Palate shape and size and palatal rugae morphology of children with anterior open bite and normal vertical overbite

Helena Alvarez-Solarte[1]

Valentina Sierra-Alzate[2]

Juliana Sánchez-Garzón[3]

Paola Botero-Mariaca[4]

[1]Postgraduate Student of Orthodontics. Universidad Cooperativa de Colombia – Medellín – Colombia
[2]Speech Therapist, Assistant Professor, Universidad Cooperativa de Colombia – Medellín – Colombia
[3]Dentist, Master in epidemiology CES University. Assistant Professor, Universidad Cooperativa de Colombia – Medellín – Colombia
[4]Dentist, Orthodontist CES University, Associate Professor, Universidad Cooperativa de Colombia – Medellín – Colombia

Corresponding author:

paola.botero@ucc.edu.co

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KEYWORDS

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ABSTRACT

Purpose: To determine differences between open bite and normal vertical overbite regarding distribution, size and clinical appearance of palatal rugae, depth and length of the palate, intercanine and intermolar widths and arch perimeter.

Methods: A cross-sectional study was performed in 264 superior models were studied with a 3D analysis system. A total of 132 individuals with AOB and 132 individuals with normal vertical overbite were evaluated, chosen from public schools with ages between 8 and 16 years. Palatal anthropometric features were evaluated. Qualitative analysis of palatal rugae was performed, exploring the shape, direction, unification and sensitivity of the palate. The Mann Whitney and Chi Square tests were used for statistical analyses.

Results: The average age was 11.37 +/- 2.27 years for normal overbite and 11.87 for anterior open bite, with 54.9% of women. No significant differences were found between subjects with AOB and subjects with normal vertical overbite regarding intermolar or intercanine width. The maxillary length and depth and the height and width of palatal rugae were lower in the AOB group. The most common rugae shapes were curved and wavy, predominating in the horizontal direction with a parallel distribution.

Conclusion: Qualitative evaluation demonstrated asymmetry in the shape, direction and unification of rugae in both groups. Most arch measurements were greater in individuals with AOB.

INTRODUCTION

An anterior open bite (AOB) is present when no vertical overlap between the incisors occurs and an interincisal separation can be measured.[1] Subjects with this class of malocclusion can show other impairments associated with open bite such the presence of a narrow palate, prominent palatal rugae, atypical deglutition and a forward position of the tongue at rest.[2-4]

The widening of the palate occurs primarily during the first 5 years of life, at the level of the intermaxillary and interpalatine sutures. In later stages of development, any increase in the width is the result of bone apposition on the outer surfaces of the maxillary and buccal eruption of permanent teeth, generating an increase of up to 2.2 mm in intermolar width.[5] Width increases are correlated with the vertical growth of the alveolar process, whose direction in the upper arch is divergent, forming the palatal walls.[6]

A narrow or triangular palate is consistent with an abnormal lingual position at rest and during swallowing because the tongue does not remain in the palatal rugae but on the floor of mouth, exerting force on the teeth. A low position of the tongue can generate expansion of the lower dental arch and promote collapse of the upper arch.[2]

The palatal rugae are crests located in the anterior part of the palatal mucosa on each side of the palatine raphe and behind the incisive papilla. They appear by the third month of intrauterine life (weeks 12–14) with connective tissue covering the palatine process of the maxillary bone. The palatal rugae growth and development are controlled by epithelial-mesenchymal interactions through the extracellular matrix.[5] With an increasing size of the front of the palate in the early years of life, the length of the rugae and the distance between them increases; from this moment, the model of rugae orientation becomes clearer and remains unchanged throughout life.[7-10] The number of palatal rugae and their arrangement, shape and length are particular to each individual, similar to fingerprints.[11] Physiologically, the palatal rugae are involved in the oral stage of swallowing and help to improve the relationship between food and the taste receptors on the dorsal surface of the tongue. Additionally, the rugae participate in speech and sucking.[12-14]

Palatal rugae are considered as stable references for the quantitative analysis of models due to their shape, design and features and because they are not altered by tooth eruption or loss[15]. Although palatal rugae show little bilateral symmetry in their distribution pattern, the number of rugae on each side varies between three and five; they are not extended posteriorly beyond the anterior half of the hard palate and never cross the midline. The anterior palatal rugae are generally more prominent than the posterior ones.[14] A relationship has been observed between the clinical appearance and size of the palatal rugae and the presence of open bite,[4] for which an increased size has been reported.

Moreover, individuals with AOB can show kinaesthetic and proprioceptive limitations generated by alterations in reciprocal contact between the physiological contacts of the lingual tip and palatal rugae and by the difficulty in recognizing the tongue location within the oral cavity.[16] It has been stated that this alteration in rugae proprioception is influenced by the size of the palatal rugae. Finally, it has been found that a slight roughness, corresponding to the pressure exerted by the tongue at a resting position, and pronounced or hypertrophic palatine folds may occur due to a lack of stimulation of the tongue at rest or during swallowing; however, this criterion is not the result of studies with sufficient evidence.[17]

Being able to determine the differences in palatal features and size between individuals with AOB and individuals with normal vertical overbite (NVO) is critical to establish other aetiological factors involved, which helps to establish a treatment scheme according to the interventions required by the patient. There are a few studies available in the literature that compare the shape and size of the maxilla and palatal rugae [8,9,18] between individuals with AOB and NVO, but none of them compares the shape and size of the palatal rugae. It should be normal to find that AOB patients have a narrower palate and thicker palatal rugae. Therefore, the aim of the present study is to determine if there are differences between patients with AOB and with NVO regarding the distribution, size and clinical appearance of the palatal rugae, depth, palatal length, intercanine and intermolar widths and arch perimeter.

MATERIALS AND METHODS:

A cross-sectional study was performed in which a total of 264 cast models were obtained from schoolchildren from 5 public schools in the municipality of Envigado. A total of 132 dental models were obtained from children with AOB, and 132 dental models were obtained from children with NVO. The sample size was calculated based on 2% AOB prevalence with a 95% confidence interval and a sampling error of 7%, based on a population of 22.955 inhabitants. The 264 students selected met the following inclusion criteria: schoolchildren aged 8–16 years with AOB and NVO from public schools from the municipality of Envigado, with four upper and lower incisors fully erupted and without posterior crossbite. Children whose parents did not sign the consent form, individuals who had a mental syndrome and facial and/or skeletal malformations, children who received or were in interceptive and/or corrective treatment and children with finger and lower lip sucking habits

were excluded. AOB definition considered for the study was the following: anterior teeth that do not reach the line of occlusion and do not contact the antagonists by at least 1 mm, as measured from the incisal edges of upper incisors to the incisal edges of lower incisors. While NVO definition was: incisal edges of the mandibular incisors in contact with the palatal surfaces of the maxillary incisors, with approximately one-third of the crowns of the lower incisors covered.

This research was approved by the bioethics committee of the Cooperative University of Colombia. The informed consent and assent forms were signed before beginning the study.

Impressions were obtained in alginate, the powder and liquid were mixed in a ratio according to the manufacturer's instructions, and the mixture was poured into type III plaster (the ratio of water to powder was obtained by dividing the water volume by the powder weight). Two consistencies were prepared: one consistency was more fluid to copy perfectly palatal rugae and teeth surfaces, while the second consistency was denser and was poured over the first one to finish the filling of the impression.

The superior models of AOB and NVO were digitised by the company i3D with an optical 3D scanner (The ATOS Core Kinematics) using a lens with a distance of 440 mm, a volume of 300 x 230 x 230 mm and a scanner with a precision of 15 microns. The measurements were performed on the 3D digital dental models using GOM's inspection software; palatal rugae patterns and measurements and palatal measurements: intercanine width, intermolar width, arch perimeter, arch length, anterior arch length, palatal depth, anterior arch width and rugae size (Table 1) were performed by a single examiner after calibration.

A qualitative evaluation of the rugae was performed to determine their clinical appearance and distribution (figure 1). Each ruga was classified as straight, wavy, curvy or circular based on the classification of Kapali et al[19]. The direction and unification were recorded according to the classification of Thomas and Kotze[20] (Table 1); similarly, unification was described according to the ruga origin and course.

The clinical assessment of palatal sensitivity was performed by a speech therapist. Subjects were seated and a mild sensory stimulus was applied in the anterior-posterior direction in a linear and circular way on the median raphe and on the rugae edges (figure 2). The reaction shown by the subject was classified as normal sensitivity, hypersensitivity or hyposensitivity.[17]

A total of 10 3D digital dental models were chosen for the calibration by the examiner in the models measurements. All measurements were performed at two time points by two independent examiners. Inter- and intra-observer reproducibility for all variables were tested by repeated landmark identification. Two sets of measurements were quantified with two weeks between them. For each variable, Dahlbergs's error was calculated and values between 0.05 to 0.6 mm were obtained. A less than 10% of the maximum value was obtained for each variable.

Statistical Analysis

Quantitative variables were assessed by a non-parametric comparison (Mann-Whitney U test). A Chi square test of independence was performed for qualitative variables, and the association among the variables was verified. Values of $p \leq 0.05$ were considered significant differences using SPSS v 19.

RESULTS

A total of 264 dental models of schoolchildren from five schools of the municipality of Envigado were considered for this study. They were divided into two groups based on the type of bite: 132 with NVO and 132 with AOB. The average age in the NVO group was 11.37 ± 2.27 years, and the average age in the AOB group was 11.87 ± 2.84 years, which demonstrates that the groups were comparable based on the age (p = 0.117).

The general data showed that 54.9% of the students were female, both groups had a higher proportion of females with the highest percentage in the AOB group at 59.1%. (p = 0.174).

Significant differences (p = 0.003) between the groups were found in the mean arch length when evaluating the dental arch features, and the group with the greatest length was the AOB group at 26.99 mm ± 2.67 (Table 2). No significant differences between the groups were found for the intercanine or intermolar widths.

Similarly, significant differences (p = 0.000) were found when comparing the posterior and anterior palatal depths between the groups. Both depths were greater in the AOB group, with values of 18.59 ± 2.76 and 16.04 ± 2.41, respectively (Table 2).

Table 1. Measurements for the anthropometric features of the palate

Measurement	Definition	
Intercanine width	Straight line between cusp tips of right and left canines or the middle of the facet resulting from attrition. The measurement was not performed when one or both of the canines were absent (30).	
Intermolar width	Straight line measured between the centre point of the mesial fossa of the right molar and the mesial fossa of the left molar. The measurement was not performed when one or both of the molars were absent (30).	
Arch perimeter	Sum of four segments: from distal surface of primary second molars or mesial surface of first permanent molar on one side (passing over the contact points) to mesial deciduous or permanent canine on both sides. The other segments were measured from mesial deciduous or permanent canine to a point between two central points on both sides (30).	
Arch length	Straight distance from interdental papilla tip between upper central to a tangent through mesial surfaces of the second molars (30).	
Anterior arch length	Corresponds to the perpendicular distance from the interincisive papilla to a tangent line formed by the interpapillary line of premolars or deciduous molars.	
Palatal depth	Distance from the occlusal plane to the posterior and anterior palatal depth. To take these measurements, first a plane of three points was established using the mesio-palatal cusps and one disto-palatal cusp from the first upper molars. Then, a tangent was made through the midline of the model to section it sagitally and to be able to measure posterior and anterior depth.	**Posterior palatal depth:** with the cutaway model, the distance from the occlusal plane to the depth of the palate, having as a reference the mesiobuccal cusp of the first upper molar, is measured. **Anterior palatal depth:** with the cutaway model, the distance from the occlusal plane to the depth of the palate at the level of the interpremolar or deciduous intermolar is measured.
Anterior arch width	Distance form interpremolar or deciduous intermolar papilla to the contralateral side.	
Rugae size	The first 3 and/or 4 rugae pairs were measured. The rugae size was determined according to the height and width. First, the rugae are outlined with software, and a tangent is drawn on the more elevated area that cuts the ruga cross-sectionally, forming the ruga curve (Figure 3). Then, the ruga width is measured at the level of the curve base, taking both edges as reference, to later measure the distance between them and proceed with the measurement of the ruga height, drawing a perpendicular line from the highest edge of the curve to the base (Figure 1). Both right and left rugae were measured for 3 or 4 pairs in each model. The right rugae were identified with the letter A, and according to their number, they were ordered as A1 (the first ruga of the right side), A2 (the second ruga of the right side), and so on until the fourth ruga. The left side rugae were identified with the letter B, and according to the number they were ordered in a similar manner (Figure 4).	

Table 2. Anthropometric features based on study group

MEASUREMENT	NVO n = 132 Ẋ (SD)	AOB n = 132 Ẋ (SD)	P Value
Intermolar	46.90 ± 2.96	47.31 ± 3.18	0.252
Intercanine	34.21 ± 2.67	33.65 ± 2.77	0.065
Perimeter	74.12 ± 4.67	73.28 ± 5.45	0.069
Total length	26.01 ± 2.03	26.99 ± 2.67	0.003*
Anterior width	35.47 ± 2.72	35.57 ± 3.25	0.562
Anterior length	18.77 ± 2.44	19.02 ± 2.15	0.219
Posterior depth	16.74 ± 2.36	18.59 ± 2.76	0.000*
Anterior depth	14.48 ± 2.26	16.04 ± 2.41	0.000*
Height of first right ruga	0.74 ± 0.23	0.84 ± 0.25	0.020*
Height of first left ruga	0.81 ± 0.27	0.94 ± 0.30	0.000*
Height of second right ruga	0.61 ± 0.19	0.71 ± 0.18	0.000*
Height of second left ruga	0.66 ± 0.24	0.78 ± 0.27	0.000*
Height of third right ruga	0.58 ± 0.20	0.65 ± 0.23	0.008*
Height of third left ruga	0.59 ± 0.21	0.71 ± 0.24	0.000*
Height of fourth right ruga	0.46 ± 0.20	0.49 ± 0.22	0.352
Height of fourth left ruga	0.47 ± 0.16	0.56 ± 0.22	0.003*
Width of first right ruga	2.8 ± 0.62	3.08 ± 0.65	0.033*
Width of first left ruga	2.97 ± 0.71	3.2 ± 0.73	0.01*
Width of second right ruga	2.40 ± 0.46	2.51 ± 0.49	0.136
Width of second left ruga	2.43 ± 0.49	2.55 ± 0.55	0.70
Width of third right ruga	2.28 ± 0.49	2.27 ± 0.42	0.985
Width of third left ruga	2.24 ± 0.50	2.30 ± 0.51	0.280
Width of fourth right ruga	2.10 ± 0.69	2.13 ± 0.57	0.600
Width of fourth left ruga	2.03 ± 0.47	2 ± 0.54	0.179

*Significance p ≤ 0.05 Mann-Whitney U test

Similarly, significant differences (p = 0.000) were found when comparing the posterior and anterior palatal depths between the groups. Both depths were greater in the AOB group, with values of

18.59 ± 2.76 and 16.04 ± 2.41, respectively (Table 2). In the quantitative evaluation of the rugae, significant differences were found when comparing the height of the first three rugae on both the right and left sides between the groups. The rugae with the greatest heights were found in the AOB group (Table 2). Significant differences between the NVO and AOB groups were found in the width of the first ruga, with a greater width for rugae from AOB patients (3.08 ± 0.65; p = 0.033) (Table 2).

The qualitative analysis revealed that the rugae shape was asymmetric. The first rugae on the right side had a straight shape in individuals with NVO and a wavy shape in individuals with AOB. A higher proportion of the curvy shape was found on the left side for both groups. The wavy shape was predominant in the posterior rugae of the NVO group for both the right and left sides. In contrast, straight and wavy rugae were found in the same proportion in the AOB group (Table 3).

General asymmetry was found when assessing the direction. When evaluating the first right ruga, a higher proportion of horizontal rugae were found in both the NVO and AOB groups. On the left side, most rugae had a forward direction in both types of bite. For the posterior rugae, the horizontal direction predominated, and only the third and fourth rugae of the NVO group showed a higher proportion of the backward direction (Table 3 and 4).

Table 3. Classification of rugae based on direction

RUGA	RIGHT			LEFT		
	NVO	AOB	p value	NVO	AOB	p value
1	Horizontal 67.4%	Horizontal 68.2%	0.631	Forward 52.3%	Forward 58.3%	0.416
2	Horizontal 52.3%	Horizontal 49.2%	0.622	Horizontal 49.2%	Horizontal 47%	0.493
3	Backward 44%	Horizontal 53.8%	0.064	Horizontal 45.5%	Horizontal 56.1%	0.219
4	Backward 31.1%	Horizontal 39.4%	0.645	Horizontal 34.1%	Horizontal 45.5%	0.542

*Significance p ≤ 0.05 - Chi square test

Table 4. Classification of rugae based on unification. For palatal rugae unification, parallel rugae predominated in both study groups without significant differences.

RUGA	RIGHT			LEFT		
	NVO	AOB	p value	NVO	AOB	p value
1	Parallels 69.7%	Parallels 68.9%	0.791	Parallels 68.9%	Parallels 81.1%	0.065
2	Parallels 73.5%	Parallels 71.2%	0.755	Parallels 78%	Parallels 78%	1
3	Parallels 87.9%	Parallels 92.4%	0.547	Parallels 90.9%	Parallels 88.6%	0.362
4	Parallels 69.7%	Parallels 81.7%	0.645	Parallels 65.2%	Parallels 78.8%	0.564

*Significance p≤0.05 - Chi square test

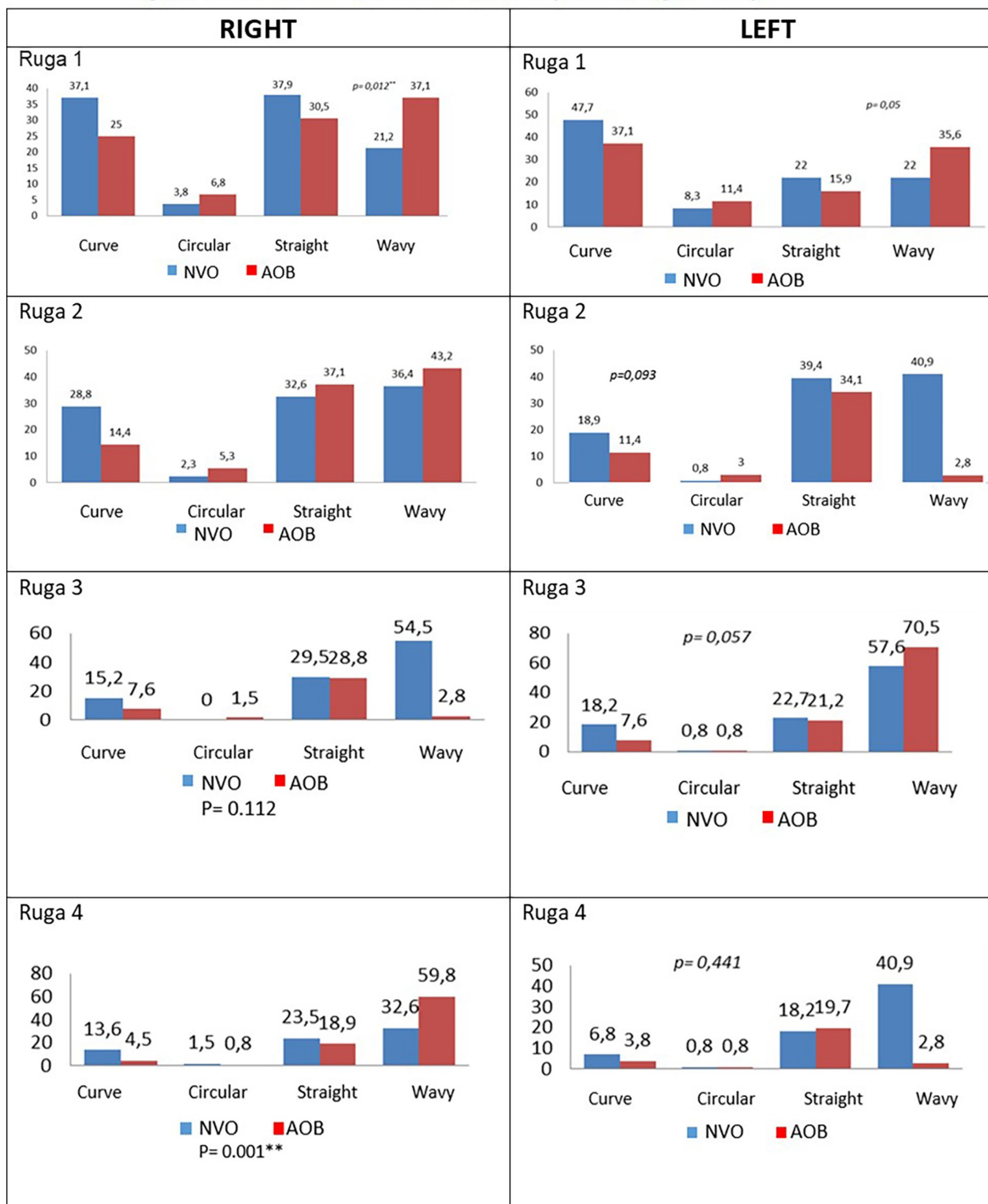**Figure 1:** Features and distribution of palatal rugae shape

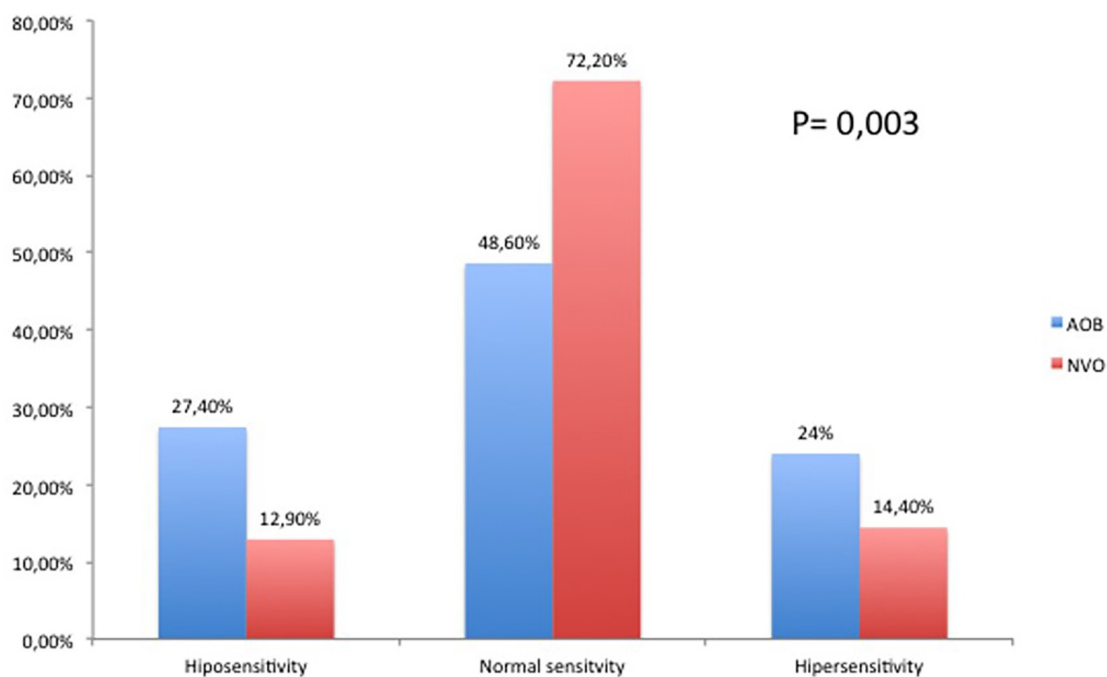**Figure 2:** Evaluation of rugae sensitivity
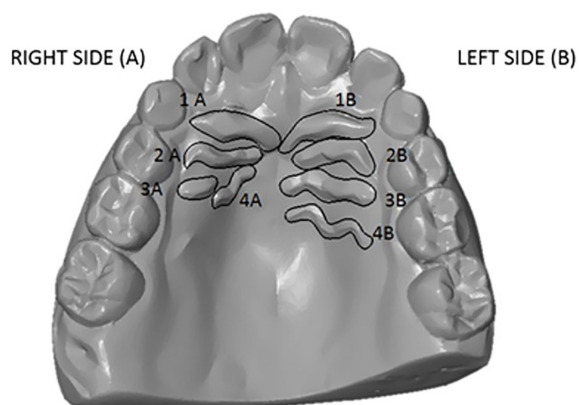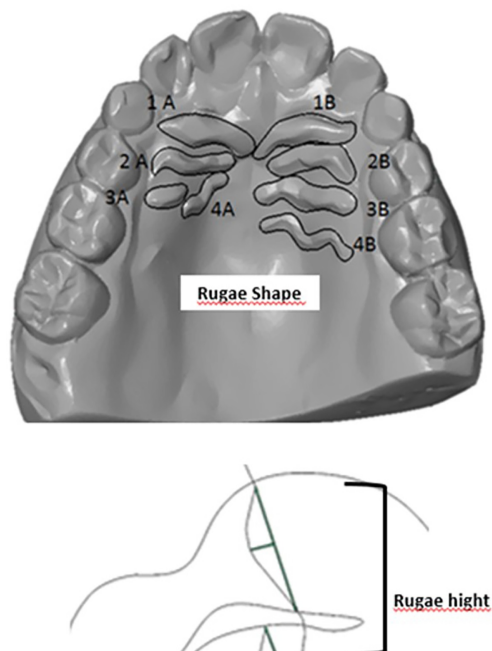

Figure 3: Outlined rugae and denomination

Figure 4: Rugae shape and size measurement method

CONCLUSION

Individuals with AOB show different shapes and sizes of the palatal rugae compared with individuals with NVO, even though palatal size was different, it was non-statistical significant. It would be ideal to perform an analytical study that allows the determination of the type of association between thick and prominent palatal rugae and the presence of open bite, and also to determine if the differences between AOB and NVO are associated with lingual protrusion.

AVAILABILITY OF SUPPORTING DATA:

The database is available in:
https://mynotebook.labarchives.com/
The data is in anonymized form that complies with data protection/privacy laws.

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