Effect of Rapid Maxillary Expansion on Voice

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Summary: Objective. The purpose of this investigation is to evaluate the effect of rapid maxillary expansion (RME) on the fundamental frequency (F0) and formant frequencies F1–F4.

Study Design. Cross-sectional study.

Materials and Methods. A total of 14 consecutive patients between the ages of 9.6 years and 15 years with a constricted maxilla undergoing RME were included in this study. Measurements were made before (T1) and after treatment (T2). These included maxillary arch length, depth, width, and perimeter in addition to F0, habitual pitch, and formants F1, F2, F3, and F4 for the vowels /ɑ/, /i/, /o/, and /u/.

Results. There was a significant difference in the mean of F1/ɑ/ and F2/ɑ/ before and after treatment (*P* value of 0.04 and 0.013, respectively). It is worth noting that F1/ɑ/ decreased in 11 and F2/ɑ/ decreased in 10 of the 14 subjects.

Conclusion. The application of RME in the treatment of maxillary constriction leads to a significant lowering of the first and second formants for the vowel /ɑ/ in most subjects. Subjects undergoing rapid maxillary application should be aware of the potential change in voice quality especially in case of professional voice users.

Key Words: Maxilla–Formants–Fundamental frequency–Voice–Vowel.

INTRODUCTION

The larynx produces a spectrum of sound frequencies that are shaped and modulated by resonances within the vocal tract structures among which is the maxillary arch. The authors of this article have previously reported the association between craniofacial morphology and voice.[1,2] The results indicated that both mandibular and maxillary lengths inversely correlate with the fundamental frequency and the habitual pitch.[2] However, there was no correlation between the sagittal position of both maxilla and mandible and the fundamental frequency and habitual pitch. Similarly, in another investigation on the association between formant frequencies and length and sagittal projection of the maxilla and mandible, the authors have demonstrated "a significant negative association between F3, F4 and the length of both upper and lower jaw."[2] Along the same line of investigation, Marunick et al have investigated the relationship between intraoral measurements (maxillary dental arch) and voice classification in nine professional female singers.[3] In Marunick et al's study, the maxillary dental arch form, dimensions, and volume have been shown to be predictors of the different voice types (soprano, mezzo, and alto). Although no single dental cast measurement was a predictor for voice classification, palatal depth and volume gave optimal results according to which group each singer was classified.[3]

Studies on the impact of surgery of the orofacial and craniofacial structures on voice are few.[4,5] Adenoidectomy, tonsillectomy, inferior turbinectomy, septoplasty, and uvulopalatoplasty are surgeries carried out on soft tissues of the upper airway with resultant alterations in the resonant characteristics of the vocal tract.[4–6] The impact of these surgically induced alterations is at times a change in voice quality. Outcome measures used to report vocal changes are nasalance scores, formant frequencies, and formant amplitude.[4–8] Similarly, orthognatic surgery for the treatment of cleft palate, craniofacial anomalies, and malocclusion has also been expected to have an effect on voice.[4,5] These surgeries consist primarily of maxillary and mandibular osteotomies, distraction osteogenesis, and repair of cleft palate.

To the best of the authors' knowledge, no previous study has examined the impact of rapid maxillary expansion (RME) on voice. RME is an accepted treatment modality for patients with constricted maxilla. Posterior crossbite because of constricted maxilla is a commonly encountered problem in orthodontics with an occurrence rate of 8% up to 22%,[9,10] making it one of the most prevalent malocclusion in both primary and mixed dentition.[10] RME is an orthodontic procedure used in patients with posterior crossbite with the purpose of widening the maxillary jaw and allowing better fit of the mandibular and the maxillary teeth.

The purpose of this investigation is to evaluate, in an orthodontic population, the effect of RME on voice parameters (fundamental frequency and formant frequencies F1–F4). Our hypothesis is that RME will impact voice by altering its resonant characteristics.

MATERIALS AND METHODS

A total of 14 consecutive patients between the ages of 8 years and 15 years seeking orthodontic treatment using RME for a constricted maxilla at the Division of Orthodontics and Dentofacial Orthopedics at a university medical center were recruited for this study. All patients' guardians have read and signed the consent form, which was approved by the internal review board of the university. Patients were excluded from the study if they presented with any history of respiratory infection, laryngeal manipulation, or dysphonia. The presence of dysphonia was ruled out by an expert speech language pathologist who performed later the acoustic analysis.

Accepted for publication September 22, 2015.
This article has no actual or potential conflict of interest.
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Journal of Voice, Vol. ■■, No. ■■, pp. ■■-■■
0892-1997

http://dx.doi.org/10.1016/j.jvoice.2015.09.013

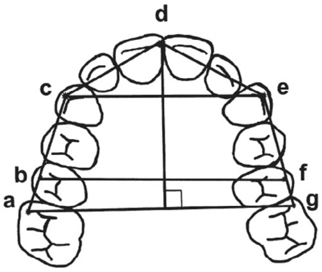

FIGURE 1. Arch length: distance from point d to line ag. Arch perimeter: ac + cd + de + eg. Arch width: distance between bf and ag.

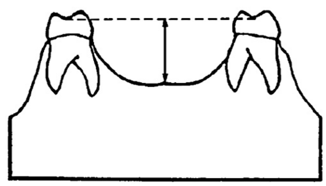

FIGURE 2. Arch depth.

Within an hour, before the initiation of the RME (T1) and after 2 weeks (T2) of active expansion, the following set of records was taken on all patients included in the study:

A. Maxillary alginate impressions were taken to perform dental models. Cast measurements included (Figure 1) (1) arch length—distance from midline perpendicular to the intermolar plane passing through the mesiobuccal cusps of the first molar; (2) arch perimeter—sum of distances of right and left buccal segments (from mesiobuccal cusps of first molars to the canine's cusp) and anterior segment of teeth (from canine's cusp to midline between central incisors); (3) arch width—measurement from mesiobuccal cusps of the right first molar to the left first molar; and (4) arch depth—distance from the intermolar line (through the mesiobuccal cusps of the first molars) to the palate (Figure 2).

B. Acoustic analysis using Visi-Pitch IV (model 3300; KayPENTAX, Montvale, NJ) was conducted between 2 and 5 pm to rule out the daily variations and time influence on the voice parameters. Using a condenser SM48 vocal microphone (Shure, Americas) coupled to the KayPENTAX Visi-Pitch IV 3950B), at a distance of 10–15 cm, the patient transmitted the vocal signal. The vocal signal was recorded directly into the system. The following measurements were included: (1) average fundamental frequency F_0 of the voice registered by asking the patient to pronounce continuously the vowel "ɑ" for 2 seconds at a comfortable pitch and loudness; (2) habitual frequency recorded by asking the patient to count from 1 to 10 in a normal voice; (3) formant frequencies recorded by asking each individual to pronounce and sustain, at a comfortable pitch and intensity level, the vowel sounds /ɑ/, /i/, /o/, and /u/. After the registration of each vowel, formant frequencies F1, F2, F3, and F4 were determined by placing the cursor in the middle of the formant band for consistency. Each singer was seated in a quiet room in front of a unidirectional condenser microphone at a constant mouth-to-microphone distance of 10 cm. Each singer was asked to phonate a sustained /ɑ/, /i/, and /u/ sound at a comfortable pitch and intensity level, both in a spoken manner and in a well-produced Middle Eastern style singing manner. Three consistent responses were recorded for each trial. Measures were made in real time and formant frequencies for singing groups across F1, F2, F3, and F4 were determined by using the Real-time Spectrogram of VP 3950 (Kay Elemetric Corporation, Lincoln Park, New Jersey). The cursor was placed at the centermost point of the steady-state formant band when looking at the spectrogram.

Statistical method

Means ± SD were used for continuous variables. For each subject, the parameters were collected before and after treatment, and the appropriate statistical analysis for small-size samples (Wilcoxon nonparametric paired test) was conducted. The analysis took into consideration the design (before and after) and modality of data collection (paired data). Differences were considered significant for $P < 0.05$. All analysis was conducted using IBM SPSS Statistics 22 (Chicago, IL).

RESULTS

Demographic data

Fourteen subjects were enrolled in this study: seven males and seven females. The mean age of the 14 subjects was 11.64 ± 1.69 with a range of 8–15 years.

Maxillary arch measurements

Four arch measurements were considered for this study, namely the width, length, depth, and perimeter of the maxillary arch. The means of these parameters for 14 subjects before and after surgery are listed in Table 1.

Means of fundamental frequency and habitual pitch before and after surgery

The means of F0 and habitual pitch before surgery were 218.9 Hz and 214.3 Hz, respectively. The means postoperatively were 220.5 Hz and 212.6 Hz, respectively. There was no significant difference in the means before and after surgery. Even when stratified by gender, there was still no significant difference before and after the treatment. There was also no significant difference in the means of any of the remaining acoustic variables before and after surgery (Table 2).

Means of formants F1–F4 before and after RME

There was a significant difference in the mean of F1/ɑ/ and F2/ɑ/ before and after the surgery (P value of 0.04 and 0.013, respectively). It is worth noting that F1/ɑ/ decreased in 11 of the 14 subjects and similarly F2/ɑ/ decreased in 10 and remained the same in two of the 14 subjects (Figure 3 and Figure 4).

There was no significant difference in any of the other formants F1, F2, F3, and F4 for the vowels /i/, /o/, and /u/ (Table 3).