Risk of Narrow Upper Airway in Class II Children with Large Horizontal Maxillary Overjet Assessed By Acoustic Reflection: a Case-Control Study

Camilla Hansen[1], Merete Bakke[2], Liselotte Sonnesen[1]

[1]Section of Orthodontics and Dental Sleep Clinic, Department of Odontology, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark.
[2]Section of Clinical Oral Physiology, Department of Odontology, Faculty of Health and Medical Sciences, University of Copenhagen, Copenhagen, Denmark.

Corresponding Author:
Liselotte Sonnesen
20 Noerre Allé, DK-2200 Copenhagen N
Denmark
Phone: 0045 35326670
E-mail: alson@sund.ku.dk

ABSTRACT

Objectives: The aim of this case-control study was to examine upper airway by acoustic reflection in class II children with large horizontal maxillary overjet compared to children with neutral occlusion.
Material and Methods: The study group included children of 9 to 14 years with class II and large horizontal maxillary overjet (≥ 6 mm) compared to children with neutral occlusion (controls). Acoustic pharyngometry and rhinometry were performed in natural head position. Differences between groups were tested by chi-square test, general linear model (adjusted for age, gender and body mass index [BMI]), and Mann-Whitney test.
Results: The study and control group consisted of 37 (boys: 19, girls: 18) and 32 (boys: 16, girls: 16) participants, respectively. No significant differences in age, gender, and BMI were found between the groups. For the acoustic rhinometry measurements significantly increased resistance (P = 0.04), reduced volume (P = 0.03) and distance to minimal cross-section area (MCA) (P = 0.035) were found in the study group, but only for the right nostril. However, significantly reduced MCA for both nostrils was found in the study group (P = 0.025 to 0.04). No significant differences in acoustic pharyngometry measurements were found.
Conclusions: Nasal airway dimensions were significantly reduced, and nasal resistance was significantly increased in the study group compared to controls. Thus, class II and large overjet with indication for growth adaptive treatment may be a risk factor for sleep-disordered breathing. In the future, orthodontic paediatric patients may benefit from non-invasive risk assessment of narrow upper airway using acoustic reflection.

Keywords: acoustic rhinometry; acoustics; airway resistance; angle class II; child; malocclusion.

Accepted for publication: 29 September 2024
To cite this article:
Hansen C, Bakke M, Sonnesen L.
Risk of Narrow Upper Airway in Class II Children with Large Horizontal Maxillary Overjet Assessed By Acoustic Reflection: a Case-Control Study
J Oral Maxillofac Res 2024;15(3):e5
URL: http://www.ejomr.org/JOMR/archives/2024/3/e5/v15n3e5.pdf
doi: 10.5037/jomr.2024.15305

INTRODUCTION

Sleep related disorders as for example sleep-disordered breathing (SDB) has a great impact on children's growth, development, and well-being. Accordingly, it is important to prevent and diagnose SDB in children and adolescents [1]. Predisposing factors for SDB are primarily adenotonsillar hypertrophy and/or adenoid vegetations [1,2]. As upper airway dimensions and dento-craniofacial development are closely related, obstruction of nasal airways may result in abnormal dento-craniofacial development and mouth breathing [1,2]. Likewise, dento-craniofacial morphology may have a great influence on the dimensions and the resistance of the upper airway. Additionally, studies have shown that different anatomical variations of the dento-craniofacial morphology may increase the risk of increased resistance and reduced volume of the upper airway. Example of these different dento-craniofacial traits may be convex facial profile, high and narrow palate, increased lower vertical face height, and mandibular retrognathia [3-6].

Angle class II malocclusion with large horizontal maxillary overjet (large overjet) due to mandibular retrognathia is one of the most common malocclusions in children and adolescents [7]. The majority of these children and adolescents have indication for growth adaptation of the mandible during their pubertal growth spurt with functional appliance [8-10]. Accordingly, examination of the upper airway in this group of children is of high relevance to assess the risk of SDB [3-5,8,11-13].

Previous studies have shown that acoustic pharyngometry and rhinometry are useful, non-invasive methods [14,15] that are reliable in children and adolescents and can be used in risk assessment of SDB [15,16]. As acoustic reflection is non-invasive, it is possible to examine the upper airway resistance and dimensions in children and adolescents without radiation exposure when lateral cephalograms or cone-beam computed tomography (CBCT) are not indicated [14].

No previous study has used acoustic reflection to examine if children with class II and large overjet with indication for growth adaptive treatment have increased resistance and reduced upper airway dimensions. Accordingly, acoustic reflection has not previously been used to describe an eventual clinical risk assessment of SDB in this pediatric, orthodontic population. The null hypothesis of the present case-control study was that there was no significant difference in upper airway dimensions and resistance, assessed by acoustic pharyngometry and rhinometry, between children with class II and large overjet compared to children with neutral occlusion.

MATERIAL AND METHODS

The present study was conducted at the Section of Orthodontics, Department of Odontology, University of Copenhagen, Denmark from August 26, 2020 to June 1, 2023. It was registered at ClinicalTrials.gov (registration no. NCT04964830) prior to the recruitment of participants. Some of the previously published papers were partly based on the same cohort but on different topics [16-19]. This study was approved by the Committee on Health Research Ethics for the Capital Region (protocol no. H-17011521) and the Danish Data Protection Agency (protocol no. SUND-2017-29). A written informed consent was obtained from the children's parents/caregivers prior to the enrolment. The study followed the declaration of Helsinki and was conducted according to the STROBE statements [20].

Study sample

The power calculation was based on previous studies [5,8], and it was assumed that children in the present study group have 40% risk of narrow upper airway dimensions and that children in the control group have a risk of 10%. With a risk of type 1 error of 5%, risk of type 2 error of 20%, and power of 80%, at least 32 participants should be included in both the study and control group to have sufficient power.

Subjects

The participants were included for a study group and a control group [16-18] from August 26, 2020 to June 1, 2023. The participants were recruited from different municipal dental health care centres in the area of Copenhagen, Denmark and the Postgraduate Program in Orthodontics, Department of Odontology, University of Copenhagen.

The study group consisted of children aged 9 to 14 years with class II and horizontal maxillary overjet ≥ 6 mm with indication for growth adaptive treatment of the mandible during the pubertal growth spurt [8-10]. The participants in the study group had moderate to severe mandibular retrognathia [10] (retrognathia of the mandible 75.6° [SD 3.5°] and ANB angle 5.1° [SD 1.5°]) assessed on lateral cephalograms in standard natural head position, using the mirror position [21]. The cephalometric X-rays were taken of the participants in the study group as part of the orthodontic treatment planning.

The control group included children aged 9 to 14 years with neutral occlusion [22] and with no indication for orthodontic treatment according to the procedure for screening the child population for severe malocclusion entailing health risks [23]. Exclusion criteria for both groups were syndromes, diseases, SDB, adenoid vegetations, and hypertrophied tonsils.

Methods

General recordings

Height in meters and weight in kilograms were obtained to calculate body mass index (BMI, kg/m^2). BMI was graded individually in the categories “underweight”, “normal weight”, and “overweight” according to their age in months and gender [24]. Horizontal maxillary overjet and vertical overbite were clinically registered [10,22].

Acoustic pharyngometry and rhinometry

The upper airway dimension and upper airway resistance of the participants were examined using the Eccovision® Acoustic Pharyngometer and Rhinometer (Sleep Group Solutions; Hollywood, Florida, USA). Acoustic pharyngometry and rhinometry were calibrated and performed according to the operator manual [25], and in standing natural head position, using the mirror position, as previously described in details [16,26]. All examinations were performed by the same examiner (C.H.). The following measurements were registered: volume, mean area of the pharynx, calculated resistance of the nostrils, minimum cross-sectional area (MCA), and distance to MCA. A recording was excluded if the graph continued through the upper border of the screen [16].

Reliability

For assessment of the reliability of the craniofacial morphology of the study group, 25 lateral cephalograms were randomly chosen to be scored again after two weeks. No systematic error was found. The method error ranged between 0.2° to 1.72° [27,28] and the reliability coefficient ranged between 0.896° to 0.995° [27,28]. Regarding the acoustic pharyngometry and rhinometry, the method error ranged between 0.001 to 0.082, and Houston reliability coefficient ranged between 0.956 to 0.999 as previously reported [16].

Statistical analysis

Statistical data analyses were performed using the SPSS® Statistics version 29.0 (IBM Corp.; Armonk, New York, USA). Descriptive statistics were made, and test of normality of the residuals for all variables were tested by Quantile-Quantile-plots. Differences in gender were tested by chi-square test, and differences in age and BMI across the groups were tested by non-parametric Mann-Whitney test. Differences in horizontal maxillary overjet and vertical overbite were analysed between the groups using general linear model (GLM) adjusted for age and gender.

Differences between the groups of the normally distributed data were analysed using GLM adjusted for age, gender, and BMI. Volume of the nostrils was transformed using the natural logarithm to be normally distributed and then the difference between the two groups were analysed by GLM adjusted for age, gender, and BMI. Afterwards the results were back-transformed using exponential function and the relative differences between the explanatory variables were listed. Distance to MCA of the nostrils were non-normally distributed and analysed by non-parametric Mann-Whitney test. A participant was excluded from analysis of a specific variable in the presence of missing data of the specific variable. Parametric data was expressed as mean and standard deviation (M [SD]) and 95% confidence intervals and non-parametric data as quartiles. The significance level was set at 5%.

RESULTS

The flowchart of participants is shown in Figure 1. In total, 62/69 (90%) of the acoustic pharyngometry recordings and 66/69 (96%) acoustic rhinometry recordings were sufficient for further analyses. General descriptive statistics regarding gender, age, BMI, and incisal relationship of the groups are shown in Table 1. No significant differences in age, gender, and BMI were found between the groups. The results of the pharyngometry and rhinometry are shown in Table 2 and 3, respectively, comparing the study group and the control group adjusted for gender, age, and body mass index categories.

Significantly larger calculated resistance (P = 0.04) and reduced volume of the right nostril (P = 0.03) were found in the study group compared to controls (Table 3). The distance to MCA of the right nostril was significantly larger in the study group (P = 0.035) compared to controls. Significantly reduced MCA for both nostrils (P = 0.025 to 0.04) were found in the study group compared to controls (Table 3).

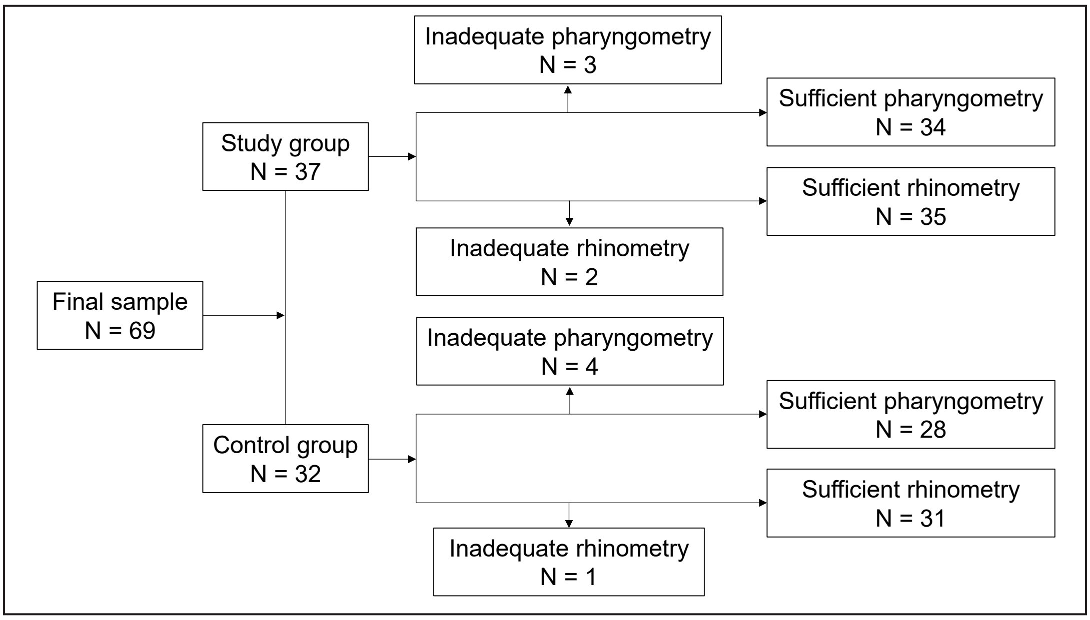

Figure 1. Flowchart of the acoustic pharyngometry and rhinometry examination of the participants in the study.

Table 1. Descriptive statistics of the groups

		Group		**P-value**
		Study	**Control**	
Participants	N	37	32	-
Gender	N (boys; girls)	19; 18	16; 16	0.911[a]
Age (years)	Median (min; max)	12.3 (9.8; 14.7)	12.2 (9.5; 14.6)	0.527[b]
Body mass index categories				
Underweight	N (%)	10 (27)	2 (6)	
Normal weight	N (%)	24 (65)	21 (66)	0.507[b]
Overweight	N (%)	3 (8)	9 (28)	
Horizontal maxillary overjet (mm)	Mean (95% CI)	9 (8.3; 9.7)	2.7 (2.4; 3)	< 0.001[c]*
Vertical overbite (mm)	Mean (95% CI)	4.1 (3.6; 4.6)	3 (2.7; 3.4)	< 0.001[c]*

[a]Chi-square test; [b]Mann-Whitney test; [c]general linear model adjusted for age and gender.
*Statistically significant difference at P < 0.001.
N = number; CI = confidence interval.

Table 2. Acoustic pharyngometry measurements

		Group		**P-value**	**Difference of the mean**	**95% CI of the difference**	
		Study	**Control**			**Lower**	**Upper**
	Mean (SD)	25.14 (5.32)	24.27 (5.2)				
Volume (cm³)	95% CI of mean	23.28; 27	22.24; 26.27	0.628[a]	0.667	-2.073	3.407
	Min; max	17.09; 34.43	13.22; 34.19				
	Mean (SD)	2.51 (0.53)	2.41 (0.52)				
Mean area (cm²)	95% CI of mean	2.32; 2.7	2.21; 2.61	0.565[a]	0.079	-0.195	0.353
	Min; max	0.71; 3.44	1.32; 2.1				
	Mean (SD)	1.7 (0.45)	1.55 (0.34)				
MCA (cm²)	95% CI of mean	1.54; 1.88	1.42; 1.68	0.259	0.126	-0.095	0.347
	Min; max	0.98; 2.53	1; 2.17				
	Mean (SD)	12.81 (3.26)	13.12 (3.51)				
Distance to MCA (cm)	95% CI of mean	11.67; 13.95	11.75; 14.48	0.63[b]	-0.42	-2.159	1.319
	Min; max	10.16; 19.17	10.16; 18.74				

[a]Positively associated with increased age; [b]significantly increased in boys.
MCA = minimum cross-sectional area; SD = standard deviation; N = number; CI = confidence interval.

Table 3. Acoustic rhinometry measurements

		Group		P-value	Difference of the mean	95% CI of the difference	
		Study	Control			Lower	Upper
Left nostril							
Calculated resistance (cm H_2O/L/min)	Mean (SD)	2.54 (1.11)	2.35 (1.49)	0.602[c]	0.168	-0.473	0.809
	95% CI of mean	2.26; 2.93	1.8; 2.9				
	Min; max	1.11; 5.58	0.31; 7.69				
Volume (cm^3)[a]	Mean (SD)	6.64 (1.38)	7.06 (1.57)	0.951[d]	0.595	0.787	1.148
	95% CI of mean	5.94; 7.42	5.98; 8.34				
	Min; max	3.9; 12.81	2.86; 23.57				
MCA (cm^2)	Mean (SD)	0.53 (0.1)	0.63 (0.25)	0.025[d]*	-0.109	-0.204	-0.014
	95% CI of mean	0.49; 0.56	0.54; 0.73				
	Min; max	0.31; 0.75	0.38; 1.49				
Distance to MCA (cm)	Q1	0.42	0.18	0.158[b]	-	-	-
	Q2	0.42	0.42		-	-	-
	Q3	1.86	1.62		-	-	-
	Min; max	0.18; 2.1	0.8; 4.5		-	-	-
Right nostril							
Calculated resistance (cm H_2O/L/min)	Mean (SD)	2.78 (1.13)	2.17 (1.04)	0.04[c]*	0.58	0.027	1.134
	95% CI of mean	2.39; 3.16	1.79; 2.55				
	Min; max	0.85; 5.78	0.21; 4.84				
Volume (cm^3)[a]	Mean (SD)	6.17 (1.38	7.73 (1.62)	0.03[d]*	0.793	0.645	0.977
	95% CI of mean	5.52; 6.9	6.47; 9.24				
	Min; max	3.49; 15.49	4.18; 36.23				
MCA (cm^2)	Mean (SD)	0.52 (0.11)	0.62 (0.27)	0.04[d]*	-0.109	-0.212	-0.005
	95% CI of mean	0.48; 0.56	0.52;0.72				
	Min; max	0.35; 0.76	0.4; 1.55				
Distance to MCA (cm)	Q1	0.18	0.18	0.035[b]*	-	-	-
	Q2	1.62	0.42		-	-	-
	Q3	1.86	1.62		-	-	-
	Min; max	0.2; 2.1	0.2; 1.9		-	-	-

[a]The relative differences are listed due to analysis using the natural logarithm scale; [b]Mann-Whitney test; [c]significantly negatively associated with age; [d]significantly positively associated with age.
*Significant difference at $P < 0.05$.
MCA = minimum cross-sectional area; SD = standard deviation; CI = confidence interval; Q1 = first quartile; Q2 = second quartile, median; Q3 = third quartile.

The calculated resistance was negatively associated with age (P = 0.002 to 0.011). The volume (P = 0.001 to 0.014) and the MCA of the nostrils (P = 0.022) were positively associated with age. No significant differences between the groups were found for the left nostril regarding calculated resistance, volume, or distance to MCA. No significant difference in the pharyngometric measurements was found. Although, the volume (P = 0.033) and mean area (P = 0.032) were significantly positively associated with age, and the distance to MCA (P = 0.025) was significantly increased in boys.

DISCUSSION

The present study is the first to examine upper airway dimension in children with class II and large overjet with indication for growth adaptive treatment compared to a control group using acoustic pharyngometry and rhinometry. This type of malocclusion represents the majority of young patients with indication for orthodontic treatment in the juvenile and adolescent period. Accordingly, this population is highly clinical relevant to examine. The power calculation was fulfilled, the success rates of the acoustic pharyngometry (90%) and rhinometry (96%) were high [15]. The method error for both acoustic pharyngometry and rhinometry was considered good [16,26]. However, training of the method before final registration may be beneficial [16].

Overall, the study showed that class II and severe large overjet was associated with risk of narrow nasal upper airway dimensions. Significantly larger nasal resistance of the right nostril was found in the study group but no difference for the left nostril. This difference between the nostrils may be due to local, anatomical factors. Reduced volume and MCA for both nostrils and reduced distance to the MCA of the right nostril were found in the study group compared to controls. The results are in accordance with previous studies based on lateral cephalograms and CBCT [3,6,8,29,30]. The findings of narrow nasal upper airways in children with class II and large overjet by acoustic rhinometry is of great clinical relevance as acoustic reflection is a non-invasive method. Accordingly, it may be beneficial to use this method as a part of a clinical risk assessment of narrow upper airway. As narrow upper airway is associated with SDB [6,8], children with class II and large overjet and reduced nasal airway dimensions may have increased risk of SDB.

No significant differences in the results of the acoustic pharyngometry were found between the groups. The results are in contrast with previous studies based on lateral cephalograms and CBCT [6,30,31], which found reduced pharyngeal volume and MCA in children with increased sagittal jaw relation. Previous studies found that acoustic reflection differ from measurements on CBCT, computed tomography and magnetic resonance [32-35], while other studies found moderate to good correlation with CBCT and lateral cephalogram [30,32]. The discrepancy in the literature may be due to the individual variation and morphology of the upper airway, which are influenced by multiple factors [1,2], e.g. age, gender, BMI, dento-craniofacial morphology, and head posture [1,3,4,11,36-40]. Accordingly, it is a strength that all examinations are performed in standing natural head position, using the mirror position [16,21,26,36-39]. Furthermore, the acoustic reflection and CBCT take the transverse dimension into account in contrast to the lateral cephalograms [33]. A limitation in the present study may be the compensatory mechanism due to extended head posture of the participants in the study group [21], which may have camouflaged an eventual difference in the pharyngeal airway volume [36,41]. In addition, it may be a limitation that no X-rays for analysis of the craniofacial morphology of the control group was taken due to ethical reasons. Consequently, the degree of dentoalveolar compensation mechanism in the control group may have camouflaged a skeletal discrepancy of the jaws. Therefore, this limitation was attempted to be minimized as the participants in the control group had neutral occlusion with no indication for orthodontic treatment [42].

The volume and mean area of the pharynx and the volume and MCA of the nasal airway were positively associated with age, whereas the calculated resistance of the nostrils was negatively associated with age. These results are in accordance with the increase of the volume of the upper airway during growth, including increased age and skeletal maturation [6,43]. Accordingly, children with narrow nasal upper airway may benefit from transverse expansion of the maxilla and growth adaptation treatment of the mandible during their pubertal growth spurt [6,8,44-47]. No significant association between the results of the acoustic pharyngometry and rhinometry and gender were found, besides the distance to MCA, which was increased in boys. This is in accordance with previous studies on children and adolescents [6,48,49] but in contrast to results of an adult population assessed by computed tomography [43].

In this study, no significant effect of BMI on the upper airway was found, which is surprising as previous studies have shown that increased BMI may be associated with reduced dimensions and increased resistance of the upper airway [2,15,40,50]. The reason for this result may be due to variation in underweight and overweight between the groups and the dento-craniofacial morphological deviations in the study group.

The present study improves the understanding of acoustic assessment of the upper airway in children with class II and large overjet with indication for growth adaptive treatment of the mandible. Because narrow upper airway is of great importance for the risk of SDB [1,4] whose etiology is multifactorial [1,2], studies using non-invasive techniques to examine or screen for narrow upper airway may prove valuable. Future research may examine the effect of growth adaptive treatment of the mandible with removable functional appliance on upper airway dimensions and resistance compared to a control group. However, inclusion and exclusion criteria for such studies should be clear and consistent. Furthermore, statistical adjustment of possible confounding factors should be performed, as airway resistance can be affected by multiple factors [1,2]. The results of the present study may contribute to an increased focus on the importance of interdisciplinary collaboration between medical doctors and specialists in orthodontics in diagnostics, prevention, and treatment of non-syndromic children at risk for narrow upper airways.

CONCLUSIONS

The study was the first of its kind to demonstrate reduced nasal airway dimensions in children with class II and large overjet with indication for growth adaptive treatment of the mandible compared to children with neutral occlusion using acoustic reflection. Bias regarding age, gender and body mass index were minimized in the study due to a comparable control group and statistical adjustments. The study showed that class II and severe large overjet is associated with risk of narrow upper airway dimensions. The results may prove valuable in using acoustic rhinometry as a non-invasive risk assessment of narrow upper airways in children with class II and large overjet to prevent and diagnose eventual risk of sleep-disordered breathing.

ACKNOWLEDGMENTS AND DISCLOSURE STATEMENTS

The authors thank the Postgraduate Program in Orthodontics, Department of Odontology, University of Copenhagen and the municipal dental health cares in Copenhagen, Gladsaxe, Hvidovre, Hørsholm, and Rødovre for help in the recruiting process of the participants. Thanks to Ib Jarle Christensen, Senior researcher, Department of Pathology, Copenhagen University Hospitals, The Capital Region of Denmark for statistical assistance and to Arman Teymouri Niknam, Administrative officer, University of Copenhagen, Denmark for language support. Many thanks to all the participants and their families for participating in the study. The authors thank the Danish Dental Association and the Health Foundation (Helsefonden) for economic support, which made the study possible. Thanks to Sleep Group Solutions for sponsoring disposable filters, nose tips, and mouth pieces for the acoustic pharyngometer and rhinometer. The authors declare no conflict of interest. This work was supported by the Danish Dental Association and The Health Foundation (Helsefonden). Sleep Group Solutions sponsored disposable filters, nose tips, and mouth pieces for the acoustic pharyngometer and rhinometer.

REFERENCES

1. Kaditis AG, Alonso Alvarez ML, Boudewyns A, Alexopoulos EI, Ersu R, Joosten K, Larramona H, Miano S, Narang I, Trang H, Tsaoussoglou M, Vandenbussche N, Villa MP, Van Waardenburg D, Weber S, Verhulst S. Obstructive sleep disordered breathing in 2- to 18-year-old children: diagnosis and management. Eur Respir J. 2016 Jan;47(1):69-94. [Medline: 26541535] [doi: 10.1183/13993003.00385-2015]
2. Bixler EO, Vgontzas AN, Lin HM, Liao D, Calhoun S, Vela-Bueno A, Fedok F, Vlasic V, Graff G. Sleep disordered breathing in children in a general population sample: prevalence and risk factors. Sleep. 2009 Jun;32(6):731-6. [Medline: 19544748] [PMC free article: 2690559] [doi: 10.1093/sleep/32.6.731]
3. Galeotti A, Festa P, Viarani V, Pavone M, Sitzia E, Piga S, Cutrera R, De Vincentiis GC, D'Antò V. Correlation between cephalometric variables and obstructive sleep apnoea severity in children. Eur J Paediatr Dent. 2019 Mar;20(1):43-47. [Medline: 30919644] [doi: 10.23804/ejpd.2019.20.01.09]
4. Fagundes NCF, Gianoni-Capenakas S, Heo G, Flores-Mir C. Craniofacial features in children with obstructive sleep apnea: a systematic review and meta-analysis. J Clin Sleep Med. 2022 Jul 1;18(7):1865-1875. [Medline: 35074045] [PMC free article: 9243277] [doi: 10.5664/jcsm.9904]
5. Aroucha Lyra MC, Aguiar D, Paiva M, Arnaud M, Filho AA, Rosenblatt A, Thérèse Innes NP, Heimer MV. Prevalence of sleep-disordered breathing and associations with malocclusion in children. J Clin Sleep Med. 2020 Jul 15;16(7): 1007-1012. [Medline: 32052740] [PMC free article: 7954063] [doi: 10.5664/jcsm.8370]
6. Anandarajah S, Dudhia R, Sandham A, Sonnesen L. Risk factors for small pharyngeal airway dimensions in preorthodontic children: A three-dimensional study. Angle Orthod. 2017 Jan;87(1):138-146. [Medline: 27304232] [PMC free article: 8388599]] [doi: 10.2319/012616-71.1]
7. Helm S, Prydsö U. Prevalence of malocclusion in medieval and modern Danes contrasted. Scand J Dent Res. 1979 Apr;87(2):91-7. [Medline: 388614] doi: 10.1111/j.1600-0722.1979.tb00659.x]
8. Abdalla Y, Brown L, Sonnesen L. Effects of a fixed functional appliance on upper airway volume: A 3-dimensional cone-beam computed tomography study. Am J Orthod Dentofacial Orthop. 2020 Jul;158(1):40-49. [Medline: 32389570] [doi: 10.1016/j.ajodo.2019.07.013]
9. Miltenburg Caspersen L, Sonnesen L. Secular trend of the skeletal maturation in relation to peak height velocity-a comparison between two groups of children born 1969-1973 and 1996-2000. Eur J Orthod. 2020 Dec 2;42(6):612-618. [Medline: 31942968] [doi: 10.1093/ejo/cjz098]
10. Björk A. [Kæbernes relationer til det øvrige cranium]. In: Lundström A, editor. [Nordisk lärobok i ortodonti]. Stockholm: Sveriges Tandläkarförbunds Förlagsförening; 1971. p. 69-110.
11. Hansen C, Markström A, Sonnesen L. Sleep-disordered breathing and malocclusion in children and adolescents-a systematic review. J Oral Rehabil. 2022 Mar;49(3):353-361. [Medline: 34779522] [doi: 10.1111/joor.13282]
12. Hansen C, Markström A, Sonnesen L. Specific dento-craniofacial characteristics in non-syndromic children can predispose to sleep-disordered breathing. Acta Paediatr. 2022 Mar;111(3):473-477. [Medline: 34847264] [doi: 10.1111/apa.16202]

13. Liu Y, Zhao T, Ngan P, Qin D, Hua F, He H. The dental and craniofacial characteristics among children with obstructive sleep apnoea: a systematic review and meta-analysis. Eur J Orthod. 2023 May 31;45(3):346-355. [Medline: 36763565] [doi: 10.1093/ejo/cjac074]
14. Hoffstein V, Fredberg JJ. The acoustic reflection technique for non-invasive assessment of upper airway area. Eur Respir J. 1991 May;4(5):602-11. [Medline: 1936231] [doi: 10.1183/09031936.93.04050602]
15. Bokov P, Essalhi M, Medjahdi N, Boureghda S, Konofal E, Lecendreux M, Delclaux C. The utility of acoustic pharyngometry and rhinometry in pediatric obstructive sleep apnea syndrome. Sleep Med. 2019 Jun;58:75-81. [Medline: 31132575] [doi: 10.1016/j.sleep.2019.03.003]
16. Hansen C, Sonnesen L. Reliability of Acoustic Pharyngometry and Rhinometry Examination in Children and Adolescents. J Oral Maxillofac Res. 2022 Sep 30;13(3):e4. [Medline: 36382012] [PMC free article: 9617254] [doi: 10.5037/jomr.2022.13304]
17. Hansen C, Sonnesen L, Markström A. Signal quality of home polygraphy in children and adolescents. Acta Paediatr. 2023 Dec;112(12):2583-2588. [Medline: 37661830] [doi: 10.1111/apa.16964]
18. Hansen C, Bakke M, Sonnesen L. Oro-facial function and quality of life in children and adolescents with large horizontal maxillary overjet-A case-control study. J Oral Rehabil. 2024 Jun;51(6):982-991. [Medline: 38414127] [doi: 10.1111/joor.13669]
19. Hansen C, Sonnesen L, Bakke M, Markström A. Prevalence of sleep-disordered breathing in children and adolescents with large horizontal maxillary overjet due to mandibular retrognathia: a case control study. J Clin Sleep Med. 2024 Jul 3. [Medline: 38958059] [doi: 10.5664/jcsm.11248]
20. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008 Apr;61(4):344-9. [Medline: 18313558] [doi: 10.1016/j.jclinepi.2007.11.008]
21. Siersbaek-Nielsen S, Solow B. Intra- and interexaminer variability in head posture recorded by dental auxiliaries. Am J Orthod. 1982 Jul;82(1):50-7. [Medline: 6961777] [doi: 10.1016/0002-9416(82)90546-2]
22. Björk A, Krebs A, Solow B. A method for epidemiological registration of malocculusion. Acta Odontol Scand. 1964 Feb;22:27-41. [Medline: 14158468] [doi: 10.3109/00016356408993963]
23. Solow B. Orthodontic screening and third party financing. Eur J Orthod. 1995 Feb;17(1):79-83. [Medline: 7737348] [doi: 10.1093/ejo/17.1.79]
24. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity. Pediatr Obes. 2012 Aug;7(4):284-94. [Medline: 22715120] [doi: 10.1111/j.2047-6310.2012.00064.x]
25. Sleep Group Solutions. Eccovision® Acoustic Pharyngometer and Rhinometer Operator Manuals [Internet]. Hollywood, Florida, USA: Sleep Group Solutions. [URL: https://eccovision.net/]
26. Knappe SW, Sonnesen L. The Reliability and Influence of Body Position on Acoustic Pharyngometry and Rhinometry Outcomes. J Oral Maxillofac Res. 2020 Dec 31;11(4):e1. [Medline: 33598109] [PMC free article: 7875104] [doi: 10.5037/jomr.2020.11401]
27. Houston WJ. The analysis of errors in orthodontic measurements. Am J Orthod. 1983 May;83(5):382-90. [Medline: 6573846] [doi: 10.1016/0002-9416(83)90322-6]
28. Dahlberg G. Statistical Methods for Medical and Biological Students. Br Med J. 1940 Sep 14;2(4158):358-9. [PMC free article: 2179091] [doi: 10.1136/bmj.2.4158.358-b]
29. Iwasaki T, Sato H, Suga H, Takemoto Y, Inada E, Saitoh I, Kakuno K, Kanomi R, Yamasaki Y. Influence of pharyngeal airway respiration pressure on Class II mandibular retrusion in children: A computational fluid dynamics study of inspiration and expiration. Orthod Craniofac Res. 2017 May;20(2):95-101. [Medline: 28414873] [doi: 10.1111/ocr.12145]
30. Kumar S, Jayan B, Kumar MPP, Sharma M, Nehra K, Bansal AK. Acoustic pharyngometry vs lateral cephalometry: A comparative evaluation of pharyngeal airway dimensions in patients with skeletal class I and skeletal class II malocclusion. Orthodontic Waves. 2019;78:118-25. [doi: 10.1016/j.odw.2019.07.001]
31. Claudino LV, Mattos CT, Ruellas AC, Sant' Anna EF. Pharyngeal airway characterization in adolescents related to facial skeletal pattern: a preliminary study. Am J Orthod Dentofacial Orthop. 2013 Jun;143(6):799-809. [Medline: 23726330] [doi: 10.1016/j.ajodo.2013.01.015]
32. Gökçe G, Akan B, Göde S, Veli I. Comparative Evaluation of Upper Airway Dimensions With Acoustic Rhinometry and Cone-Beam Computed Tomography. Eastern Journal of Medicine. 2022;27:235-41. [doi: 10.5505/ejm.2022.58224]
33. Tsolakis IA, Venkat D, Hans MG, Alonso A, Palomo JM. When static meets dynamic: Comparing cone-beam computed tomography and acoustic reflection for upper airway analysis. Am J Orthod Dentofacial Orthop. 2016 Oct;150(4): 643-650. [Medline: 27692422] [doi: 10.1016/j.ajodo.2016.03.024]
34. Sakai RHUS, Marson FAL, Sakuma ETI, Ribeiro JD, Sakano E. Correlation between acoustic rhinometry, computed rhinomanometry and cone-beam computed tomography in mouth breathers with transverse maxillary deficiency. Braz J Otorhinolaryngol. 2016 Nov 25;84(1):40-50. [Medline: 28017262] [PMC free article: 9442894] [doi: 10.1016/j.bjorl.2016.10.015]
35. Corey JP, Gungor A, Nelson R, Fredberg J, Lai V. A comparison of the nasal cross-sectional areas and volumes obtained with acoustic rhinometry and magnetic resonance imaging. Otolaryngol Head Neck Surg. 1997 Oct;117(4):349-54. [Medline: 9339795] [doi: 10.1016/S0194-5998(97)70125-6]

36. Solow B, Skov S, Ovesen J, Norup PW, Wildschiødtz G. Airway dimensions and head posture in obstructive sleep apnoea. Eur J Orthod. 1996 Dec;18(6):571-9. [Medline: 9009421] [doi: 10.1093/ejo/18.6.571]
37. Solow B, Tallgren A. Natural head position in standing subjects. Acta Odontol Scand. 1971 Nov;29(5):591-607. [Medline: 5290983] [doi: 10.3109/00016357109026337]
38. Sonnesen L, Petersson A, Berg S, Svanholt P. Pharyngeal Airway Dimensions and Head Posture in Obstructive Sleep Apnea Patients with and without Morphological Deviations in the Upper Cervical Spine. J Oral Maxillofac Res. 2017 Sep 30;8(3):e4. [Medline: 29142656] [PMC free article: 5676314] [doi: 10.5037/jomr.2017.8304]
39. Hellsing E. Changes in the pharyngeal airway in relation to extension of the head. Eur J Orthod. 1989 Nov;11(4):359-65. [Medline: 2591483] [doi: 10.1093/oxfordjournals.ejo.a036007]
40. Andersen IG, Holm JC, Homøe P. Obstructive sleep apnea in children and adolescents with and without obesity. Eur Arch Otorhinolaryngol. 2019 Mar;276(3):871-878. [Medline: 30689039] [doi: 10.1007/s00405-019-05290-2]
41. Solow B, Kreiborg S. Soft-tissue stretching: a possible control factor in craniofacial morphogenesis. Scand J Dent Res. 1977 Sep;85(6):505-7. [Medline: 271349] [doi: 10.1111/j.1600-0722.1977.tb00587.x]
42. Solow B. The dentoalveolar compensatory mechanism: background and clinical implications. Br J Orthod. 1980 Jul;7(3):145-61. [Medline: 6934010] [doi: 10.1179/bjo.7.3.145]
43. Shigeta Y, Ogawa T, Venturin J, Nguyen M, Clark GT, Enciso R. Gender- and age-based differences in computerized tomographic measurements of the orophaynx. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008 Oct;106(4): 563-70. [Medline: 18602313] [PMC free article: 2621333] [doi: 10.1016/j.tripleo.2008.03.032]
44. Bucci R, Rongo R, Zunino B, Michelotti A, Bucci P, Alessandri-Bonetti G, Incerti-Parenti S, D'Antò V. Effect of orthopedic and functional orthodontic treatment in children with obstructive sleep apnea: A systematic review and meta-analysis. Sleep Med Rev. 2023 Feb;67:101730. [Medline: 36525781] [doi: 10.1016/j.smrv.2022.101730]
45. Li L, Liu H, Cheng H, Han Y, Wang C, Chen Y, Song J, Liu D. CBCT evaluation of the upper airway morphological changes in growing patients of class II division 1 malocclusion with mandibular retrusion using twin block appliance: a comparative research. PLoS One. 2014 Apr 4;9(4):e94378. [Medline: 24705466] [PMC free article: 3976395] [doi: 10.1371/journal.pone.0094378]
46. Pavoni C, Cretella Lombardo E, Franchi L, Lione R, Cozza P. Treatment and post-treatment effects of functional therapy on the sagittal pharyngeal dimensions in Class II subjects. Int J Pediatr Otorhinolaryngol. 2017 Oct;101:47-50. [Medline: 28964309] [doi: 10.1016/j.ijporl.2017.07.032]
47. Entrenas I, González-Chamorro E, Álvarez-Abad C, Muriel J, Menéndez-Díaz I, Cobo T. Evaluation of changes in the upper airway after Twin Block treatment in patients with Class II malocclusion. Clin Exp Dent Res. 2019 Mar 18;5(3): 259-268. [Medline: 31249707] [PMC free article: 6585589] [doi: 10.1002/cre2.180]
48. Kim YJ, Hong JS, Hwang YI, Park YH. Three-dimensional analysis of pharyngeal airway in preadolescent children with different anteroposterior skeletal patterns. Am J Orthod Dentofacial Orthop. 2010 Mar;137(3):306.e1-11; discussion 306-7. [Medline: 20197163] [doi: 10.1016/j.ajodo.2009.10.025]
49. Monahan KJ, Larkin EK, Rosen CL, Graham G, Redline S. Utility of noninvasive pharyngometry in epidemiologic studies of childhood sleep-disordered breathing. Am J Respir Crit Care Med. 2002 Jun 1;165(11):1499-503. [Medline: 12045123] [doi: 10.1164/rccm.200111-061OC]
50. Kang JH, Kim HJ, Song SI. Obstructive sleep apnea and anatomical structures of the nasomaxillary complex in adolescents. PLoS One. 2022 Aug 4;17(8):e0272262. [Medline: 35925992] [PMC free article: 9352039] [doi: 10.1371/journal.pone.0272262]

To cite this article:
Hansen C, Bakke M, Sonnesen L.
Risk of Narrow Upper Airway in Class II Children with Large Horizontal Maxillary Overjet Assessed By Acoustic Reflection: a Case-Control Study
J Oral Maxillofac Res 2024;15(3):e5
URL: http://www.ejomr.org/JOMR/archives/2024/3/e5/v15n3e5.pdf
doi: 10.5037/jomr.2024.15305