligner therapy is less intuitive than fixed mechanics for both the doctor and patient. The advice of Invisalign technicians is based on algorithms developed with a massive data base which is the actual science of the mechanics. One can view the process for sophisticated aligner treatment as a form of artificial intelligence (*AI*), a type of technology based on massive data bases that is increasingly prevalent in dentistry. Utilizing vast resources, Invisalign has developed 3 innovative technologies to expand the scope of aligner therapy and make patients more comfortable during treatment.

At the initial consult, patients should be encouraged to share their chief complaint(*s*) so the doctor can properly diagnose the malocclusion, relative to the patient's needs, and decide on a general treatment plan. If a fixed appliance is selected, the mechanics are described in a straight-forward manner. On the other hand, an Invisalign consolation should focus on desirable outcomes and the necessity to follow instructions precisely. The actual mechanics are determined by technicians, utilizing automated routines and attachments based on industrial experience. The process is not intuitive so the doctor and the patient are not going to "*understand*" it, but must accept the necessity to adhere to the instructions provided, to achieve a predictable clinical outcome. Some problems, mechanics, and patients may be better suited to another CAD/CAM appliance, e.g. the Insignia™ system.

Aligner material is based on sophisticated polymer science and progressive mechanics are a stepwise iterative approach for applying loads directly to teeth and/or via attachments. The greatest advantage for aligners is esthetics during treatment, but space management and protrusion can be a problem so enamel stripping and/or extractions are often required. Fixed mechanics are based largely

on metals technology with an increasing emphasis on long range superelastic loads. The latter has substantial potential for controlling indeterminate mechanics to decrease treatment time for a precise correction of malocclusion. In addition, most severe skeletal problems can be conservatively managed with determinate mechanics, that is anchored with extra-alveolar bone screw anchorage.[17] It is clear that both CAD/CAM technologies (*Invisalign and Insignia*) are in the realm of a well-trained orthodontist.

In addition personalized treatment is rapidly advancing, based on specific genetic and environmental factors presented by the patient.[18] Orthodontist of the future must evaluate the patient carefully to prescribe an appropriate therapy. The preference of the patient will usually be the determining factor, because both CAD/CAM approaches (*aligners and fixed appliances*) offer excellent outcomes. The choice for the patient is esthetic treatment with aligners, but the treatment time will be substantial, and enamel stripping and/or extractions are often required. The emerging alternative with Insignia-SmartArch™ is relatively rapid, non-extraction treatment with braces. From the patient's perspective, the outcomes will be similar. The treatment will largely depend on patient preference: braces or not. A general dentist may only be comfortable with aligners, but a specialist should offer both options.

Conclusion

For clinicians transitioning from a "*brackets and wires*" practice to offering clear aligners, there is uncertainty relative to planning treatment and monitoring progress. The doctor must understand that Invisalign® is a very sophisticated therapeutic system that is not intuitive, so the aligners must be applied as prescribed. If progress is disappointing, it may be necessary to refine (*reboot*) the treatment process to achieve the desired outcome. Standard attachments can be changed at that time because a new series of aligners will be made. However, it is important for the clinician to refrain from changing mechanics while a series of aligners is being worn. The "*see it and fix it*" mentality that is common with fixed appliances is inappropriate for complex aligner treatment. Clinicians should practice and master the 3 check points as described in this article. The only periodic adjustments by the doctor are to replace attachments, increase the time an aligner is worn, or to insure that the teeth are well seated in the aligner with "*chewie*" exercises. The doctor and the patient must precisely follow instructions to benefit from the efficiency and precision of the prescribed treatment.

Acknowledgement

Thanks to Dr. Rungsi Thavarungkul for the delicate original illustrations. Thanks to Mr. Paul Head for proof-reading this article.

References

1. Invisalign® introduces SmartTrack. Align Technology, Inc. 2013.
2. Material safety data sheet. Align Technology, Inc. 2013.
3. SmartTrack FAQ . Align Technology, Inc. 2012.
4. Nicozisis J. Invisalign case report. Orthotown Magazine 2010 October:44-48.

5. Glaser BJ. The Insider's guide to Invisalign treatment: A step-by-step guide to assist your ClinCheck treatment plan. California, USA: 3L Publishing; 2017.
6. Tommaso C, Francesco G, Alberto L, Cesare D. Upper-incisor root control with Invisalign appliances. J Clinical Orthod 2013 June;47(6):346-51.
7. Morton J, Derakhshan M, Kaza S, Li C. Design of the Invisalign system performance. Semin Orthod 2017;23:3–11.
8. Peydro Herrero D, Chang CH, Roberts WE. Severe malocclusion with openbite, incompetent lips and gummy smile (DI 29) treated in 16 months with clear aligners to a board quality result (CRE 18). Int J Orthod Implantol 2017;48:74-94
9. Shuo W, Yuhong S, Xianming H. Innovation of Invisalign technology and its efficacy for tooth movement. Jounal of Prevention and Treatment for Stomatological Diseases 2018;26(11):743-748.
10. Align Technology. Discover new possibilities with first premolar extraction solution. 2018. Available here: http://www.invisalign-g6.com/en-GB/firstpremolarextraction.aspx
11. Grünheid T, Loh C, Larson BE. How accurate is Invisalign in non-extraction cases? Are predicted tooth positions achieved?. Angle Orthod 2017;87(6): 809-815.
12. Charlene C, Angle L, Chris CH, Roberts WE. Bimaxillary protrusion treated with Insignia® system customized brackets and archwires. Int J Orthod Implantol 2017;48:50- 70.
13. Braun S, Sjursen RC Jr, Legan HL. On the management of extraction sites. Am J Orthod Dentofacial Orthop 1997;112:645–55.
14. Xu TM, Zhang XY, Oh HS, Boyd RL, KornEL, Baumrind S. Randomized clinical trial comparing control of maxillary anchorage with 2 retraction techniques. Am J Orthod Dentofacial Orthop 2010;138:544-45.
15. Rizk MZ, Mohammed H, Ismael O, Bearn DR. Effectiveness of en masse versus two-step retraction: a systematic review and meta-analysis. Prog Orthod 2018;18:41.
16. Roberts WE, Arbuckle GR, Analoui M. Rate of mesial translation of mandibular molars using implant-anchored mechanics. Angle Orthodontist 1996;66(5):331-338.
17. Roberts WE, Viecilli RF, Chang CH, Katona TR, Paydar NH. Biology of biomechanics: finite element analysis of a statically determinate system to rotate the occlusal plane for correction of skeletal Class III malocclusion. Am J Orthod Dentofacial Orthop 2015;148:943-955.
18. Hartsfeld JK Jr, Jacob GJ, Morford LA. Heredity, genetics and orthodontics - How much has this research really helped? Semin Orthod 2017 Dec;23(4):336-347.