

Roberta Lione, Chiara Pavoni, Paola Cozza

Management of crowding in mixed dentition with Invisalign First: 10 steps to successful digital planning



Roberta Lione

KEY WORDS *clear aligners, digital planning, early treatment, growing patients, maxillary arch expansion, mixed dentition*

Mixed dentition orthodontic treatment aims to correct dental arch irregularities and abnormalities in occlusal relations, and to eliminate functional interferences. Proper management of space in the mixed dentition can prevent unnecessary loss of arch length, allowing for beneficial use of the leeway space. Invisalign First clear aligners (Align Technology, San Jose, CA, USA) are specifically designed to simplify the management of malocclusion in younger patients, who often present shorter clinical crowns, erupting dentition and dental arch expansion. The present study seeks to provide indications for successful digital planning and to describe a standardised treatment protocol for maxillary development with Invisalign First.

Invisalign First aligners make it possible to treat a broad range of phase 1 orthodontic problems such as anterior crowding and spacing (mild to moderate), loss of arch length due to premature loss of primary teeth and mesial drift, constricted arches (up to edge-to-edge buccal horizontal overlap), anter-

ior reverse articulation (usually one or two teeth), midline diastemas, mild to moderate deep bite, and flared/protruded incisors. It is also possible to treat patients with a mild Class II or Class III molar relationship by rotating and distalising the molars by ~1 mm.

The clinical protocol described for phase 1 treatment with Invisalign First aligners has been designed to manage the developing occlusion, guiding the teeth into a proper maxillary arch form. The 10 steps outlined in the present study are intended to be easy to follow during digital planning to help practitioners to deliver such predictable therapies by developing the maxillary arch using clear aligners.

Introduction

Mixed dentition orthodontic treatment aims to correct dental arch irregularities and occlusal relation abnormalities, and to eliminate functional interferences¹. Two studies reported dental crowding in 38% of patients in mixed dentition; this is one of the main reasons for dissatisfaction with dental appearance and increases the desire for orthodontic correction in children or their parents^{2,3}. If crowding is evident in the early mixed dentition, it will not improve with further growth and development^{4,5}.

Proper management of space in mixed dentition can prevent unnecessary loss of arch length, allowing for beneficial use of the leeway space⁶. Treating space problems requires

Roberta Lione, DDS, MS, PhD
Research Assistant, Department of Systems Medicine, University of Rome Tor Vergata, Rome, Italy

Chiara Pavoni, DDS, MS, PhD
Research Assistant, Department of Systems Medicine, University of Rome Tor Vergata, Rome, Italy

Paola Cozza, MD, DDS, MS
Professor and Department Chair, Department of Systems Medicine, University of Rome Tor Vergata, Rome, Italy

Correspondence to: Dr Chiara Pavoni, Department of Systems Medicine, University of Rome Tor Vergata, Viale Oxford 81, 00133 Rome, Italy. Email: dott.chiarapavoni@gmail.com



an understanding of the aetiology of crowding and development of the dentition to plan treatment for mild, moderate and severe cases of crowding. Nance⁷ described dental crowding as a dentoalveolar discrepancy between available space (offered by bone to distribute all the teeth) and the space needed (equivalent to the mesiodistal width of all the teeth). It is most frequently associated with Class I malocclusion, although it may be found with Class II malocclusions with maxillary protrusion and a normal skeletal pattern. The factors that influence dental crowding include the position of the permanent tooth germs, the timing of the loss of primary teeth and permanent tooth eruption, the order of replacement of the dentition from primary to permanent, soft tissue pressure, and the position of the opposite teeth⁸. Clinical expression of crowding involves an abnormal alignment of teeth and anomalous dental inclination, position or rotation due to a disparity in the relationship between tooth size and jaw size^{9,10}. Patients with dental crowding always present with narrow, tapered and irregular dental arches⁹. Indeed, a primary factor that often contributes to dental crowding is transverse or sagittal maxillary deficiency¹¹. The position of the mandibular dentition may be influenced more by the maxillary skeletal morphology than by the size and shape of the mandible as the mandibular posterior teeth have often erupted into occlusion in a more lingual orientation due to the associated constricted maxilla¹¹. Expanding a compressed arch as a method of resolving crowding can increase arch length, providing more space for tooth alignment and improving the transverse dimension of the smile to correct dentoalveolar posterior reverse articulation¹²⁻¹⁴. Recovering a proper buccolingual inclination of both posterior and anterior teeth is also essential to ensure stability and a proper occlusal relationship, and has a significant impact on smile aesthetics and the soft tissue profile^{15,16}. Treating younger children with Invisalign First aligners (Align Technology, San Jose, CA, USA) can be efficient and easy, especially when seeking to obtain simultaneous dental changes. These aligners are specifically designed to simplify the management of malocclusion in younger patients, who often present with shorter clinical crowns, erupting dentition and dental arch expansion. To improve aligner retention on teeth with short clinical crowns, new Optimized Retention attachments (Align Technology) are also available. These attachments are automatically sized and positioned based on the available buccal crown surface of the patient's teeth.

They are highly aesthetic and well tolerated, and the fact that they can be removed for eating and brushing is appreciated by patients and their parents¹⁷. Correction of mild to moderate crowding can be managed both predictably and efficiently by following the same steps as would be taken in a rational approach to correct crowding in mixed dentition with aligners. Thus, the present paper seeks to provide clinical indications for successful digital planning and to describe a standardised treatment protocol for maxillary development with Invisalign First.

Digital planning

Step 1: Maxillary arch expansion

The first aim in mixed dentition is to expand the maxillary arch form to resolve crowding and correct sagittal and vertical malocclusion¹¹. Achieving transversal coordination between the maxillary and mandibular arch forms is necessary to obtain a good relationship between the skeletal and dental components¹⁸. Aligners can also achieve satisfactory arch expansion in growing patients and change the initial arch form using attachments alone. Adequate digital planning is crucial to permitting the clinician to examine specific movements for all teeth and to program the movements sequentially in order to increase treatment predictability. The sequential staging pattern for maxillary arch expansion, 'molars move first', followed by simultaneous expansion of all the posterior primary teeth and canines, is recommended to gain space for the transition from primary to permanent dentition.

The present authors found that increases in the transverse dimensions occur relatively uniformly in all subjects; however, they observed that the magnitude of changes at the level of the first molars was less than that arising in the maxillary canine and primary molar dimensions. The new transverse dimension should be set to an ideal cusp-fossa relationship and not to an overcorrected position, to avoid introducing heavy inclined plane contacts to the posterior occlusion.

Step 2: Distorotation of maxillary first molars

Crowding is also associated with maxillary first molar mesiorotation in subjects with mixed dentition¹⁹. This rotation is due to the mesiolingual cusp of the maxillary first

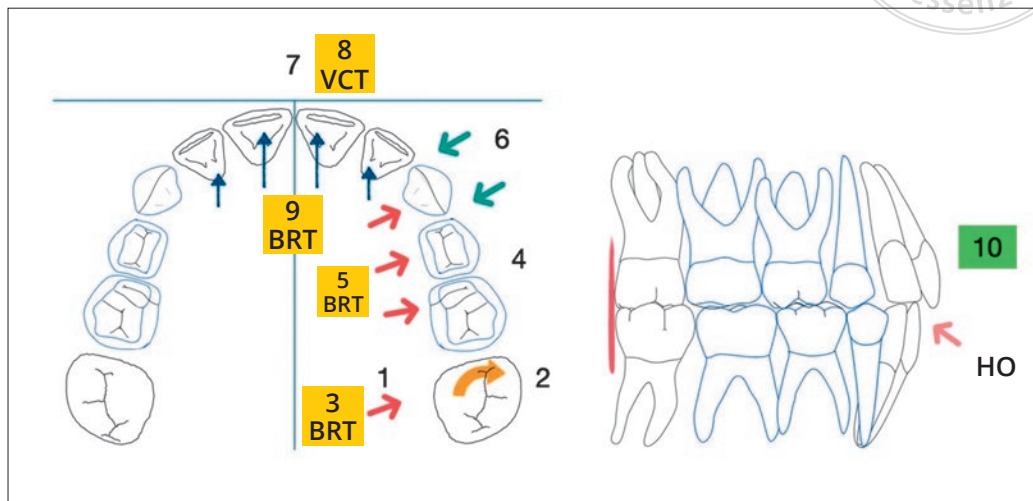
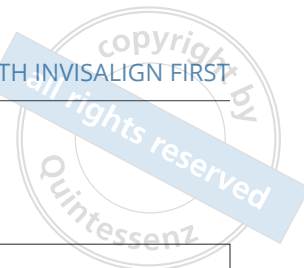


Fig 1 10 steps to successful digital planning with Invisalign First. BRT, buccal root torque; HO, horizontal overlap; VCT, vestibular crown torque.

molar firmly occluding in the central fossa of the mandibular first molar, acting as a centre of rotation and causing a mesial movement of the mesiobuccal cusp. Furthermore, the maxillary first molar has a rhomboidal shape, being wider buccolingually than it is mesiodistally; thus, more space is required between adjacent teeth when the maxillary first molar is rotated²⁰.

Orthodontic correction of mesial maxillary molar rotation, which requires that the buccal surfaces of the maxillary molars be nearly parallel to each other on the ClinCheck (Align Technology), may provide a gain of between 1 and 2 mm in arch perimeter per side that can be used to relieve crowding²¹. The present authors' experience suggests that to promote the change in arch shape from ovoid to parabolic, maxillary molar distorotation should be planned simultaneously to intermolar width expansion, with the former representing a fundamental step towards enabling maxillary arch expansion in lateral segments because of the derotated molars working as anchorage elements during buccal displacement of all other teeth (Fig 1).

Step 3: Application of compensatory buccal root torque on maxillary molars

Two degrees of compensatory buccal root torque are required for each aligner. Arch expansion devices tend to tip the crowns buccally, so countermoments for buccal root torque are required to produce bodily movement without tipping. With the new Expansion Support attachments

(Align Technology), the surface area needed to create a proper countermoment is calculated for each individual tooth and automatically built into the attachment design.

Step 4: Expansion of lateral segments

Molar and anterior movements should be staged first, followed by buccal expansion of the primary molars and canines. The maxillary molars become a new point of reference to which the lateral segments can be expanded in the maxillary arch. The primary canine plays a key role that can help facilitate arch expansion and the development of a parabolic arch form. The crowns provide an extra point of aligner contact and the roots offer additional anchorage. Preserving the primary canine makes the aligner structurally stronger and less vulnerable to breakage. Dentoalveolar expansion in mixed dentition is particularly favourable because the unerupted succedaneous teeth tend to move along with the overlying primary teeth.

Step 5: Application of compensatory buccal root torque on primary molars

As planned for the maxillary permanent molars, transversal movements of the primary molars should be accomplished by minimising molar tipping and inclination during dental expansion. Compensatory buccal root torque is automatically added whenever the arches are widened. Expansion Support attachments are also automatically placed whenever dental arch expansion is programmed. Like Optimised



Retention attachments, these are automatically sized based on the height and shape of the clinical crown. The optimised Expansion Support attachments work in tandem with SmartStage technology (Align Technology) to achieve predictable dental arch expansion.

Step 6: Interproximal spaces around maxillary primary canines

The extra arch length that results from dentoalveolar arch expansion and the remaining space obtained after resolving crowding and maxillary incisor protrusion should be managed by creating interproximal space around the maxillary primary canines²². Generating space mesial and distal to the maxillary primary canines is necessary to avoid impaction of the permanent canines and balance the anticipated space deficit between the primary and secondary dentition²³.

Step 7: Retracing flared maxillary anterior teeth

Excessive horizontal overlap in patients with flared and spaced maxillary incisors often reflects a skeletal problem, but can also develop in patients with good jaw proportions. Crowded teeth sometimes align themselves completely or partially at the expense of the lips, moving the lips forward and separating them at rest. Increased horizontal overlap and inadequate lip coverage heighten the risk and severity of incisor trauma. Early orthodontic treatment prevents dental trauma in such cases²⁴. If adequate vertical clearance is present, the teeth can be tipped lingually and brought together. Maxillary expansion and uprighting of the posterior teeth will create additional anterior arch length.

Step 8: Application of compensatory buccal crown torque on maxillary incisors

An important biomechanical aspect in the use of clear aligners is related to the side effect of posterior expansion on the frontal teeth. Since the aligner works as a single active unit, transversal expansion induces reciprocal effects, retracting frontal teeth that do not have direct forces applied. Successful and efficient biomechanics can be achieved by knowing how to deal with unwanted reactive forces. Thus, counteracting moments should be managed by digitally planning compensatory buccal crown torque on the maxillary incisors.

Step 9: Application of compensatory buccal root torque on maxillary incisors

Anterior dental crowding is an easily recognisable clinical condition that may be the result of maxillary deficiency. Due to the more palatal intraosseous position of the developing lateral incisors and the eruption sequence, primary crowding may cause palatal displacement of the lateral incisors²³. In these conditions, it is necessary to encourage the expression of labial root torque during the alignment of displaced lateral incisors in the buccal segment. Thus, compensatory buccal root torque should be applied to allow the root to follow the crown movement when the tooth is pushed forward by the aligner.

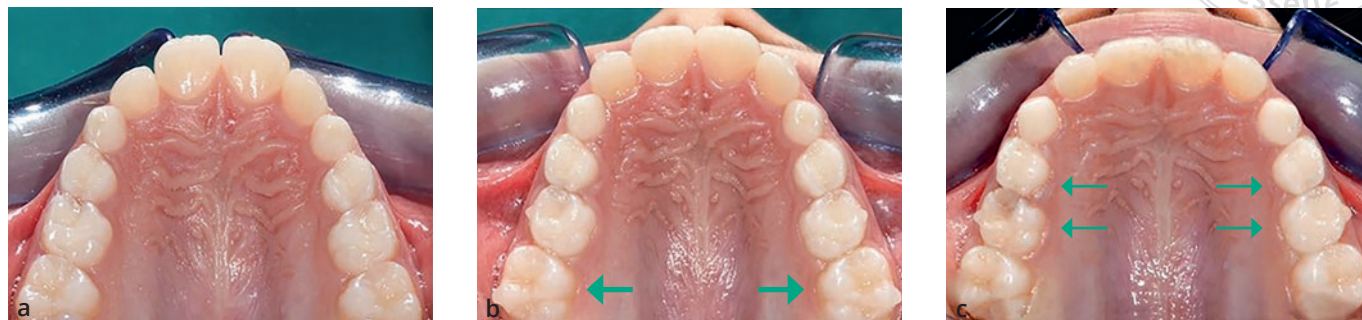
Step 10: Management of horizontal overlap

Generally, the main focus of phase 1 treatment for growing Class I and Class II subjects is the management of the transverse and vertical dimensions. Correction of transverse discrepancies is the first step towards future spontaneous improvement of the skeletal relationship on the sagittal plane¹¹ (Fig 2). Therefore, the maintenance of a proper horizontal overlap of a minimum of 2 mm in the digital plan is an important skeletal and dental condition to achieve a Class I molar relationship by forward mandibular repositioning during growth.

Discussion

The clinical protocol outlined for phase 1 treatment with Invisalign First is designed to manage the developing occlusion, guiding the teeth into a proper maxillary arch form. The 10 steps presented in the present study are intended to be easy to follow during digital planning to help practitioners to deliver such predictable therapies by developing the maxillary arch using clear aligners.

Invisalign First aligners make it possible to treat a broad range of phase 1 orthodontic problems such as anterior crowding and spacing (mild to moderate), loss of arch length due to premature loss of primary teeth and mesial drift, constricted arches (up to edge-to-edge buccal horizontal overlap), anterior reverse articulation (usually one or two teeth), midline diastemas, mild to moderate deep bite, and flared/protruded incisors. It is also possible to treat patients with a mild Class II or Class III molar relation-



Figs 2a-c Occlusal view showing changes in maxillary arch shape from ovoid to parabolic during Invisalign First treatment.

ship by rotating and distalising the molars by ~1 mm. For more significant arch expansion (i.e., skeletal expansion) and for patients with airway problems, phase 1 treatment should begin with use of a fixed rapid maxillary expander, followed by additional appliances as needed. Orthodontic tooth movement requires a bone remodelling sequence to occur, consisting of bone resorption in the direction of the tooth movement and bone formation on the opposite side. Dentoalveolar expansion can also have beneficial effects on the eruption of the secondary dentition, making it possible to create the extra arch length required to accommodate the transition from mixed to permanent dentition. Expanding the maxillary and mandibular arches creates space in the maxillary labial segment²³. Indeed, a common early sign of crowding is a lack of space for the development of the permanent lateral incisors. Delaying orthodontic treatment until all the permanent teeth have erupted may cause these permanent teeth to become rotated or displaced palatally or even impacted due to the lack of space. As described by Geran et al²⁵, untreated growing subjects observed from the early mixed dentition stage present a physiological decrease in arch perimeter that can worsen the initial crowding.

Maxillary arch expansion (when there is no reverse articulation) often requires concomitant expansion of the mandibular arch. For arch development with Invisalign First aligners, the present authors set up 4 to 6 mm of dental expansion per arch, without adding any extra width for overcorrection aligners, because the biological response seems to be better in mixed dentition patients than in teenagers and adults. This could be partially due to the severity of the expansion performed or to differences related to patients' age when growing patients are treated. The better

effect during maxillary expansion may be due to the fact that clear aligners move teeth by exerting a push force closer to the centre of resistance of primary teeth. In particular, the crowns of primary teeth are wider mesiodistally in comparison with their cervicoincisal length than are the crowns of permanent teeth. This different proportion between crown and root length moves the centre of resistance towards the occlusal plane, thus reducing the distance over which the force is applied and facilitating the translational movement²⁶. However, there are only a limited number of studies examining the efficiency of tooth movement in the transverse dimension^{27,28}. The most used method to quantify the predictability of expansion is taking measurements on casts without assessing root movement. Zhou and Guo¹⁴ reported that in adult patients, the crown-root ratio was approximately 2:5. An appropriate amount of negative torque applied to the crown of primary molars should also therefore be preset in the ClinCheck to improve the efficiency of bodily expansion (Fig 3). The great advantage of this interceptive approach is that the aligner shields extending to the vestibule prevent abnormal pressure from the cheeks and lips during function. The buccal shields exert periosteal pull, which assists bone formation and lateral expansion of the maxillary apical base²⁹.

Successful uprighting of flared incisors with Invisalign is particularly impressive. Individuals with good skeletal proportions commonly present excessive maxillary incisor protrusion as compensation for potential crowding. Crowding and protrusion are two sides of the same phenomenon: insufficient space to properly align the teeth may result in crowding, protrusion or, most likely, a combination of the two²⁴. For patients with dental protrusion, the posterior teeth serve as an anchor unit against which the incisors can



Figs 3a-d Patient profile: intraoral records (a) before, (b) after 4 months and (c) after 8 months of treatment, and (d) extraoral records taken at the same observation periods. Expanding the maxillary arch improved the patient's aesthetic appearance.

be retracted while the arch is being expanded to create adequate space. Elimination of tooth displacement gives the patient and their parents a better treatment experience than phase 1 treatment with traditional appliances (Fig 3). Patients and their parents want to see smile improvements early in treatment, and initiating anterior improvements at this stage helps sustain the patient's initial enthusiasm (Fig 4). Moreover, expanding the maxillary arch improves the patient's aesthetic appearance, not only by aligning the front teeth but also by reducing the amount of negative space when smiling^{30,31}.

Conclusions

Treating children with early mixed dentition using Invisalign First aligners can be efficient and easy, particularly when the main aim is to obtain dental changes. Understanding the strengths and weakness of clear aligners will assist clinicians in managing developing occlusion.

Declaration

The authors declare there are no conflicts of interest relating to this study.



Figs 4a-d Smile improvement during phase 1 treatment.

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