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Original article

Palatal surface and volume in mouth-breathing subjects evaluated with three-dimensional analysis of digital dental casts—a controlled study

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Summary

Objective: To compare the anatomical characteristics of the maxillary arch, identified as palatal surface area and volume, between mouth-breathing and nose-breathing subjects using a three-dimensional (3D) analysis of digital dental casts.
Methods: Twenty-one Caucasian subjects (14 females and 7 males) with a mean age of 8.5 years [standard deviation (SD) 1.6 years] were selected according to the following criteria: mouth-breathing pattern due to allergic rhinitis, early mixed dentition, skeletal Class I relationship, and pre-pubertal stage of cervical vertebral maturation. This study group (SG) was compared with a control group (CG) of 17 nose-breathing subjects (9 females and 8 males, mean age: 8.5 years; SD: 1.7 years). For each subject, initial dental casts were taken and the upper arch was scanned using a 3D laser scanner. On each digital model, 3D measurements were performed to analyse maxillary arch morphology. Between-group differences were tested with the independent sample Student's *t*-test ($P < 0.05$).
Results: In mouth-breathing subjects, changes in physiological function of the upper respiratory tract resulted in skeletal adaptations of the maxillary arch. In the SG, both palatal surface area and volume were significantly smaller when compared with values of the CG. In particular, the palatal surface area and palatal volume were, respectively, 13.5 and 27.1 per cent smaller in the SG when compared to the CG.
Conclusions: Subjects with prolonged mouth breathing showed a significant reduction of the palatal surface area and volume leading to a different development of the palatal morphology when compared with subjects with normal breathing pattern.

Introduction

Ordinarily, the inspiratory and expiratory airstreams are channelled through the nose as the mouth is usually closed. However, in some individuals, because of nasal airway inadequacy or habit, the oral cavity becomes the established and predominant route for the passage of respiratory airflow (1).

The influence of breathing mode on orofacial growth has been a widely debated for decades and is still a controversial issue. According to the Moss theory (2, 3) of functional matrix, only nasal breathing allows proper growth of the dentofacial complex. This theory is based on the principle that normal nasal respiratory activity influences the development of craniofacial structures, favouring their harmonious growth by adequately interacting with mastication and swallowing (2, 3).

There have been many attempts to determine a casual relationship between dentofacial deformities and nasal airway inadequacy (4–8). However, the relationship between mouth breathing and dentofacial development is still controversial.

Some authors do not associate nasal obstruction as a major factor causing abnormal growth of craniofacial structures with special regard to the transverse dimension of the whole maxillary arch (9–11). In contrast, several investigators (12–15) have described a special facial type in mouth-breathing subjects presenting with enlarged adenoids and/or palatine tonsils. Generally referred to as 'adenoid facies', this facial type is characterized by a long, narrow face, pinched nostrils, short upper lip, prominent maxillary incisors, and lips-apart posture, narrow V-shaped upper arch with a high palatal vault and a somewhat dull appearance due to constant open-mouth posture (12–15).

The aim of this study was to compare the anatomical characteristics of the maxillary arch, identified as palatal surface area and volume, between mouth- and nose-breathing subjects using three-dimensional (3D) analysis of digital dental casts with the primary objective to visualize the effects of chronic mouth breathing on the development of the maxillary arch.

Subjects and methods

For the present study, ethical approval was obtained from the Ethical Committee of the University of Rome "Tor Vergata", and informed consent was obtained from the subjects' parents before inclusion.

Twenty-one Caucasian subjects (14 females and 7 males) with a mean age of 8.5 years [standard deviation (SD) 1.6 years] who sought for orthodontic treatment at the Department of Orthodontics at the University of Rome "Tor Vergata" were included. The inclusion criteria for the enrolment of the subjects in the study group (SG) were mouth-breathing pattern due to allergic rhinitis, early mixed dentition with a Class I or edge-to-edge molar relationship, skeletal Class I relationships, and pre-pubertal stage of cervical vertebral maturation as assessed on lateral cephalograms (CS1, CS2) (16). The mode of breathing was assessed by an experienced otorhinolaryngologist by complete physical examination, including rhinomanometry for measuring nasal airflow and pressure during respiration, skin testing, anterior rhinoscopy, flexible nasopharyngoscopy, or nasopharyngeal x-ray. Furthermore, the history of either nose or mouth breathing was collected by a questionnaire answered by the subjects' parents. Only at the end of the complete examination, the otorhinolaryngologist classified the subjects as nose breathers or as exclusive mouth breathers.

Exclusion criteria were sucking habits, previous history of nasal respiratory surgery, previous orthodontic treatment, cleft lip and/or palate, and other genetic diseases.

The SG was compared with a control group (CG) of 17 pre-pubertal subjects (9 females and 8 males) with no transverse or vertical skeletal discrepancies presenting with nose-breathing pattern and mean age of 8.5 years (SD 1.7 years). The CG matched the SG in terms of dentition stage, skeletal relationships, and skeletal maturation.

In order to analyse the palatal surface area and volume, study casts of the maxillary arches of all subjects were scanned using a 3D laser scanner (D800, 3Shape A/S, Copenhagen, Denmark) with a reported accuracy of 15 µm.

Each dental cast was scanned from 10 or more views that were then combined and rendered into 3D by using a specific software (3shape-ScanItOrthodontics™ 2010-2p3, 3Shape A/S).

As described in a previous study by Primozic *et al.* (17), each dental cast of the SG and CG was preprocessed to remove unwanted data. In order to measure palatal surface area and calculate palatal volume, the boundaries for the palate must be defined. The gingival plane and a distal plane were used as boundaries for the palate. The gingival plane was obtained by connecting the centre of the dentogingival junction of all erupted permanent and deciduous teeth (Figure 1). The distal plane was created through two points at the distal of the second primary molars perpendicular to the gingival plane.

Statistical analysis

To determine the reliability of the method, measurements on 20 digital dental casts were performed by one trained examiner (LTHG) and repeated by the same examiner after an interval of approximately 2 weeks. A paired *t*-test was used to compare the two measurements (systematic error). The magnitude of the random error was calculated by using the method of moment's estimator (18). The power of the study for the independent sample *t*-test was calculated on the basis of the sample size of two groups and an effect size equal to 0.9 (19). The power was 0.80 at an alpha level of 0.05 (SigmaStat 3.5, Systat Software, Point Richmond, California, USA).

Descriptive statistics were calculated for all the measurements in each group. Exploratory statistics revealed that all variables were normally distributed (Kolmogorov–Smirnov test) with equality of variances (Levene's test). Significant between-group differences were tested with the independent sample Student's *t*-test (Table 1). All statistical computations were performed by using a specific software (SigmaStat 3.5, Systat Software).

Results

No systematic error was found between the repeated digital measurements. The systematic error was reduced by precise definitions of points in the presence of a previously trained examiner. The mean random error for the palatal surface area was 26.1 mm^2, while for the palatal volume, it was 143.8 mm^3 and within acceptable limits because the software allowed a more accurate view of the anatomic details. Descriptive statistics and significant between-group differences are given in Table 1.

Forty-four per cent of the subjects of the SG presented with palatine and/or pharyngeal tonsil hypertrophy, though the pathological feature that was found in all subjects of the SG was the prolonged allergic rhinitis. Eleven subjects of the SG presented with a unilateral posterior crossbite, five with a bilateral posterior crossbite, and five without posterior crossbite. In five patients with unilateral posterior crossbite, an associated anterior open bite due to lack of space to allow the complete eruption of upper incisors was observed.

The SG presented with significant lower values of the palatal surface area (798.8 mm^2) and palatal volume (2738.7 mm^3) with respect

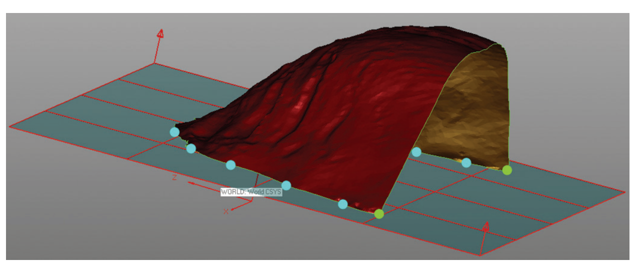

Figure 1. Gingival plane constructed by connecting the midpoints of the dentogingival junction of all erupted teeth. The distal plane is built perpendicular to the dentogingival plane and passing from the two most distal points corresponding to the distal surface of the second primary molars.

Table 1 Descriptive statistics and statistical comparisons on palatal surface area and volume between study and control groups.

Variables	Study group (n = 21)		Control group (n = 17)		Difference	t-Test	
	Mean	SD	Mean	SD		t	P
Surface area (mm^2)	798.8	90.6	923.0	88.1	124.2	4.3	0.000
Volume (mm^3)	2738.7	567.8	3756.6	559.7	1017.9	5.5	0.000

SD, standard deviation.

to the CG (923.0 mm^2 and 3756.6 mm^3, respectively). In particular, the palatal surface area and palatal volume were, respectively, 13.5 and 27.1 per cent smaller in the SG when compared to the CG.

Discussion

This study aimed to assess the differences of the palatal region morphology between mouth-breathing and nose-breathing subjects. To our knowledge, this is the first attempt to evaluate the 3D anatomical characteristics of the maxillary arch in growing subjects who were primarily diagnosed to be affected by oral breathing respiratory pattern.

Conflicting conclusions are reported in the literature about the influence of the mode of breathing on the development of maxillofacial complex. This could be due to the fact that nasal airway inadequacy is usually subjective and the judgement of breathing mode differs among investigators (20). In order to evaluate respiratory function and its effects on the morphology of the palatal region, a clear differentiation between nose and mouth breathers is required. However, this distinction is not easily made since most mouth breathers usually have some nasal respiratory capacity as well (21). Therefore, in this study, only data from a group of subjects classified at the end of complete physical examination as exclusive mouth breathers were included.

Moreover, the morphology of the palate and of the maxillary arch has been assessed usually by measuring transverse dental distances on study casts giving incomplete information about the 3D morphology of the palatal vault. To overcome this limitation, an evaluation of 3D characteristics of the maxillary arch by means of 3D laser technology has been used (22).

In this study, subjects who were mouth breathers due to a complete blockage of the nasal airway resulted in skeletal adaptations of the palatal region. In fact, among mouth-breathing subjects, both palatal surface area and volume were significantly smaller with respect to the values in subjects with normal breathing pattern. In particular, the palatal surface area and the palatal volume were, respectively, 13.5 and 27.1 per cent smaller in children with a mouth-breathing pattern when compared with subjects with normal breathing pattern. A smaller palatal volume and surface in the mouth-breathing subjects could be related, at least in part, to a smaller dimension of the head of the subjects of the SG with respect to the CG. Therefore, we measured the length of the anterior cranial base (distance from point Sella to point Nasion) on the lateral cephalograms corresponding to the dental casts of all subjects in both groups (data available on request from the authors). The Sella-Nasion length of each subject of both groups was compared to European norms (23). As for the enlargement factor, all measurements were corrected to life size. The length of the anterior cranial base was considered normal when it fell within 1 SD around the mean value for age and gender. Only one female subject of the CG presented with a dimension of the anterior cranial base larger than the mean + 1 SD, while all other subjects in both groups presented with normal lengths of the anterior cranial base. The average values and SDs of S-N length in SG and CG were 63.6 ± 1.6 and 62.9 ± 1.4 mm, respectively, with no statistically significant difference (P = 0.118). Therefore, the dimension of the head of the individual subjects appeared not to have a direct influence on the dimension of the palate.

It has been shown that there is sexual dimorphism for the maxillary arch width in the mixed dentition with males showing larger widths both at the deciduous canines and at the second deciduous molars (24). However, no study has analysed sexual dimorphism for either palatal volume or surface during the mixed dentition. In the current investigation, the SG presented with a larger female-to-male ratio than CG though this difference was not statistically significant (chi square with Yates correction = 0.278, P = 0.598). Both palatal volume and surface were very similar in male and female subjects in both groups (Supplementary Table). The relative small sample size in both groups did not allow to derive definitive conclusions on sexual dimorphism for palatal volume or surface and, therefore, further studies are required.

Probably, a change in the mode of breathing leads to a change in the balance between tongue and cheek pressures. As reported by Harvold *et al.* (25), the maxillary arch form is mainly determined by tongue posture and movements especially during certain stages of dental development such as during complete eruption of the maxillary first molars. In growing children, the development of the palatal vault is influenced by local factors like which muscles are recruited and how they are used in the deviant respiratory pattern as well as by gene products that provide factors that may affect the receptivity and responsiveness of cells to intrinsic and extrinsic stimuli (17, 26).

As shown in Figures 2 and 3, prolonged mouth breathing in growing subjects influenced the development of a different palatal morphology with a narrower and higher palatal vault compared to subjects with a nose-breathing pattern. These modifications in the anatomy of the maxilla were clearly quantified by 3D measurements of the palatal surface area and volume that have been reported as reliable indicators of palatal growth (17).

The results of the current investigation are in agreement with previous studies that showed that nasal deformities and maxillary growth deficiencies were correlated with increased nasal airway resistance (27). Moreover, Bresolin *et al.* (4), Harari *et al.* (7), and Berwig *et al.* (28) compared plaster casts of nasal and mouth breathers at the age of 8–12 years demonstrating that a change in the breathing pattern of children can lead to a narrowing of both intermolar and intercanine widths.

However, our findings are in disagreement with those reported by Primozic *et al.* (11) who did not find differences in palatal surface area and volume between mouth and the nose breathers. These conflicting results may be due to a different group selection since in this study the primary inclusion criteria was the abnormal respiratory pattern and not the dentition stage and occlusal characteristics. Furthermore, the subjects included in this study were older than those analysed in the study by Primozic *et al.* (11) that included mainly 5-year-old subjects in the primary dentition phase. Therefore, it seems advisable to correct the breathing pattern already at early developmental phases in order to prevent adverse maxillary growth.

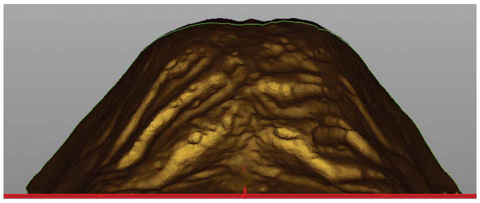

Figure 2. Three-dimensional palatal volume rendering in a nasal-breathing subject.

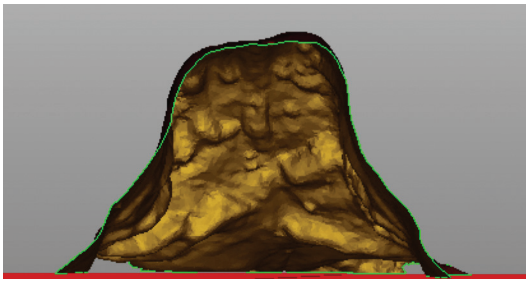

Figure 3. Three-dimensional palatal volume rendering in a mouth-breathing subject.

Conclusions

Subjects with a mouth-breathing pattern have a different palatal morphology with significantly smaller palatal surface areas and volumes compared with nose-breathing subjects.

Supplementary material

Supplementary material is available at *European Journal of Orthodontics* online.

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