Mixed-Dentition Treatment with Clear Aligners and Vibratory Technology

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The demand for esthetic, comfortable orthodontic treatment appears to be on the rise across all age groups. Not surprisingly, parents' perceptions of the types of appliances that are acceptable for their children closely mirror their standards of esthetics for themselves. According to a survey by Rosvall and colleagues, clear aligners and lingual appliances are generally preferred, followed in order by ceramic appliances, ceramic self-ligating appliances, and self-ligating stainless steel (including hybrid).[1] The same study found that esthetic appliances were acceptable to more than 90% of adults, while traditional stainless steel and metal self-ligating brackets were acceptable to only 55% and 58%, respectively.

Like all orthodontic modalities, clear aligner therapy has its advantages and disadvantages. Compared with fixed orthodontic appliances, aligner therapy has been associated with better oral hygiene,[2] fewer appointments, shorter treatment duration, fewer emergency visits, and less overall chairtime.[3] The relative efficiency of clear aligner treatment was a significant biomechanical concern in the past, when such therapy was restricted mostly to anterior teeth and a limited number of stages.[4] In more recent years, however, the scope of aligner treatment has been greatly expanded by improvements in materials and computer-assisted manufacturing methods; a better understanding of aligner biomechanics, treatment staging, and overcorrection; and the availability of such auxiliaries as buttons, hooks, elastics, and attachments or engagers. Patient considerations such as lifestyle, convenience, and compliance also affect the choice of appliances.

Similarly, there are advantages and disadvantages of early orthodontic treatment in the mixed dentition. Benefits include a greater ability to modify growth, improved patient self-esteem and parental satisfaction, better and more stable results, and less need for extensive treatment in the permanent dentition.[5] Critics question the efficiency and cost of two-phase treatment,


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however, and point to a lack of significant differences in outcomes.[6,7] Because current research on Phase I treatment has yet to provide clear answers, the decision whether to supervise or treat is generally based on clinical experience, timing of craniofacial growth and development, prevention and treatment goals, and individual patient factors.

In recent years, orthodontists have shown an increased awareness of the effects of Phase I expansion on airway measurements such as the minimum cross-sectional area and total airway volume. While several articles indicate an improvement in airway volume beyond that expected with normal growth after the use of a rapid palatal expander (RPE),[8,9] there is limited evidence concerning the effects of other expansion methods. The potential airway benefits that could be achieved with clear aligner therapy in the mixed dentition have yet to be elucidated.

Orthodontists have also demonstrated considerable interest in approaches designed to accelerate tooth movement and potentially reduce pain, including the use of vibratory stimuli.[10-12] Although the effects of vibratory technology on specific movements such as canine retraction,[13] leveling and alignment,[14] and molar distalization[15] have been studied, its application in mixed-dentition treatment has not.

This article reports the results of three cases involving Phase I treatment with clear aligners and vibratory technology.

Case 1

A 7-year-old female presented with the chief complaints of spaces between her upper front teeth and excessive overjet (Fig. 1). Her mother had concerns about lower anterior crowding and questions about discomfort during treatment and the potential toxicity of orthodontic materials. This was their third orthodontic consultation, and they specifically sought clear aligner treatment.

Clinical examination revealed an early eruption pattern, generalized plaque accumulation with gingivitis, proclined maxillary incisors, a 6mm overjet, an impinging deep overbite, a 2mm mandibular arch-length deficiency, and gingival hyperplasia. The patient had a lip-biting habit and a history of nail biting.

Cone-beam computed tomography (CBCT) showed a Class I skeletal pattern with proclined upper incisors. Cephalometric data were unremarkable. The minimal cross-sectional area of the airway measured 77mm^2, within normal limits for the patient's age.[16]

Treatment goals included arch expansion, anterior space consolidation, and general leveling and alignment. Our plan called for Phase I nonextraction treatment using the Invisalign* system and an AcceleDent** intraoral vibratory appliance.

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Fig. 1 Case 1. 7-year-old female patient with upper spacing, lower crowding, proclined upper incisors, and Class I skeletal pattern before treatment.

No interproximal reduction was prescribed. An iTero Element* intraoral scanner was used to produce a scan that was submitted digitally to Align Technology. The ClinCheck* simulation was intentionally finished with excessive proclination of the upper anterior teeth to counteract the loss of torque that commonly occurs with anterior space closure.

Dynamic precision bite ramps were incorporated into the aligners on the lingual side of the upper anterior teeth throughout treatment. Horizontal rectangular attachments were bonded to the second deciduous molars and all anterior teeth to help level the lower curve of Spee and control root angulation and torque during space closure. Pontics were placed in the areas of both lower canines, which had spontaneously exfoliated at age 7.

Twenty upper and 11 lower active aligners were delivered, and the patient was instructed to

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Fig. 2 Case 1. Patient after six months of treatment.

wear the aligners 20-22 hours per day, to use the AcceleDent device for 20 minutes every day, and to change aligners once a week. She was given Chewies*** for seating the aligners and Clinpro 5000† toothpaste to use in place of regular toothpaste during orthodontic treatment.

Upper anterior gingival tissue gathered in the areas of space closure, but the family declined laser gingivectomy. As a result, aligners 13-17 had to be trimmed to clear the interdental papilla between the upper central incisors.

Although the estimated treatment time was 12 months, aligner treatment was completed one day short of six months (Fig. 2). No refinement phase was needed. The maxillary and mandibular archforms developed from V-shaped to a broader U-shape with lateral expansion, particularly in the area of the deciduous molars. All anterior spacing was closed, the overjet was reduced from 6mm to 2mm, and the impinging overbite was improved to 3mm.

Treatment required six regular visits, plus another to bond a lower 2-2 lingual retainer. The final upper aligner was used for retention until further dental development resulted in fit issues. At that time, an in-house thermoformed retainer

was delivered for nighttime wear, with palatal coverage and cutouts in the areas of the deciduous canines and deciduous molars to permit transition to the permanent dentition. Because the patient did not like the palatal coverage of this retainer and felt it was too "floppy," a Hawley-type retainer with an anterior bite plate and maximum horseshoe cutout over the palate was provided. She wore this retainer nightly without issue.

A period of eruption supervision was planned, to be followed by Phase II treatment once permanent tooth eruption was completed. CBCT images taken one year after the initial records showed an improved inclination of the upper anterior teeth, as well as a minimum cross-sectional airway area of 103mm^2—a greater improvement than would be anticipated based on growth alone. In addition, both upper permanent canines had descended into centered positions over the deciduous canines.

Case 2

A 9-year-old male presented with the chief complaint of his "teeth hitting wrong" (Fig. 3). His mother had concerns about compliance with bulky removable appliances, and she wanted a comfortable, hygienic treatment modality that would work well with his active lifestyle.

Clinical examination showed an end-on relationship of the rotated upper right lateral incisor with the lower right lateral incisor, narrow upper lateral incisors (especially the upper right), and an occlusal cant in a downward direction on the right of the lower arch and an upward direction on the right of the upper arch. We also observed a mild Class II malocclusion on the right side, a 2mm mandibular arch-length deficiency, a 5mm overjet of the upper left central incisor, and a 4mm anterior overbite. The upper dental midline was deviated 1mm to the right and the lower midline 2mm to the right of the facial midline. The dental history included a lingual frenectomy at age 4.

CBCT evaluation revealed a Class I skeletal pattern and upright upper permanent canines, which were developing with a palatal angulation. Because the upper right canine appeared to be bypassing the root of the deciduous canine, we were concerned that it could become impacted. The minimal cross-sectional area of the airway was 187mm^2, greater than would be expected for the patient's age.

Goals for Phase I nonextraction treatment included arch expansion, correction of the single-tooth anterior end-on relationship, and general leveling and alignment. The Invisalign system was prescribed, along with the AcceleDent device. The mother asked that no attachments be placed, and no interproximal reduction was needed.

An iTero Element intraoral scan was digitally submitted. Eruption compensation "teeth" were incorporated in the aligners throughout treatment in the areas of the upper left first premolar, lower left canine, and lower left second premolar—all replacing teeth that had exfoliated prior to ClinCheck approval. Unlike pontics, these teeth can be moved as part of the treatment-planning process. Because of the patient's busy schedule, treatment did not begin until eight months after the initial consultation, at which time updated pretreatment photos and an intraoral scan were taken.

Twenty upper and 20 lower active aligners were delivered with instructions to change aligners twice per week and to use the AcceleDent device for 20 minutes per day. The patient was given Chewies for aligner seating and Clinpro 5000 toothpaste.

Four aligners were lost during treatment. The patient was advised to move ahead to the following aligner and to use the vibratory appliance as needed for comfort, in addition to the requested 20 minutes per day. He was able to avoid taking analgesics such as acetaminophen despite "jumping ahead," and the family reported good compliance with aligner wear, averaging 20 hours per day.

Since there were no attachments, some of the movements programmed into the aligners for correction of the anterior deep bite and the occlusal cant were not expressed. In addition, because of the lack of significant aligner retention, the patient developed a habit of flipping the aligners out of his mouth with his tongue, reducing the amount of time they were in contact with the teeth. Although this contributed to excessive aligner show around the upper incisors at the end of treatment, the patient

was not concerned with the esthetic appearance.

The originally estimated treatment time was six months, but the aligner therapy was completed in a little more than eight weeks, partially owing to loss of the four aligners (Fig. 4). No refinement was needed. The maxillary and mandibular arches were significantly broadened from the initial V-shaped archform to a U-shape with lateral expansion, particularly in the areas of the deciduous molars and the upper right deciduous canine. The single-tooth end-on relationship was resolved, the overbite and overjet were improved, and general alignment was achieved.

Volumetric CBCT imaging showed a slight improvement in the positions of the unerupted upper canines, as well as some root resorption of the upper right deciduous canine. The minimum cross-sectional area of the airway was 370mm^2, reflecting a greater improvement in volume than would have been anticipated based on growth alone. The family was satisfied with the results.

Treatment was conducted in three short visits,

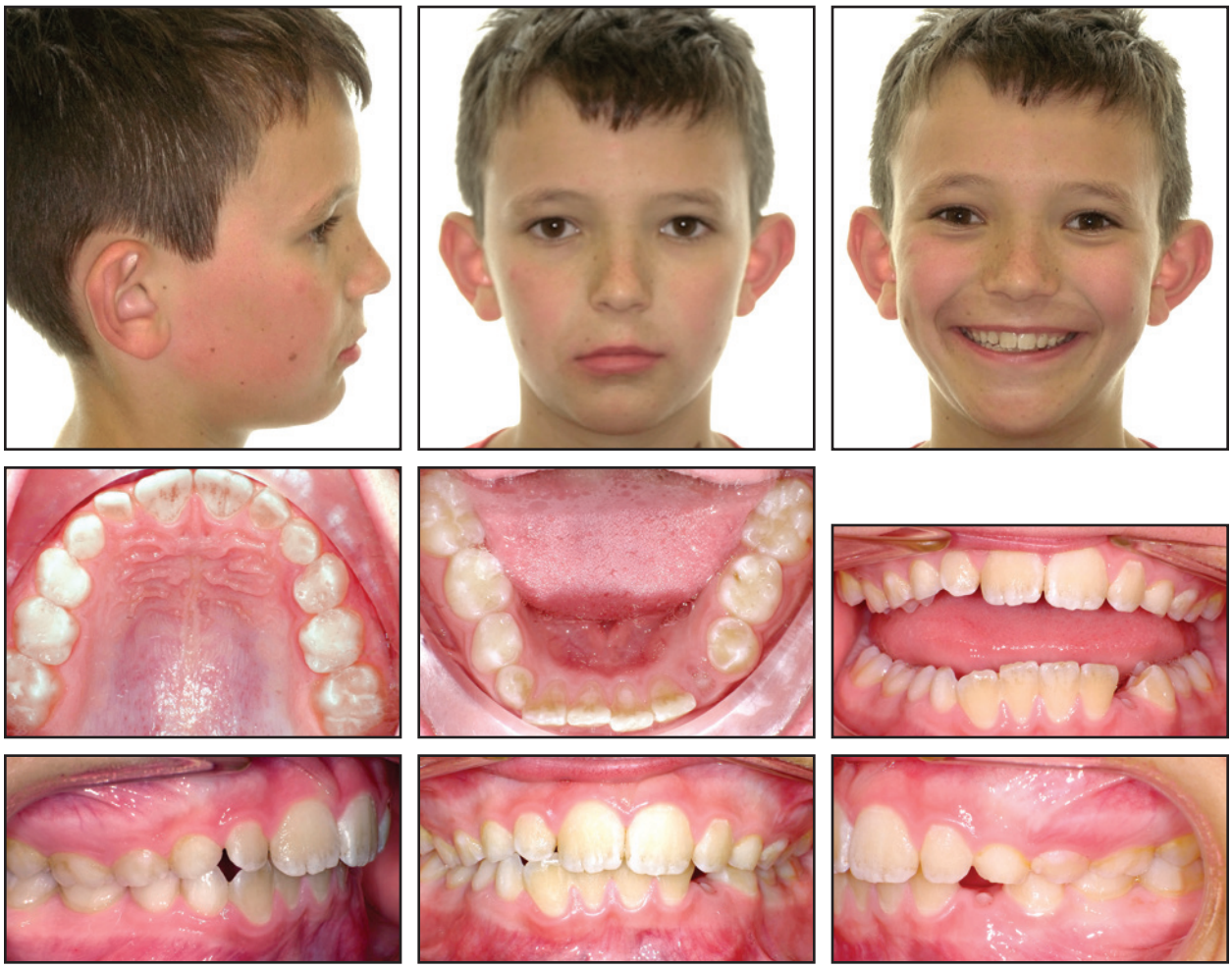

Fig. 3 Case 2. 9-year-old male patient with mild Class II malocclusion on right, end-on right lateral incisor relationship, 5mm overjet of upper left central incisor, and 4mm overbite before treatment (records taken eight months after initial consultation).

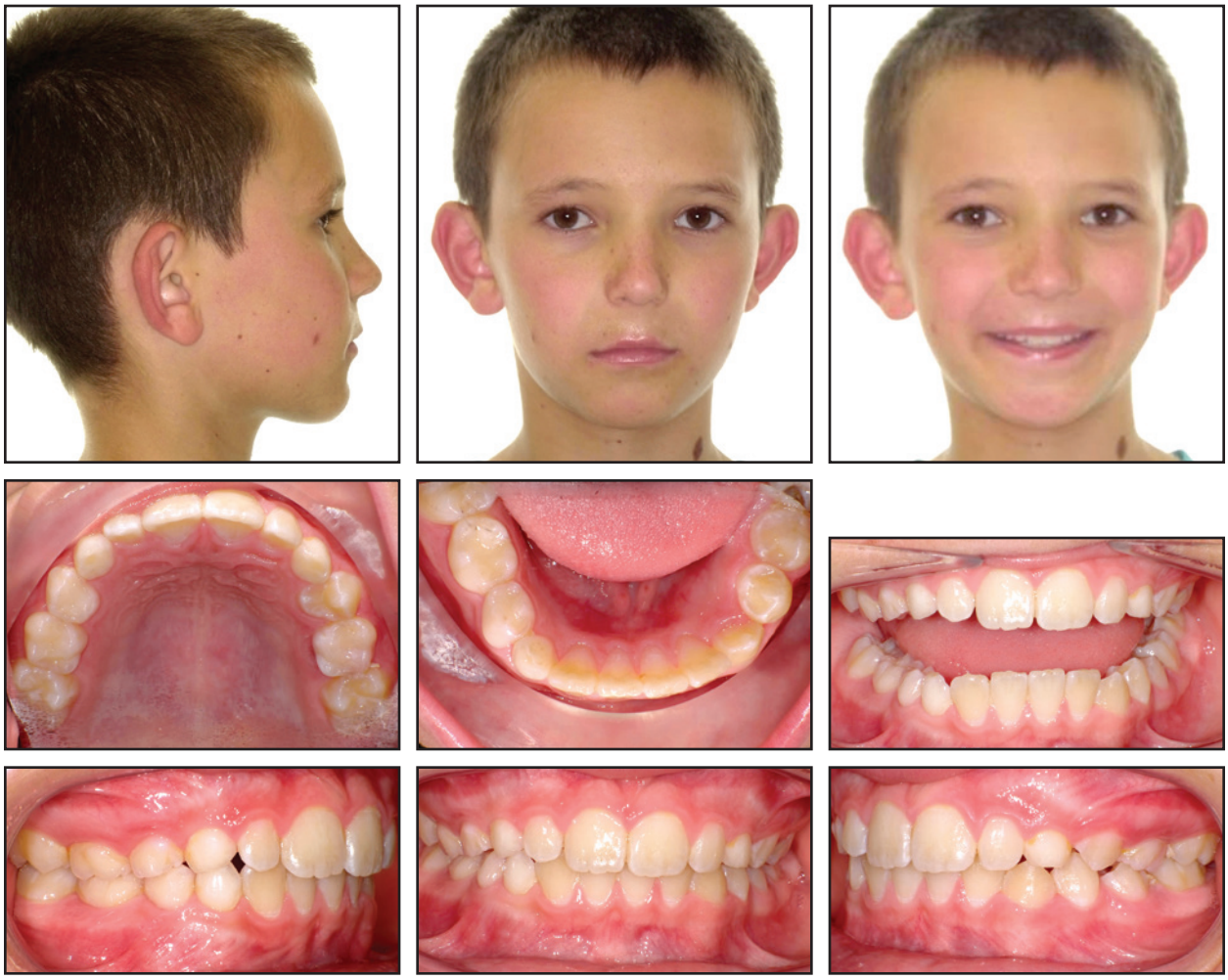

Fig. 4 Case 2. Patient after eight weeks of treatment.

including retainer delivery. The patient transitioned directly to an in-house thermoformed retainer for nighttime wear, with palatal coverage and cutouts for the deciduous canines and molars. No mandibular retention was recommended; we felt the mandibular tooth positions would be sufficiently maintained by their occlusal relationship with the retained upper arch. The family was willing to accept slight changes in alignment of the lower anterior teeth, since these would be addressed during subsequent Phase II treatment.

Case 3

An 8-year-old female presented with the chief complaint of crowding and insufficient space for erupting teeth (Fig. 5). The patient and her parents were concerned about the discomfort of conventional orthodontic expansion techniques, based on information shared by her peers.

Clinical examination found a partial anterior crossbite of the upper right lateral incisor, insufficient overjet and overbite, deficient incisal display on smiling, and an anterior tongue thrust. Severe

Fig. 5 Case 3. 8-year-old female patient with Class I skeletal pattern, severe upper and moderate lower crowding, upper right lateral incisor in crossbite, insufficient incisal display, and rotated upper left lateral incisor before treatment (continued on next page).

upper and moderate lower crowding were noted, with arch-length deficiencies of 9mm in the maxillary arch and 6mm in the mandibular arch. The upper midline was deviated 1mm to the left and the lower midline 1mm to the right of the facial midline.

CBCT imaging showed a Class I skeletal pattern and a substantially rotated upper left lateral incisor, with excessive distal root inclination and proximity to the mesially positioned crown of the unerupted upper left canine. The upper left second premolar was palatally positioned. The minimal cross-sectional area of the airway was 57mm^2, less than would be expected for the patient's age. Her parents reported quiet sleeping with no snoring or sleep apnea; the Epworth Sleepiness Scale (filled out by the parents) was low, and sleep apnea was ruled out by the local university sleep center.

Treatment goals involved arch expansion to relieve crowding, crossbite correction, general leveling and alignment, and upper incisor extrusion to enhance tooth display in smiling. Phase I

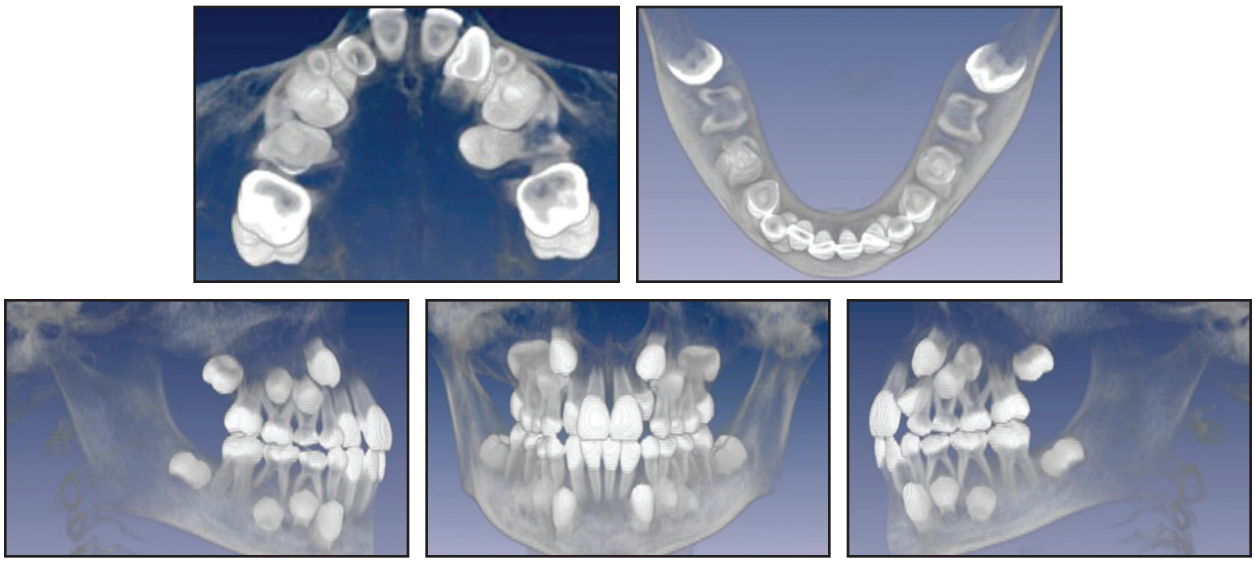

Fig. 5 (cont.) Case 3. 8-year-old female patient with Class I skeletal pattern, severe upper and moderate lower crowding, upper right lateral incisor in crossbite, insufficient incisal display, and rotated upper left lateral incisor before treatment.

nonextraction treatment was planned, using Invisalign with attachments in conjunction with AcceleDent. An iTero Element intraoral scan was submitted digitally. No interproximal reduction was prescribed.

Forty-seven upper and 47 lower aligners were delivered for the initial expansion, to be worn 20-22 hours per day and changed twice per week. The AcceleDent device was to be used for 20 minutes every day. The patient was given Chewies for aligner seating, but the family declined our recommendation of Clinpro 5000 toothpaste.

A virtual pontic was incorporated into the aligners in the area of the upper left lateral incisor during space opening and the early stages of the tooth's eruption. Aligners 4-9 required manual gingival trimming in the area of the pontic to avoid pressure on the erupting incisor. In retrospect, an eruption compensation tooth should have been requested in the ClinCheck to better mimic the tooth's rotation as seen in the CBCT.

Attachments were placed on several deciduous and permanent teeth beginning with aligner 4; an attachment for the upper left lateral incisor was added later, once sufficient tooth surface was available. Other upper attachments were prescribed to increase the incisal display of the upper anterior teeth and control root torque during alignment of the lingually displaced upper right lateral incisor. Lower attachments were placed primarily to assist with retention of the lower aligners, considering the short clinical crowns of younger patients.

The initial phase was followed by three refinement stages involving 30, 24, and 14 pairs of upper and lower aligners. During the refinement corrections for extrusions, rotations, and root tip, the aligners were changed only once per week. In the second refinement phase, additional space was programmed mesial and distal to the upper left lateral incisor to ensure a clear path for rotation and extrusion. The ClinCheck simulation was intentionally finished with some excess lingual root torque of the upper left lateral incisor to avoid contact with the crown of the unerupted upper left canine.

Although the originally estimated treatment time for Phase I was 24 months, it was actually completed in 16 months (Fig. 6). The maxillary and mandibular archforms were significantly developed with lateral expansion, particularly in the area of the deciduous molars, to resolve the

Fig. 6 Case 3. Patient after 16 months of treatment (continued on next page).

moderate upper and lower crowding. The anterior crossbite was corrected, general anterior alignment was achieved, and normal overjet and overbite were established. There was also an improvement in the incisal display on smiling. CBCT imaging showed a 95mm^2 minimum cross-sectional area of the airway, a greater improvement in volume than would be anticipated based on growth alone.

Treatment was completed in 16 months with 14 regular visits, plus one for attachment removal and retainer delivery. More frequent appointments were needed in this case because of its complexity. The patient was not amenable to fixed retention, and we did not feel that thermoformed retainers would adequately retain the upper lateral incisors. Therefore, upper and lower Hawley-type retainers were delivered for nighttime wear, with cutouts to accommodate eruption of the deciduous canines and deciduous molars, clear acrylic on the labial side for rotational control of the incisors, and C-clasps at the first molars for retention.

In this patient, the need for bite-opening auxiliaries was avoided by using clear aligners to resolve the crossbite of the upper right lateral incisor.

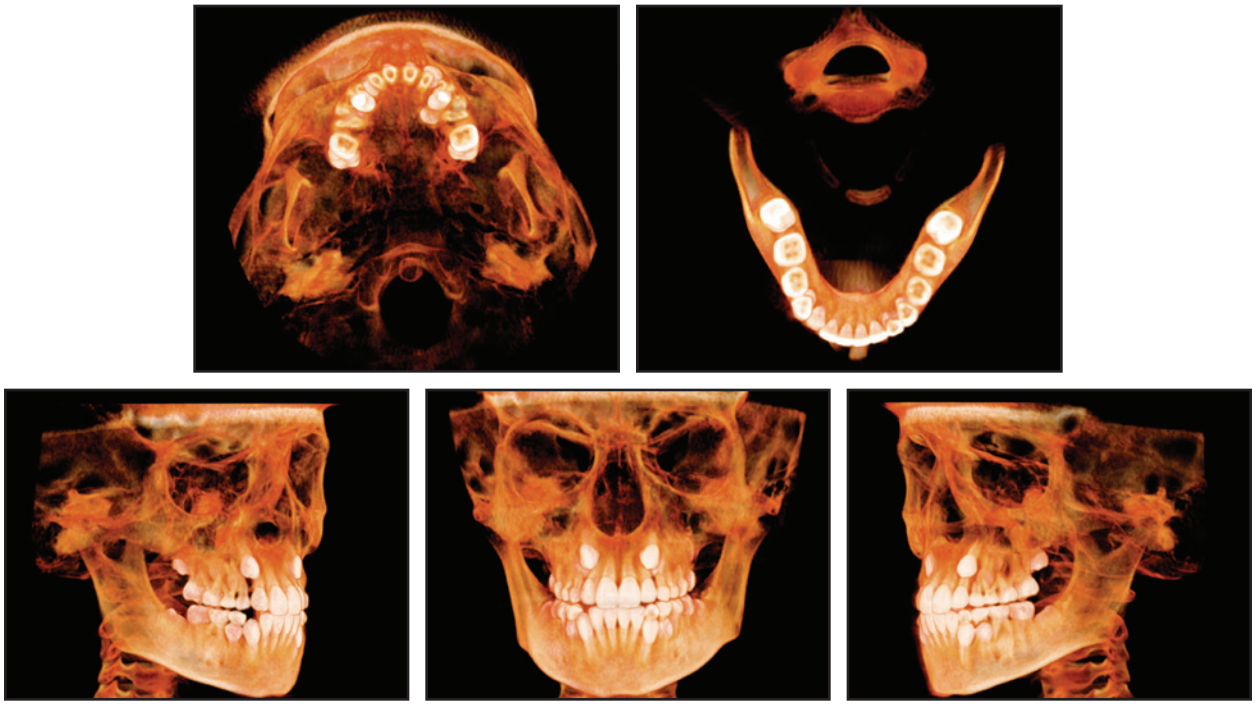

Fig. 6 (cont.) Case 3. Patient after 16 months of treatment.

The use of gentle forces from the Invisalign system, together with overtorquing of the upper left lateral incisor, helped preserve that tooth's root health. This was a significant result considering the incisor's proximity to the crown of the unerupted upper left canine. The upper left canine's eruption path remains mesiobuccal, and the upper left second premolar continues to be palatally positioned. We expect that these teeth, as well as the slightly palatally inclined upper right canine, may need assistance with eruption during the post-Phase I monitoring period. We plan to refer the patient for extraction of both upper deciduous canines and the upper left second deciduous molar to facilitate eruption of the ectopic permanent canines and second premolar. Phase II treatment is anticipated when permanent tooth eruption is complete.

Discussion

In our practice, young patients with normal airway measurements on their pretreatment CBCT images and no reported symptoms of sleep apnea or snoring have a choice of modalities for Phase I treatment. Clear aligner therapy offers the advantage of allowing simultaneous anterior alignment and expansion, with the added benefit of upper and lower arch coordination during expansion and alignment. In a case involving early loss of the deciduous canines and a lower midline shift, aligners allow space to be regained in the canine areas without brackets and consequent concerns about white-spot lesions. Patients also enjoy freedom from dietary restrictions since there is no possibility of appliance breakage, and the unrestricted access for brushing, flossing, and professional prophylaxis promotes better oral hygiene.

Two of the three mixed-dentition Phase I cases shown here were completed within six months using a combination of clear aligners and vibratory technology. The preteen years seem to be a favorable time for any orthodontic treatment requiring patient cooperation. The improved bio-

logical response in young patients allows for a rapid pace of aligner changes and a relatively short treatment period. Even in Case 2, when an aligner was lost during treatment, the patient was able to progress to the next aligner in the sequence. The longer sleep cycle of a younger patient (10 or more hours per night), during which the aligners remain in place, also contributes to success with faster aligner changes. We now ask nearly all our Phase I Invisalign patients to use AcceleDent and change aligners twice per week, with six-week appointment intervals. Because the AcceleDent device is lightweight and hands-free, we specifically recommend that it be used simultaneously with other daily tasks.

In Cases 1 and 2, the patients' short clinical crowns, combined with the bulbous morphology of primary teeth and the spaces resulting from early loss of deciduous teeth, provided few natural undercuts for aligner retention. In the absence of attachments, pliers can be used to create buccal and lingual "divots" for greater retentive capacity. Our current protocol is to place attachments on all available permanent teeth at the first aligner delivery, since the permanent teeth have more accessible bonding surfaces. Attachments on the lower deciduous molars and canines have been beneficial in the treatment of significant hypereruption of the lower anterior teeth. While patients may prefer to have minimal attachments, our current protocol is to use attachments in all cases except for patients with special needs or hypersensitivity.

Another consideration in younger children is the continued eruption and shifting of the dentition that can occur between records acquisition and aligner delivery. We now address this issue by scheduling aligner delivery three weeks after the initial records and scan. Since the goals of early treatment are usually far less complex than in a comprehensive case, this faster turnaround of the virtual tooth setup can be reliably achieved.

In Case 1, because the patient was uncomfortable with the extensive palatal coverage of a thermoformed retainer, we substituted a Hawley retainer with a horseshoe cutout over the palate. The second patient continues to wear the less retentive thermoformed cutout retainer; the third patient received a horseshoe Hawley retainer, as in Case 1. A modified version of the Invisalign retainer could be another solution, but Invisalign's current Phase I product does not include a specialized retainer option. Although we have not seen any loss of arch width during the first year after treatment, that could be a concern with retainers that are trimmed in the premolar and canine areas to allow for eruption.

In the lower arches, we prescribed a bonded lingual retainer for Case 1, no retention for Case 2, and a Hawley retainer for Case 3. In general, we have adopted a protocol of no lower retention for children with reasonable pretreatment alignment and arch length, a bonded lingual anterior retainer for those with moderate misalignment, and a lower lingual holding arch for those with severe lower crowding. We also offer a lower Hawley retainer for those patients who prefer a removable option.

Because the three patients presented here all had Class I skeletal growth patterns, no sagittal treatment mechanics were utilized. We would like to see further research on a larger scale to compare the effects of different expansion techniques on airway volume.

REFERENCES

1. Rosvall, M.D.; Fields, H.W.; Ziuchkovski, J.; Rosenstiel, S.F.; and Johnston, W.M.: Attractiveness, acceptability, and value of orthodontic appliances, Am. J. Orthod. 135:276e1-276e12, 2009.
2. Rossini, G.; Parrini, S.; Castroflorio, T.; Deregibus, A.; and Debernardi, C.L.: Periodontal health during clear aligners treatment: A systematic review, Eur. J. Orthod. 539-543, 2015.
3. Buschang, P.H.; Shaw, S.G.; Ross, M.; Crosby, D.; and Campbell, P.M.: Comparative time efficiency of aligner therapy and conventional edgewise braces, Angle Orthod. 84:391-396, 2014.
4. Nahoum, H.: The vacuum formed dental contour appliance, N.Y. St. Dent. J. 30:385-390, 1964.
5. Bishara, S.E.: Mandibular changes in persons with untreated and treated Class II division 1 malocclusion, Am. J. Orthod. 113:661-673, 1998.
6. Tulloch, J.F.; Proffit, W.R.; and Phillips, C.: Outcomes in a 2-phase randomized clinical trial of early Class II treatment, Am. J. Orthod. 125:657-667, 2004.
7. Von Bremen, J. and Pancherz, H.: Efficiency of early and late Class II division 1 treatment, Am. J. Orthod. 121:31-37, 2002.
8. Iwasaki, T.; Saitoh, I.; Takemoto, Y.; Inada, E.; Kakuno, E.; Kanomi, R.; Hayasaki, H.; and Yamasaki, Y.: Tongue posture improvement and pharyngeal airway enlargement as secondary effects of rapid maxillary expansion: A cone-beam computed tomography study, Am. J. Orthod. 143:235-245, 2013.

9. Baratieri, C.; Alves, M. Jr.; de Souza, M.M.; de Souza Araujo, M.T.; and Maia, L.C.: Does rapid maxillary expansion have long-term effects on airway dimensions and breathing? Am. J. Orthod. 140:146-156, 2011.
10. Ste. Marie, S.; Powers, M.; and Sheridan, J.J.: Vibratory stimulation as a method of reducing pain after orthodontic appliance adjustment, J. Clin. Orthod. 37:205-208, 2003.
11. Lobre, W.D.; Callegari, B.J.; Gardner, G.; Marsh, C.M.; Bush, A.C.; and Dunn, W.J.: Pain control in orthodontics using a micropulse vibration device: A randomized clinical trial, Angle Orthod. 86:625-630, 2016.
12. Shapiro, E.; Roeber, F.W.; and Klempner, L.S.: Orthodontic movement using pulsating force-induced piezoelectricity, Am. J. Orthod. 76:59-66, 1979.
13. Pavlin, D.; Anthony, R.; Raj, V.; and Gakunga, P.T.: Cyclic loading (vibration) accelerates tooth movement in orthodontic patients: A double-blind, randomized controlled trial, Semin. Orthod. 21:187-194, 2015.
14. Bowman, S.J.: The effect of vibration on leveling and alignment, J. Clin. Orthod. 48:678-688, 2014.
15. Bowman, S.J.: The effect of vibration on molar distalization, J. Clin. Orthod. 50:683-693, 2016.
16. Broujerdi, J.A.; Jacobson, R.; and Schendel, S.A.: 3D evaluation and analysis of the growth pattern of the upper airway space in normal pediatric to early adult patients, J. Oral Max. Surg. 70:e30, 2012.