Formants Frequency and Dispersion in Relation to the Length and Projection of the Upper and Lower Jaws

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Summary: Objective. Investigate the association between formants frequencies and length and sagittal projection of the maxilla and mandible.

Study Design. Cross-sectional study.

Method. A total of 47 consecutive patients were recruited. Craniofacial measures included; maxillary length (ANS-PNS), mandibular length (Co-Gn), relationship between maxilla and mandible in the sagittal plane (ANB), the sagittal projection of the maxilla (SNA), and mandible (SNB). Subjects were asked to phonate vowels /a/, /i/, /o/, and /u/. Measurements were made in real-time and formant frequencies across F1, F2, F3, and F4 were determined.

Results. There was a significant negative association between the length of the maxilla and F4 for all the vowels, and a significant negative association between the length of the mandible and F4 for vowels /o/ and /u/. The length of maxilla and mandible also negatively associated with F3 for vowels /a/, /i/, /o/, and vowels /i/, /o/, and /u/ respectively. For the first two formants, the negative association was less pronounced.

Conclusion. There was a significant negative association between the formant frequencies F3, F4, and the length of the mandible and maxilla for vowels /a/, /i/, /o/, and /u/.

Key Words: Formants frequencies–Maxilla–Mandible.

INTRODUCTION

There are several acoustic components to voice among which are the formants. These have been described in relation to timbre, a salient acoustic feature that is hard to conceptualize. The position and dispersion of formants reflect the individual's vocal characteristics and identity. They also form an acoustic cue to body size and shape. Fitch and Giedd[1] have shown a correlation between body size, vocal tract length, and formants, indicating that larger individuals have smaller formants dispersion. Sachs et al[2] reported a negative correlation between height as a measure of body size and formant dispersion. Similarly Evans et al[3] has demonstrated a significant negative correlation between formant dispersion and body size and shape, in particular the neck, shoulder, chest, and waist circumferences.

The literature is scarce on the relationship between formant frequency and the size and projection of facial bones. There have been many studies on the impact of cleft palate and orthognatic surgeries on velopharyngeal status, vocal resonance, and speech.[4–9] No study has examined the relationship between the size and facial projection of the upper and lower jaws and formant frequencies, despite the common knowledge that formants frequencies and dispersion are intimately related to the size and configuration of the vocal tract, part of which is the maxilla and mandible. This is so evident when we compare the formant frequencies in men versus women and children, with lower values being found in men.[10]

The scarcity of the literature on the relationship between formant frequencies and facial bones has intrigued the authors of this study to investigate the association between formants frequencies and length and projection of the maxilla and mandible in a group of young subjects. The hypothesis is that there is a negative correlation between the length and sagittal projection of the upper and lower jaws and formants frequencies and dispersion.

MATERIAL AND METHODS

A total of 47 consecutive patients (34 females and 13 males) presenting for the first time to the division of Orthodontics and Dentofacial Orthopedics, at a university medical center, were invited to participate in this study. These patients were seeking orthodontic treatment to correct their present malocclusion. Fifty one percent (n = 24) had class I malocclusion with crowding of the teeth, nineteen (40.5%) had class II malocclusion with increased overjet (space between the maxillary and mandibular teeth in the sagittal plane), and the remaining 4 (8.5%) had class III malocclusion with a reverse overjet (mandibular incisors occluding in a forward position to maxillary ones). It is important to note that this distribution reflects the normal population distribution of malocclusion where class I and class II are more frequently encountered than class III malocclusion.[11] All patients have read and signed the informed consent approved by the institution review board before participating in the study. Patients with recent history of respiratory tract infection, laryngeal manipulation, or dypshonia at the time of presentation were excluded from this study.

Before the initiation of any orthodontic treatment, a set of records was taken for every patient including the following[1]: Lateral cephalographs were taken using the same digital cephalostat (GE, Instrumentarium, Tuusula, Finland) in a standardized procedure. The body of the patient was covered with a lead apron and the head was placed in the natural head position. The patients were asked to occlude their teeth in the most retruded contact position and keep their lips in gentle touch. Images were saved and stored directly in a dedicated computer. The radiographs were imported and digitized into the imaging program

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(Dolphin Imaging and Management Solutions, La Jolla, California). Pertinent landmarks were digitized and consequent angular and linear measurements were computed to evaluate the sagittal and vertical positions of the maxilla, the mandible, relative to the cranial base, and to each other (Figure 1).

The skeletal measurements of both upper and lower jaws in the sagittal and vertical planes were used. These included: SNA, the angle which reflects the sagittal projection of the maxilla relative to the anterior cranial base; SNB, the angle which reflects the sagittal projection of the mandible relative to the cranial base; ANB, the angle which reflects the position of the maxilla and mandible in relation to each others; CO-GN, length of mandible; and PNS-ANS, length of maxilla (Figure 1).

After taking the lateral cephalometric radiograph, each subject was seated in a quiet room in front of a unidirectional condenser microphone at a constant mouth-to-microphone distance of 10 cm. Using the Real-time spectrogram (*Sona Speech II*, KayPENTAX, Kay Elemetrics Corp, Montvale, NJ), each subject was asked to produce and sustain the vowel sounds /a/, /i/, /o/, and /u/ at a comfortable pitch and intensity level.[12] After the production of each vowel, formant frequencies

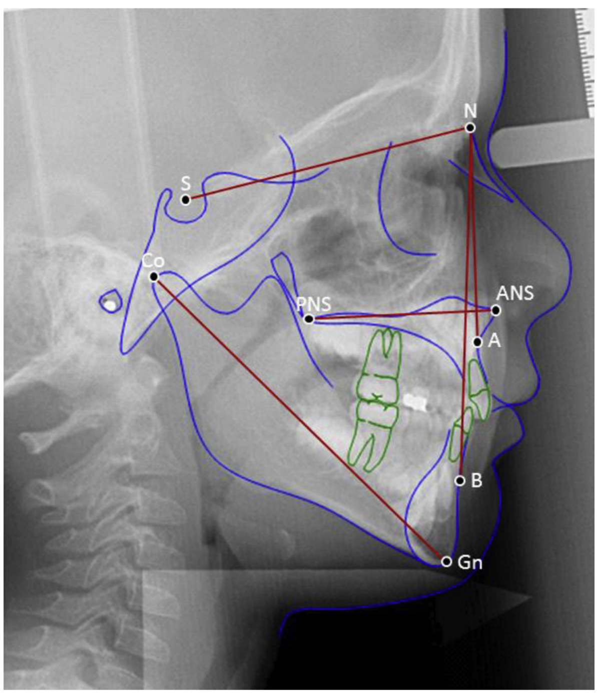

FIGURE 1. Lateral cephalometric tracing showing the landmarks, planes, and angles used in the study. S, Sella Turcica; N, Nasion; A, deepest point on the premaxilla between anterior nasal spine and dental alveolus; B, deepest point on anterior part of the mandible; ANS, anterior nasal spine; PNS, posterior nasal spine; Co, Condylion-antero-superior point of the condyle; Gn, Gnathion-midpoint between the most protruded and the lowest points of the symphysis. SNA angle, position of the maxilla relative to the cranial base in the sagittal plane; SNB angle, position of the mandible relative to the cranial base in the sagittal plane; ANB angle, inter-jaws relationship; ANS-PNS, maxillary length; Co-Gn, mandibular length.

F1, F2, F3, and F4 were determined by placing the cursor in the middle of the formant band for consistency.

Statistical method

Descriptive statistics for the continuous variables: cephalometric measures, formants (F1, F2, F3, and F4 for the vowels /a/, /i/, /o/, /u/and formants dispersion (F_2-F_1; F_3-F_2; F_4-F_3) were computed using mean, range, and standard deviation. Linear regressions model was used to report R as a measure of association between the dependent variables (F1, F2, F3, F4 for the vowels /a/, /i/, /o/, /u/) and the independent variables SNA, SNB, ANB, C0-GN, ANS-PNS.

A P value <0.05 was considered as significant. Analyses were performed using *Statistical Analysis Package for Social Sciences* (SPSS, version 19.0 Chicago, IL).

RESULTS

Demographic data

A total of 47 subjects, 13 males and 34 females were enrolled in this study. The mean age was 15.19 years with a range extending from eight to 36 years. All subjects were nonsmokers.

Cephalometric measurements

The means of SNA, SNB, and ANB for all the subjects were 80.77, 77.54, and 3.21° respectively. The mean length of the mandible and maxilla were 103.99 mm and 50.109 mm respectively. The means and range were also reported in subgroups taking into consideration two demographic variables: age and gender (Tables 1 and 2).

Formant frequencies and dispersions for vowels /a/, /i/, /o/, and /u/

The mean, range, and SD of all the formants for the vowels /a/, /i/, /o/, and /u/ were computed in the total group, in the prepubertal (females aged <11 years old; males aged <12 years old) and postpubertal group (females aged >15.5 years; males aged >15.9 years)[13] (Tables 3 and 4). The analysis was also done taking into consideration the gender effect (Tables 5 and 6).

The formant dispersion for all vowels /a/, /i/, /o/, and /u/ were also computed in the total group (Table 7).

Associations between formant frequencies and length and sagittal projection of the upper and lower jaws in the total group

There was a significant negative association between many of the formant frequencies for the various vowels and the length and sagittal projection of the mandible and maxilla. The results are displayed in Table 8. Note that the association was more pronounced for the F3 and F4 compared with the first and second formants. There was a moderate negative association (R value >0.3) between F4 and the length of the maxilla that was statistically significant (P values <0.05) for all the vowels /a/, /i/, /o/, /u/) and a moderate negative association between F4 and the length of the mandible for the vowels /o/ and /u/ (R values 0.378 and 0.522, P values of 0.009 and 0.001 respectively) and a borderline significance (P value of 0.07) for the vowel /a/. Similarly there was a moderate negative statistically significant association