Evaluation of the Posterior Airway Space Following Biobloc Therapy: Geometric Morphometrics

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ABSTRACT: The aim of this study was to evaluate changes in the posterior airway space in patients following Biobloc therapy, using geometric morphometrics. Pre- and post-treatment lateral cephalographs of 53 children (mean age, 12.9±1.5 years; mean treatment time, 21.3±6.2 months) were scanned and 27 landmarks encompassing the airway were digitized. Mean configurations were computed using Procrustes superimposition, followed by principal components analysis (PCA) and finite-element scaling analysis (FESA). Marked shape-changes were identified using PCA for the airway following treatment ($p<0.01$). Using pseudo-colored FESA, a relative 31% increase in nasopharyngeal airway area was found above and behind the soft palate. Additionally, a 23% increase in oropharyngeal airway area was located behind the base of the tongue with a 9% increase in hypopharyngeal area near the level of the hyoid bone. Functional airway improvements are associated with Biobloc treatment in actively growing patients.

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Functional appliances have been used since the 1920s to guide the growth and development of the skeletal components of the face, putatively using the forces of the musculature and the corresponding soft tissues. Vig and Vig[1] indicated that there is a relatively poor understanding of functional appliance therapy, even though studies have used cephalometry to analyze 2-D skeletal, dental and facial changes produced by functional orthodontic treatments.[2,3] The overall aim of Biobloc therapy is to achieve facial balance and correct oral posture. More importantly, it aims to redirect jaw growth anteriorly in a more horizontal direction so that a better posture and soft tissue facial profile are developed. The technique consists of several appliances used in sequence. The first appliance has an expansion screw to laterally expand the maxilla and advance the maxillary anterior teeth to an ideal position in the face. The second appliance, which attaches to the upper teeth, postures the mandible forward and has flanges that prevent mandibular retrusion (**Figures 1a-d**). Details of the clinical technique can be obtained from Mew.[4]

Thus, the aim of Biobloc therapy is to correct malocclusions in actively growing children by redirecting maxillo-mandibular growth in a more horizontal direction so

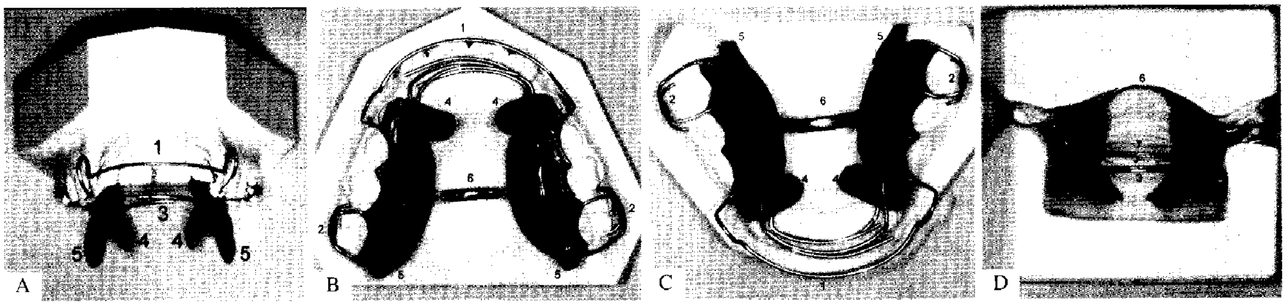

Figure 1
A: Anterior view of Stage IV Biobloc appliance. **1**. Maxillary anterior labial bow for retention; **3**. Mandibular incisor support wires; **4**. Anterior *lock* to engage mandible and prevent hinge opening; **5**. Posterior *lock* to engage mandible and prevent hinge opening. **B**. Palatal view of Stage IV Biobloc appliance. **1**. Maxillary anterior labial bow for retention; **2**. Hang's Clasps on maxillary first molars for retention; **4**. Anterior *lock* to engage mandible and prevent hinge opening; **5**. Posterior *lock* to engage mandible and present hinge opening; **6**. Palatal support bar. **C**. Lingual view of Stage IV Biobloc appliance. **1**. Maxillary anterior labial bow for retention; **2**. Hang's Clasps on maxillary first molars for retention; **4**. Anterior *lock* to engage mandible and prevent hinge opening; **5**. Posterior *lock* to engage mandible and prevent hinge opening; **6**. Palatal support bar. **D**. Posterior view of Stage IV Biobloc applinance; **3**. Mandibular incisor support wires; **4**. Anterior *lock* to engage mandible and prevent hinge opening; **5**. Posterior *lock* to engage mandible and prevent hinge opening; **6**. Palatal support bar; **7**. Maxillary incisor support wires.

that a better facial profile is developed. As the posture of the mandible is manipulated anteriorly during treatment, it is postulated that there may be a concomitant improvement in the posterior airway space. Therefore, the aim of this study was to evaluate changes in the posterior airway space in patients with Class II division 1 malocclusion following Biobloc appliance therapy, using geometric morphometrics. The null hypothesis to be tested was that there are no statistically significant changes in the posterior airway space associated with Biobloc treatment.

Materials and Methods

After obtaining consent, pre- and post-treatment lateral cephalographs of 53 children (mean age 12.9±1.5 years) were obtained from an orthodontic practice. Exclusion criteria for the study were Class III malocclusion, a history of previous orthodontic treatment, oral and/or maxillofacial surgery, any facial injury that resulted in hospital attendance, or any other congenital craniofacial malformation. Inclusion criteria were Class I or Class II malocclusions with maxillary retrognathia based on an Indicator Line >5 mm from ideal. (According to Mew,[5] a maxilla is ideally positioned in the face if the distance in millimeters from the tip of the nose to the incisal edge of the upper central incisor is 23 mm plus the child's age in years.) The mean treatment time was 21.3±6.2 months. The cephalographs were scanned and 27 landmarks encompassing the posterior airway space (**Figure 2**) were digitized using MorphoStudio (3dMD, Atlanta, GA) software. Mean airway configurations were calculated using Procrustes superimposition, which was implemented on a personal computer. This technique normalizes and registers all configurations with respect to one another.[6] Thus, the mean pre- and post-treatment airway configurations were determined.

Information obtained from geometric morphometrics is more robust than traditional cephalometric methods.[7] For example, principal components analysis (PCA) can be used to compare different groups of patients with specific characteristics. Normally, a few modes (the principal components) are sufficient to describe all of the shapes approximately. Additionally, the points representing the shapes in the mode space are grouped according to their main characteristics.[8] Therefore, we employed PCA to determine whether any differences in statistical shape space were evident for the mean pre- and post-treatment airway configurations, using *t*-tests on the two most significant modes to display the results.

Finite-element scaling analysis (FESA) can also be used to depict clinical transformations in terms of allometry (size-related shape-change) and anisotropy (directionality of shape-change). The change in form between the reference configuration and the final configuration is viewed as a continuous deformation, which can be quantified based on major and minor strains (principal strains). If the two strains are equal, the form change is characterized by a simple increase or decrease in size. However, if one of the principal strains changes in a greater proportion, transformation occurs in both size and shape.[9] A pseudocolor-coded scale was used in this study to provide a graphic display of size-changes evident for the mean pre- and post-treatment airway configurations.

Results

Duplicate digitization of landmarks showed there were no statistical differences between the values obtained

Figure 2
Lateral cephalograph showing the 27 landmarks used in this study. **0**: S (Sella) = center of sella turcica; **1**: N (Nasion) = the middle point located on nasofrontal suture intersected by the median sagittal plane; **2**: PCB (Posterior Cranial Base) = point directly below sella in the vertical plane that intersects with the inferior surface of the posterior cranial base; **3**: PNS (Posterior Nasal Spine) = the posterior-most point on the tip of the posterior nasal spine; **4**: PTS (Superior Pterygomaxillare) = the superior point where the pterygoid process of the sphenoid bone and the pterygoid process of the maxilla form the pterygomaxillary fissure; **5**: PPW (Posterior Pharyngeal Wall 1) = point directly opposing the PNS in the horizontal plane on the posterior pharyngeal wall; **6**: AA (Atlas) = anterior-most point on anterior process of the Atlas; **7**: AAS (Atlas Soft) = anterior-most point on posterior pharyngeal wall in the horizontal plane directly opposing AA (as defined above); **8**: U (Uvula) = the most inferior point on the tip of the uvula; **9**: UD (Uvula Dorsum) = the most superior and posterior point on the dorsum of the soft palate; **10**: PPS (Posterior Pharyngeal Wall 2) = point directly opposite to the tip of the uvula in the horizontal plane on the surface of the posterior pharyngeal wall; **11**: G (Gonion) = the lowest and posterior-most point on the angle of the mandible; **12**: PT (Base of tongue) = intersection of posterior surface of the dorsum of the tongue and mandible; **13**: C2 (Second cervical vertebra) = the lowest point of body of C2; **14**: SC2 (Soft second cervical vertebra) = point on the surface of the posterior pharyngeal wall in the horizontal plane directly opposite C2 (as defined above); **15**: C3S (Third cervical vertebra upper) = the highest point of body of C3; **16**: SC3 (Soft third cervical vertebra upper) = point on the surface of the posterior pharyngeal wall in the horizontal plane directly opposite C3S (defined); **17**: C31 (Third cervical vertebra lower) = the lowest point of the body of C3; **18**: SC31 (Soft third cervical vertebra lower) = point on the surface of the posterior pharyngeal wall in the horizontal plane directly opposite C31 (defined); **19**: C4S (Fourth cervical vertebra upper) = the highest point of the body of C4. **20**: SC4S (Soft fourth cervical vertebra upper) = point on the surface of the posterior pharyngeal wall in the horizontal plane directly opposite C4S (defined); **21**: C41 (Fourth cervical vertebra upper) = the lowest point of the body of C4; **22**: SC41 (Soft fourth cervical vertebra upper) = point on the surface of the posterior pharyngeal wall in the horizontal plane directly opposite C4S (defined); **23**: EPI (Epiglottis) = base of epiglottis; **24**: HY (hyoid) = anterior-most point on body of hyoid bone; **25**: PA (Point A) = deepest concavity on maxillary alveolus; **26**: Gn (Gnathion) = the most antero-inferior point on the mental protuberance.

($p>0.05$). Therefore, it was deemed that the study digitization error was insignificant and further investigation warranted.

Principal components analysis was used to identify shape characteristics in the mode space of the airways before and after treatment. Using PCA, it was found that the two groups were dissimilar in shape post-treatment (**Figure 3**). The first two eigenvalues were found to account for about 33% of the total shape change in the airways prior to and after treatment. When *t*-tests were applied to the two most significant modes, $p<0.01$ was obtained, suggesting that the airways are significantly different after treatment.

The finite-element analysis results indicated that Biobloc treatment had desirable effects on the airway. A 31% increase in relative airway area was found in the nasopharynx above and behind the dorsum of the soft palate, using FESA (**Figure 4**). Additionally, a 23% increase in relative airway area was located in the oropharynx behind the base of the tongue with a 9% increase in the hypopharynx near the level of the hyoid bone. These results indicate that Biobloc therapy may have beneficial effects on airway morphology in actively growing patients.

Discussion

Class II malocclusion is a complex condition that may be corrected using different modes of treatments, such as fixed, Andresen,[10] Twin Block,[10] Herbst,[11] Biobloc,[12] or headgear appliances.[6] Biobloc appliances have different effects compared to other functional appliances in the correction of Class II malocclusion.[4] For example, while the overjet was reduced by incisor angulation and by maxillary and mandibular dental base correction when using functional appliances, it was reduced by changes in the mandibular dental base alone for Biobloc appliances.[13] Similarly, while some functional treatments may involve the extraction of teeth,[14] Biobloc treatment aims to avoid this option, and thus it is claimed that Biobloc appliances putatively produce an enhanced soft tissue facial profile in the correction of malocclusions. However, some believe that studies of *alternative orthodontic treatments* have failed to illustrate better facial appearances.[15] Others[16] suggest that conventional cephalometric tech-

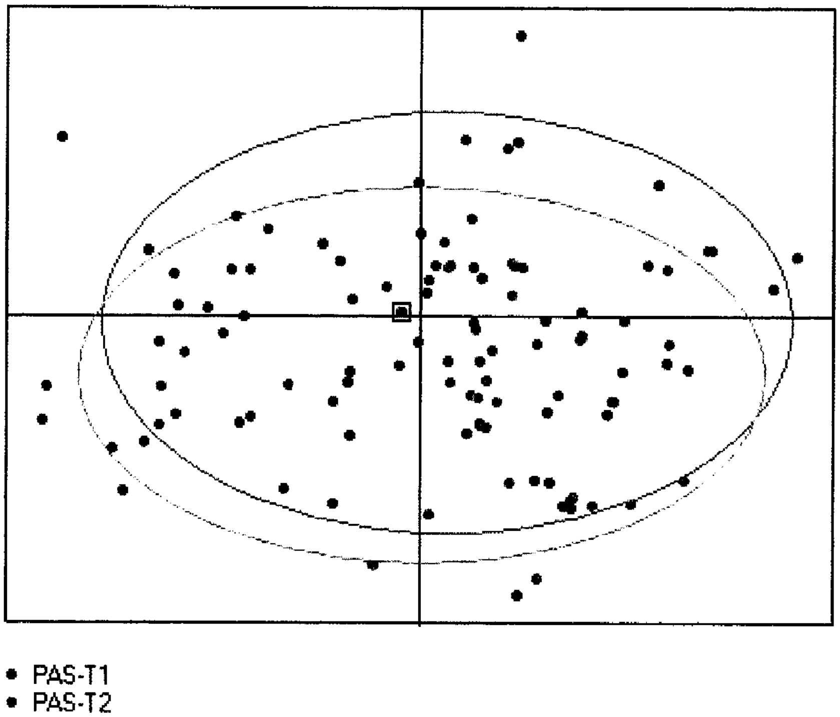

Figure 3
Shape-changes identified for the posterior airway space following Biobloc treatment confirmed using Principal Components Analysis. PAS-T1 (**red** dots) represent the airways of individual patients pre-treatment, and PAS-T2 (**green** dots) represent those airways post-treatment. The first two principal components illustrated (x- and y-axis) account for about 33% of the total shape change in the posterior airway space, which was found to be statistically significant ($p<0.01$) following treatment.

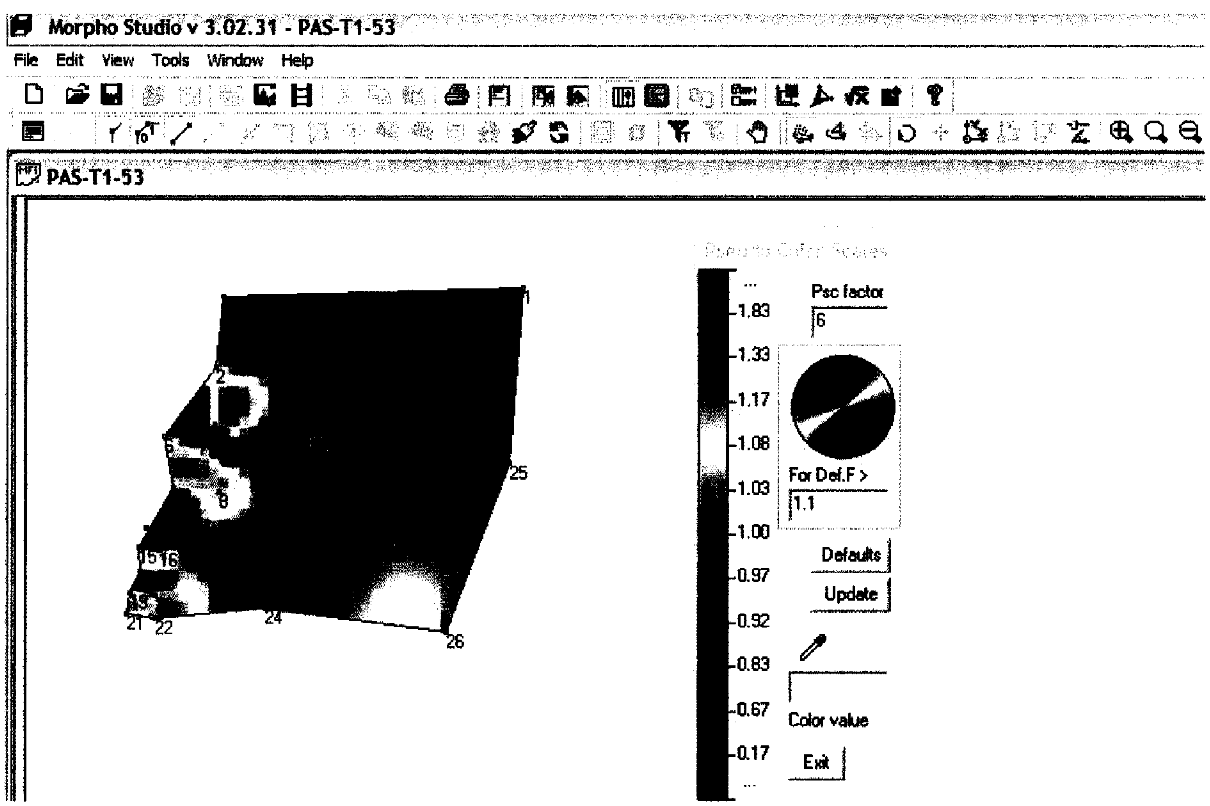

Figure 4
MorphoStudio software showing finite-element analysis. Using the pseudo-color scale, a 31% increase in relative size (**orange** color) is found in the nasopharyngeal area above and behind the dorsum of the soft palate, post-treatment. In addition, a 23% increase in relative size (**light orange** color) is located in the oropharyngeal behind the base of the tongue, and a 9% increase in relative size (**yellow** color) is identifiable in the hypopharyngeal area near the level of the hyoid bone following Biobloc treatment.

niques are inadequate for precise analyses of facial growth and associated orthodontic changes. Therefore, the aim of this study was to determine whether Biobloc functional appliances affect the posterior airway space, using robust geometric techniques.

In one study[17], when the functional airway space was investigated, the oropharyngeal airway was found to positively correlate with the length of the mandible (gonion-menton) and with the distance between the third cervical vertebra (C3) and the hyoid bone. Similarly, the distance between C3 and menton was found to correlate with the distance between the posterior pharyngeal wall and the tongue base in the pharyngeal airway space.[18] Not surprisingly, it had been earlier reported that airway obstruction or constriction may be found in patients with small mandibular dimensions, mandibular retrognathism, or with an increased mandibular plane angle.[19] In this present study, we were able to demonstrate that the effect of mandibular advancement using the Biobloc technique increases the distance between C3 and menton by 9-18% (**Figure 4**) and the distance between the posterior pharyngeal wall and the tongue base by 8-9% (**Figure 4**). Nevertheless, it could be argued that similar changes might be occurring naturally in actively growing children over the time period studied (21.3±6.2 months). Therefore, further studies with a matched, non-treated control group are indicated.

In a study on children with obstructive sleep apnea syndrome (OSAS), the length of the mandible (gonion-gnathion) and the minimal posterior airway space were found to be inversely correlated with apnea-hypopnea scores. There was also a positive correlation between the minimal posterior airway space and mandibular length.[20] In this study, we found that mandibular length increased by 8-9%, which suggests that Biobloc therapy may have a role to play in the prevention or treatment of OSAS in children. Indeed, in Chinese children with OSAS, improvement of the lowest oxygen saturation levels was found to be correlated with the body length of the mandible and the antero-posterior position of the base of the tongue.[21] Similarly, maintenance of an acceptable pharyngeal airway is associated with an increased distance in the positioning of the hyoid bone from the cervical column.[22] In this present study, we found that the hyoid bone moved antero-superiorly, increasing the pharyngeal space by some 6-18%.

In a cephalometric study carried out to determine the effects of long-term mandibular advancement on the airway following mandibular advancement for OSAS in adults, the posterior airway space increased by 1.28 mm by 12 months.[23] These findings are not dissimilar to those reported in this study on non-OSAS, actively growing children. Indeed, when changes in the upper airway induced by mandibular advancement during sleep were examined in patients with OSAS, the sagittal dimension of the superior pharyngeal airway was found to increase, no changes were found in the middle or inferior pharyngeal airway, but postero-inferior displacement of the hyoid bone was found.[24] These findings contrast with those reported here. Therefore, our findings support the suggestion that dental appliances might be effective tools in the management of OSAS in children, but that early Biobloc treatment may negate the necessity for mandibular advancement with oral appliances for life in the treatment of OSAS. In summary, the Biobloc findings of this present study used geometric morphometric analyses to depict changes in the airway. Taken together, the findings suggest that Biobloc treatment has a tendency to produce an enhanced functional airway on successful conclusion of treatment consistent with a more balanced facial profile. The physiologic consequences of the present findings and their 3-D investigation provide a premise for future studies.

Conclusion

Functional changes in the posterior airway space, as well as dentofacial improvements, are associated with Biobloc treatment.

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References

1. Vig PS, Vig KW: Hybrid appliances: a component approach to dentofacial orthopedics. *Am J Orthod Dentofacial Orthop* 1986; 90:273-285.
2. LaMastra SJ: Relationships between changes in skeletal and integumental points A and B following orthodontic treatment. *Am J Orthod* 1981; 79:416-423.
3. Mamandras AH, D'Aloisio DR, Lenizky RJ: Facial changes in children treated with the Activator appliance: a lateral cephalometric study. *J Can Dent Assoc* 1989; 55:727-730.
4. Mew J: BioBloc therapy. *Am J Orthod* 1979; 76:29-50.
5. Mew J: Use of the 'indicator line' to assess maxillary position. *Funct Orthod* 1991; 8:29-32.
6. Singh GD, Thind BS: Effects of the headgear-activator Teuscher appliance in the treatment of Class II division 1 malocclusion: a geometric morphometric study. *Orthod Craniofacial Res* 2003; 6:88-95.
7. Halazonetis DJ: Morphometrics for cephalometric diagnosis. *Am J Orthod Dentofacial Orthop* 2004; 125:571-581.
8. Singh GD, Maldonado L, Thind BS: Changes in the soft tissue facial profile following orthodontic extractions: a geometric morphometric study. *Funct Orthod* 2005; 22:34-40.
9. Singh GD, Clark WJ: Soft tissue changes in patients with Class II Division 1 malocclusions treated using Twin Block appliances: finite-element scaling analysis. *Eur J Orthod* 2003; 25:225-230.
10. Trenouth MJ: A comparison of Twin Block, Andresen and Removable appliances in the treatment of Class II division 1 malocclusion. *Funct Orthod* 1992; 9:26-31.
11. Ruf S, Pancherz H: Dentoskeletal effects and facial profile changes in young

adults treated with the Herbst appliance. *Angle Orthod* 1999; 69:239-246.
12. Trenouth MJ, Mew JR, Gibbs WW: A cephalometric evaluation of the Biobloc technique using matched normative data. *J Orofac Orthop* 2001; 62:466-475.
13. Trenouth MJ, Mew J: A cephalometric evaluation of four different methods of orthodontic treatment. *J Craniomandib Pract* 1997; 15:16-22.
14. Clark WJ: *Twin block functional therapy*. London: Harcourt, 2002.
15. DiBase AT, Sandler PJ: Does orthodontics damage faces? *Dent Update* 2001; 28:98-104.
16. Moyers RE, Bookstein FL: The inappropriateness of conventional cephalometrics. *Am J Orthod* 1979; 75:599-617.
17. Trenouth MJ, Timms DJ: Relationship of the functional oropharynx to craniofacial morphology. *Angle Orthod* 1999; 69:419-423.
18. Muto T, Takeda S, Kanazawa M, Yamazaki A, Fujiwara Y, Mizoguchi I: The effect of head posture on the pharyngeal airway space (PAS). *Int J Oral Maxillofac Surg* 2002; 31:579-583.
19. Solow B, Siersbaek-Nielsen S, Greve E: Airway adequacy, head posture, and craniofacial morphology. *Am J Orthod* 1984; 86:214-223.
20. Ozdemir H, et al.: Craniofacial differences according to AHI scores of children with obstructive sleep apnea syndrome: cephalometric study in 39 patients. *Pediatr Radiol* 2004; 34:393-399.
21. Liu Y, Zeng X, Fu M: The study on the correlation between the effect of dental appliances on OSAS and the morphology of upper airway and craniofacial structures. *Zhonghua Kou Qiang Yi Xue Za Zhi* 1998; 33:365-368.
22. Bacon W, Berreur C, Krieger J, Hildwein M, Stierle JL: Pharyngeal obstruction and the functional adaptation of the natural posture of the head and the hyoid bone in sleep apnea syndrome. *Orthod Fr* 1992; 63:595-602.
23. Robertson CJ: The effect of long-term mandibular advancement on the hyoid bone and pharynx as it relates to the treatment of obstructive sleep apnea. *Aust Orthod J* 2000; 16:157-166.
24. Hiyama S, Tsuiki S, Ono T, Kuroda T, Ohyama K: Effects of mandibular advancement on supine airway size in normal subjects during sleep. *Sleep* 2003; 26:440-445.

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