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Review

Staging Orthodontic Aligners for Complex Orthodontic Tooth Movement

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Main Points

- It is favorable to modify the location of elastics by changing the teeth used for elastic wear as treatment progresses, for distalization with aligner therapy.
- Torquing of maxillary incisors, amount of crowding, overbite, overjet, and amount of retraction of maxillary and mandibular incisors are the factors that play an important role in staging OTM for space closure with aligners.
- The tendency for underperformance of aligners for intrusion, extrusion, and rotational correction can be overcome by performing overcorrection during the staging of OTM.

ABSTRACT

The recent trend in orthodontics has shown an increased shift toward aligner therapy. For years, orthodontists have used fixed preadjusted appliances for orthodontic treatment. Even though fixed appliances have been highly efficient in the treatment of orthodontic malocclusions, they are not as esthetic as clear aligners. The purpose of this article is to review the staging of orthodontic tooth movement (OTM) with aligner therapy.

Keywords: Aligner therapy, preadjusted edgewise appliance, complex orthodontic tooth movement

INTRODUCTION

Orthodontic treatment has experienced a shift in the market, with an increasing demand for aligners.[1-3] The main benefit of aligner therapy is the superior esthetics and the use of appliances that are removable, compared to fixed orthodontic appliances. This makes it an attractive option for adult orthodontic patients. However, a limitation of aligner therapy is the lack of predictable and efficient orthodontic treatment for complex malocclusion. Aligners have been reported to be less effective in certain orthodontic tooth movements (OTMs) such as torquing, extraction space closure, intrusion, and rotations.[1,4,5]

Aligner therapy works by sequentially moving the teeth in small amounts with consecutive aligners to reach to the final orthodontic outcome. The technique of moving the teeth with successive thermoplastic appliances worn consecutively by the patient was contributed to the orthodontic community by Kesling.[6] However, in the late 1990s, with the launch of Invisalign aligners by AlignTechnology, aligners gained more popularity and changed the landscape of the orthodontic market. Using CAD/CAM in the production technology, aligners could be manufactured at a much faster pace than before. However, there have been controversies in the utility of aligners in the treatment of severe or complex malocclusions. Some proponents of aligner therapy have suggested the use of aligners for complex tooth movements such as orthodontic space closure, distalization, and intrusion. However, some others suggest using it for orthodontic treatment of mild malocclusion.[7,8]

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An important aspect in the success of aligner therapy is the staging of the OTM with the aligners. Owing to the lack of literature on the staging of OTM with aligners, most clinicians base their interpretations on expert opinions. Thus, there is an unmet need for more information on the topic of staging OTM with aligners. With an increasing number of orthodontic aligner manufacturers jumping into the orthodontic market, and the constantly evolving nature of aligner materials, attachments, and mechanics, it is important to evaluate the current information regarding aligners and staging for complex tooth movements. Thus, this review is conducted to establish the staging of OTM and how to maximize the efficiency of OTM with aligners.

Staging of OTM

Staging of OTM refers to the breakdown of the intended movement of teeth in a sequential manner with aligners. The importance of this concept lies in understanding OTM principles and their application. Aligners serve as a tool to achieve OTM, but the basic principles of OTM remain the same as in fixed preadjusted appliances. The current review will address some of the core principles of OTM with fixed preadjusted edgewise appliances (PEA) and aligners, and clinical modifications to achieve efficient OTM with aligners.

General Concepts

The staging of OTM refers to the sequential movement of the teeth with the aligner trays. The tooth that is moved the most is known as the leading tooth. It is the staging of the leading tooth that determines the total number of aligner trays. The degree of movement of a tooth with each tray determines its velocity in terms of staging. While staging the OTM, some teeth may require only linear movements, other teeth may require only rotational movement, while some may require both linear and rotational tooth movements. Thus, the linear and rotational velocities of the teeth may be staged separately. All the teeth included in the staging with aligner therapy are moved simultaneously. This concept is similar to that with PEA, where all the teeth that are bracketed move with the insertion of the wire. Although, the degree of movement of the teeth may be different, It has been reported in the literature that slowing down the tooth movements may lead to better tracking and predictability of treatment with aligners.[8-10] The leading tooth is the tooth that requires the most stages or aligner trays to achieve the predicted tooth movement. Thus, the staging of OTM with aligners can be carried out such that the velocity of tooth movement for the teeth other than the leading tooth can be slowed down to achieve better expression of tooth movement.

Distalization with Aligner Therapy

Distalization with aligners can be achieved with the sequential movement of the posterior teeth. For example, if the second molars are present, then the second molars are distalized first, followed by the first molars, followed by the premolars, and so on.[11] Newton's third law states that there is an equal and opposite reaction to an applied force, and this applies to both fixed preadjusted appliances and aligners.[12] It is important to understand that just as in a conventional distalization appliance such as pendulum, distal jet, etc., the proclination of anteriors may occur due to the forward direction of force on the anterior teeth (opposite to the distalizing force on the posteriors).[13]

The concept of reinforced anchorage states that when multiple teeth are pitted against a single tooth, the magnitude of the side effects is diluted because the force gets distributed over multiple teeth.[14] The model of sequential distalization takes advantage of this principle. Thus, when the second molars are distalized, the first molars and all the teeth anterior to it on both sides act as the anchor unit.[15] This leads to fewer side effects on the anterior teeth. In addition, the wearing of elastics, and change in position of the elastics as the orthodontic treatment progresses, help in reinforcing anchorage. It has been shown that the maxillary first molar can be distalized effectively with aligners in combination with intermaxillary elastics by 2.25 mm, without significant effects on the vertical dimension.[11] When sequential orthodontic distalization is done for second molars and first molars, the Class II elastics can be worn from the mandibular first molars to the maxillary second premolars to serve as an additional anchorage to prevent flaring of the maxillary anterior teeth.[11,16] The position of the elastics can be changed to a normal Class II elastic from the mandibular molar to the maxillary canine when the second premolars and first premolars are distalized. Thus, rather than just applying distal force on all the maxillary teeth at the same time, proper planning and staging of force application and direction can help in preserving anchorage and treating Class II malocclusions, with esthetic results.

Space Closure with Aligner Therapy

Space closure mechanics with aligners need detailed planning because of the complexity of OTM involved in space closure. Aligners apply intermittent forces, as they are removable orthodontic appliances. Thus, tipping is easily accomplished with aligners, but bodily movement is difficult.[17] Orthodontic space closure often requires translation movement of the teeth in order to achieve parallel root positioning of teeth adjacent to the extraction space. Furthermore, it is important to maintain the torque of the maxillary anterior teeth in extraction cases.[18] However, the torquing control with aligners is poor. It has been reported that imprecision in the torquing aspects of maxillary incisors ranges from 0.5° to 8.5°.[19] This is a wide range, and an imprecision of 8.5° may lead to considerable lingual tipping of the maxillary anteriors. Inadequate torque control in extraction cases can lead to consequences such as poor esthetics, running out of overjet before complete space closure, increased maxillary incisor gingival display due to lingual tipping, and extrusion.[19,20]

The use of the torquing auxiliaries follows the same principle as that of progressing to a heavy archwire such as a 19 × 25 SS wire in fixed preadjusted appliances, to fill the slot before space closure and incisor retraction. In a PEA, the torquing of the archwire due to the couple generated from the interaction of the bracket and wire slot helps in maintaining incisor torque during the retraction. The same concept should be applied to the aligner system as well. However, it has been reported that the moment/force (M/F) ratios achieved with aligners are not the same as with fixed orthodontic appliances.[21] Previously, it has been reported that the accuracy for the torquing movements

with aligners was less than 51.5%.[22] However, in more recent studies, there are conflicting findings on the accuracy of the torquing movement with aligners. While some authors have reported torquing accuracy to be as high as 72.9%, others have reported lower accuracy for torquing movements, at around 56%.[19,23] Thus, to produce adequate torquing of incisors with aligners, the authors recommend prescribing overcorrection during the staging of orthodontic treatment. For the incisors, power ridges can be added to enhance the torque.[19] However, it should be noted that due to the couple generation, power ridges and torquing lead to some intrusive effects on the maxillary incisors. Additionally, the attachments when bonded to maxillary anteriors can lead to unesthetic appearance and can be an issue with adult patients.[24] The torquing of the incisors can be staged to take effect at the same time as the incisor retraction takes place. In clinical experience, the authors usually start the torquing 2-3 trays before the incisor retraction. This additional torquing of maxillary incisors can help to prevent the uncontrolled lingual tipping during retraction and avoid issues such as running out of overjet prior to the completion of space closure. Additionally, the authors, in their clinical practice, also modify the prescription with an additional distal crown tip on the posterior teeth—the second premolars and first molars and second molars—if present (in first bicuspid extraction case), before the space closure. The purpose of this feature is to reduce the mesial tipping of the molars during the space closure. These prescriptions of additional torquing of maxillary incisors and the distal crown tip of the maxillary posterior teeth during the staging of space closure can help in decreasing the roller coaster effect, namely posterior open bite, incisor extrusion, and anterior deep bite during the retraction.

Cases with moderate to severe crowding, such as blocked-out canine or discrepancies exceeding 8 mm may be considered a better option to resolve with extraction therapy with aligners, as a significant amount of extraction space will be used in resolving the crowding. A recent study reported that mild to moderate crowding of less than 6 mm was successfully resolved with non-extraction therapy with aligners, without excessive proclination of the incisors. However, non-extraction orthodontic treatment for patients with crowding of more than 6 mm led to excessive proclination of the incisors.[25] Thus, with sound clinical judgment and appropriate diagnosis, extractions may be indicated in the treatment of patients with severe crowding, using aligners. Typical extraction patterns in orthodontic treatment include maxillary and mandibular first or second premolars.[14,26] As the average size of maxillary first and second premolars is 7-8 mm, the extraction leads to space of approximately 15 mm in the upper arch. In a case with 10 mm crowding, if extractions are performed, the amount of space remaining after the crowding is resolved is less than 5 mm. The control of torquing of anterior teeth may be expected to be better in such small spaces than in a case with mild crowding requiring 15 mm of space closure with retraction of anterior teeth. However, in such cases, there are still challenges regarding alignment, rotational correction, and mesiodistal tipping movements with aligners, which can be managed to a satisfactory degree by building overcorrection into the aligners during the staging process.[4,23]

The staging of OTM for extraction cases should be performed after taking into consideration the overbite, overjet, and dental and skeletal malocclusion. Patients with Class II Division 1 malocclusion tend to have proclination of the maxillary anteriors, increased overjet, and deep overbite.[14] In such cases, the overbite correction should be performed simultaneously while staging the orthodontic space closure.[27] If there is an increased Curve of Spee in the lower arch, the Curve of Spee should be flattened by extrusion of posteriors, intrusion of anteriors, or a combination of the 2 (most common approach).[28] Bite turbos can be used with aligners to enhance the bite-opening effect with a combination of intrusion of mandibular anteriors and extrusion of posteriors. At the same time, the maxillary space closure should be staged to retract the canines and the incisors.[28] There is a tendency for the canines to have a distal crown tip while performing retraction of canines, which leads to a mesial root tip. This tendency can be counteracted by adding the anti-tip attachments while staging the retraction. The anti-tip attachments can help to generate moment to cause distal root tipping of the maxillary canines while the force is delivered to the canines to move them distally.[27] However, the complete expression of the mesio-distal tip programmed into the aligner system is not always achieved. The imprecision of the canine mesiodistal tip has been reported to range from 0.6° to 5°.[19] Thus, it may be helpful to build-in an additional distal root tip or mesial crown tip in the canine while staging the retraction of the maxillary canine. The authors recommend adding 5° to 10° of mesial crown tip in the canine to be expressed throughout the staging of the canine retraction. In extraction cases, a critical aspect in the staging of OTM is the use of elastics. It has been suggested that elastics worn from the initial stage of OTM can help to reduce the treatment time and achieve better correction of overjet and anteroposterior discrepancies such as Class II subdivision malocclusions.[29]

Intrusion and Extrusion with Aligner Therapy

An analogy of intrusion and extrusion mechanics with fixed preadjusted appliances can help to understand the biomechanics with aligners. It has been reported that segmental arch mechanics with PEA can lead to true intrusion of incisors, ranging from 1.5 mm to 1.9 mm.[30] However, with a continuous archwire, true intrusion is rarely achieved because of the difficulty in guiding the intrusion force through the center of resistance of the incisors. The Burstone intrusion arch may help to direct the force distal to the lateral incisor so that it is closer to the center of resistance of the maxillary incisors.[31] However, the general consensus is that an intrusion greater than 1-2 mm is difficult to achieve without the use of a temporary anchorage device (TAD).[14,30-32]

With aligner therapy, it has been reported that anterior intrusion is inefficient.[3,23] Recent studies have reported maxillary incisor intrusion to be around 33%.[23] The main mechanics for the overbite correction in patients with deep overbite has been found to be the proclination of mandibular teeth.[33] The combination of intrusion of maxillary incisors and extrusion of mandibular molars also plays a role in resolving the deep overbite with aligner therapy.[33] Thus, the authors recommend building all 3 aspects into the staging, such as proclination of teeth, maxillary and mandibular incisor intrusion, and extrusion of posterior

teeth, to achieve effective bite-opening in patients with deep overbite. However, some posterior intrusion usually occurs with aligner therapy, and thus posterior open bite is a typical side effect observed with aligner therapy.[34] This may occur due to the intrusion of posterior teeth due to the thick layer of thermoplastic appliance between the maxillary and mandibular posterior teeth, resulting in a "bite-block" effect. However, in most cases, it is not a major concern and can be corrected easily with elastics. In cases with mild anterior open bite, the posterior intrusion can be helpful in closing the bite and achieving proper overbite.[35] Thus, aligners have a contrasting effect on bite closure, compared to fixed appliances which tend to open the bite slightly with continuous archwire mechanics.[9,35]

On the other hand, recent studies have suggested that extrusion of incisors is a more predictable movement than intrusion.[23,34,36] Traditionally, aligners were considered to be poor at performing extrusive movements, but with evolving mechanics and a better understanding of aligner mechanics, extrusion can now be achieved more predictably.[10,23,36] Some studies have suggested that when the intrusion of posterior teeth was planned with aligners, anterior teeth extrusion occurred as a side effect.[33] Thus, in order to close an anterior open bite, if a significant posterior intrusion is desired with aligners, then a treatment plan with TAD must be taken into consideration.[37,38] For Non-TAD-based mechanics, the tendency for incisor extrusion should be recognized and should be included in the staging. Aligners may be helpful in closing a dental open bite where the patient does not present with adequate incisor display, by incisor extrusion.

Rotational Correction with Aligner Therapy

Rotational movements are not easily achieved with fixed braces or aligners. In a preadjusted appliance, the engagement of the wire into the bracket helps to generate the couple necessary to generate rotational movement.[39] With aligners, such a couple is difficult to achieve. The rotational accuracy of the tooth movement is reported to be low with aligners.[23] The highest accuracy for rotation with aligners has been reported for maxillary central and lateral incisors, which is still less than 51%.[10,23] Thus, this tendency of underperformance of aligners for rotational correction of teeth should be taken into consideration while staging OTM. Specific resin attachments to generate the opposite forces with aligners for rotational correction may help in achieving better rotational control for canines and premolars.[4] The correction of the rotations of mandibular molars is found to be more accurate with aligners than premolars. One reason for this can be that the mandibular molars are not as rounded as premolars and have more surface area, therefore the aligners can fit the tooth better to deliver the required forces. Furthermore, the higher the degree of rotation of the tooth, the harder it is to achieve the complete rotational correction.[22,23] To overcome this tendency, it has been suggested to do overcorrection of the rotated teeth by 10% (11/10 rule) or by a 5° overcorrection beyond ideal position, to achieve better results with rotational movements using aligners.[40] Thermopliers can be a useful adjunct in aligner cases with significant rotations.[40] Recent studies have found that the accuracy of rotational correction with aligners is higher for maxillary premolars than maxillary canines.[41] In addition, the directionality of rotation, especially for canines, has also been reported to have an effect on the accuracy of the rotational correction. For example, for maxillary canines, mesial rotation can be performed relatively better and with higher accuracy of 52%, compared to the distal rotation, which has a lower accuracy of 37%.[23] Thus, a higher degree of overcorrection can be prescribed for rotational movements of maxillary canines than premolars, and specifically for distal rotation. Overall, it is a general consensus that the accuracy of the rotational correction is poor, and thus overcorrection even greater than 10% may be required to achieve complete derotation.[15] The authors recommend the overcorrection to be about 20%, and that slowing down the rotational movements to about 1° per aligner tray while staging can achieve better rotational correction, as it has been shown in previous studies stating that increasing the amount of rotational movement to more than 1.5° per aligner tray leads to decreased accuracy.[22] Additionally, when staging the OTM for correction of rotations, overcorrections should be built-in toward the end of the treatment so that other predictable movements have been achieved. When the overcorrection trays are used for rotational correction, the aligner trays often stop tracking, and thus building the overcorrection during the end of treatment ensures successful completion of OTM for other teeth.

OTM depends on multiple factors. Various parameters such as the crown anatomy, root length, dilacerations, the density of alveolar bone, age, and sex of the patient can influence the OTM. In this review, comprehensive information regarding how aligners can be used for complex OTMs is presented. However, clinicians have to consider patient-related factors and use sound clinical judgment and skills while performing the staging and formulating the treatment plans.

CONCLUSION

The staging of OTM with aligners can help achieve better orthodontic treatment outcomes. The limitations of aligner therapy must be taken into consideration while staging the orthodontic treatment, in order to limit the side effects. Tipping of teeth may be more easily achieved with the use of aligners than by torquing. Thus, the torque control should be initiated from initial aligner trays while staging orthodontic treatment. Overcorrection for rotations may help to achieve better correction. The principles of OTM do not change with the type of appliance used. If such principles are comprehended, and the modifications in the execution of the appliance are made, better treatment outcomes can be achieved.

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