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Voice changes after surgically assisted rapid maxillary expansion

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Introduction: This study aimed to investigate voice changes in patients who had surgically assisted rapid maxillary expansion (SARME). **Methods:** Nineteen adult patients with maxillary transverse deficiency were asked to pronounce the sounds "[a], [ϵ], [ɯ], [i], [ɔ], [œ] [u], [y]" for 3 seconds. Voice records were taken before the expansion appliance was placed (T0) and 5.8 weeks after removal (T1, after 5.2 months of retention). The same records were taken for the control group ($n = 19$). The formant frequencies (F0, F1, F2, and F3), shimmer, jitter, and noise-to-harmonics ratio (NHR) parameters were considered with Praat (version 6.0.43). **Results:** In the SARME group, significant differences were observed in the F1 of [a] ($P = 0.005$), F2 of [ϵ] ($P = 0.008$), and [œ] sounds ($P = 0.004$). The postexpansion values were lower than those recorded before. In contrast, the F1 of [y] sound ($P = 0.02$), F2 of [u] sound ($P = 0.01$), the jitter parameter of [ɯ] and [i] sounds ($P = 0.04$; $P = 0.002$), and the NHR value of [ϵ] sound ($P = 0.04$) were significantly than the baseline values. In the comparison with the control group, significant differences were found in the F0 ($P = 0.025$) and F1 ($P = 0.046$) of the [u] sound, the F1 of the [a] sound ($P = 0.03$), and the F2 of the [ϵ] sound ($P = 0.037$). Significant differences were also found in the shimmer of [i] ($P = 0.017$) and [ɔ] ($P = 0.002$), the jitter of [ϵ] ($P = 0.046$) and [i] ($P = 0.017$), and the NHR of [i] ($P = 0.012$) and [ɔ] ($P = 0.009$). **Conclusion:** SARME led to significant differences in some of the acoustics parameters. (Am J Orthod Dentofacial Orthop 2022;161:125-32)

The harmony of the transverse width of the maxilla and the mandible is one of the conditions necessary to achieve a stable and functional occlusion.[1] Maxillary constriction is frequently met in symptomatic and asymptomatic patients.[2,3] In young patients, the transverse deficiency of the maxilla may be corrected by orthopedic forces applied with fixed orthodontic appliances.[2] However, as the patients mature, resistance forms on the surrounding anatomic structures in connection to the metabolic and structural changes in the bones, and orthopedic forces fall short in expanding the maxilla. In connection to this, surgical assistance is indicated to achieve expansion.[2,3]

The close relationship of the vocal characteristics with the vocal tract morphology inspired Marunick and Menaldi to evaluate the maxillary dental arch linear measurements and palatal volume and to determine if these parameters could help in stratifying singers into different vocal groups; soprano, mezzo, or alto.[4] This pilot study revealed that the width measured from canine-to-canine and from the second molar to second molar could be considered together as predictors for voice classification. In addition, they suggest that sopranos have a shallow palate, mezzo-sopranos have a medium palate, and altos have a deep palate. Hamdan et al[5] further analyzed the correlation between maxillary arch dimensions and the acoustic parameters in a larger group of prepubertal patients.[5] The authors confirmed that the F3 is closely related to the size of the oral cavity. The multiple linear regressions calculated to predict the arch width on the basis of voice parameters indicated that F0 and F3 could be considered significant predictors. Given that the facial morphology is in integrity with the upper airway geometry, Macari et al[6] evaluated the association between facial width and length and fundamental frequency (F0), and the habitual pitch.[6] Considering the lateral and posteroanterior cephalometric measurements and the acoustic analysis results, the authors concluded that the facial transverse dimensions correlate significantly with both F0 and the habitual pitch.

It is known that any change in the shape or volume of the anatomic units forming the vocal tract may affect the structure of the sound.[7] Various studies have shown

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that, after orthognathic surgery, the dimensions, positions, and angular changes of the jaws may lead to changes in the tongue's position and velopharyngeal function, and this situation may affect the articulation and the sound characteristics of the patients.[8-12] Other studies showed that sudden voice changes occur during adolescence by the extension of the vocal tract because of the effects of sex hormones and increased dimensions of various anatomic units.[13,14]

In acoustics, a spectrogram is a visual representation of the frequencies of the sound. Formant frequencies are defined as high-energy regions that are observed in the form of dark bands on spectrograms. During sound analysis, it is common and practical to define the acoustic characteristics of vowels compared with other sounds.[7] Although there are 5 formants for each vowel, the first 3 of these are enough to define 1 vowel.

As a result of rapid maxillary expansion, the position of the tongue changes, and it is positioned more anteriorly.[15] Thus, it is assumed that maxillary expansion affects formant frequencies characteristics. The number of studies in the literature focused on the changes in sound resulting from the rapid maxillary expansion procedure is highly limited.[16-19] In some of these studies, there is a lack of a control group, and as the rapid maxillary expansion is performed on growing patients, the voice changes that could occur because of growth and related to hormones are neglected.[16,17,19] To isolate the voice changes caused by the expansion procedure only, we found it necessary to perform a study on adult patients. On the basis of our literature review, the unique study that investigated the effects of surgically assisted rapid maxillary expansion (SARME) among adults was carried out on only 6 patients.[18]

The purpose of our study was to investigate the effects of SARME on the acoustic characteristics of vowel sounds. We hypothesized that SARME would cause changes in the acoustic characteristics in relation to the changing vocal tract anatomy.

MATERIAL AND METHODS

This study was followed and approved by the Clinical Studies Ethics Board of Bezmialem Vakif University (document no. 19/09/2017-16668; decision no. 18/11). The voice records of 19 adult patients, with 23.2 mean age, diagnosed with maxillary constriction were collected between September 2017 and January 2019 in the Orthodontics Department of Bezmialem Vakif University (T0). Patients who presented craniofacial deformities, speech disability, or hearing disorders, those who have taken speech training, diction courses, singing training, etc, and those who had a history of orthodontic treatment were not included in the study. All the participants were informed about the aims of the project and signed an informed consent form. A McNamara-type expansion appliance was fabricated, and the expansion procedure was started on the fifth day after the surgery.

The surgical procedure consisted of a conventional Le-Fort I osteotomy, including the separation of the pterygomaxillary junction. The surgeries were all performed under general anesthesia by the same surgery team. A horizontal mucoperiosteal incision was made approximately 15 mm far from the vestibular gingival border of the teeth, extending between molars. The osteotomy line started from the lateral border of the apertura piriformis and extended to the pterygomaxillary area. The junction of the maxillary tuberosity and pterygoid plates was gently weakened with the help of a curved osteotome. In addition, a sagittal osteotomy was performed on the anterior portion of the midpalatal suture, accessed from the level of the central incisors. The expansion device was activated with 3 full turns to check the separation of the 2-maxillary halves. The expansion device was screwed back when the midline diastema opening was confirmed.

A daily expansion rate of 0.5 mm was achieved with 1 quarter turn in the morning and 1 quarter turn in the evening, constituting 2 quarter-turns daily (mean number of quarter-turns, 36.13 $\pm$ 14.84). When the required expansion was achieved, the expansion screws were locked with flowable composite, and the patients kept the expansion devices during the retention period of 5.2 months. Long-armed welded transpalatal arches were bonded the same day with the removal of the acrylic caps. The second set of voice records were collected after the removal of the expansion appliances (mean, 5.8 weeks) (T1), with the transpalatal arches maintaining the transverse dimension. It was made sure that the patients were not presenting any respiratory tract illness that could lead to voice changes at the time of record collection.

To prevent low-pitched voices that could occur in the early hours of the morning, all voice records were made between 12:00 PM and 1:00 PM by using the audio recording software Logic Pro X (version 10.0.4; Apple Inc, Cupertino, Calif) in an isolated, quiet room. The recordings were kept with a sampling rate of 44.1 kHz as 24 bit recordings. The microphones were placed onto an equilateral triangle position to have the same distance and the pop filter. The pop filter was positioned on the mouth level, 15 cm far from the patient. Before recording, the patients were informed about the definition of the habitual voice, and the patients were asked to count from 1 to 10, list the days of the week, and this was repeated 2 times in normal speaking tones. The following vowel sounds were pronounced by the

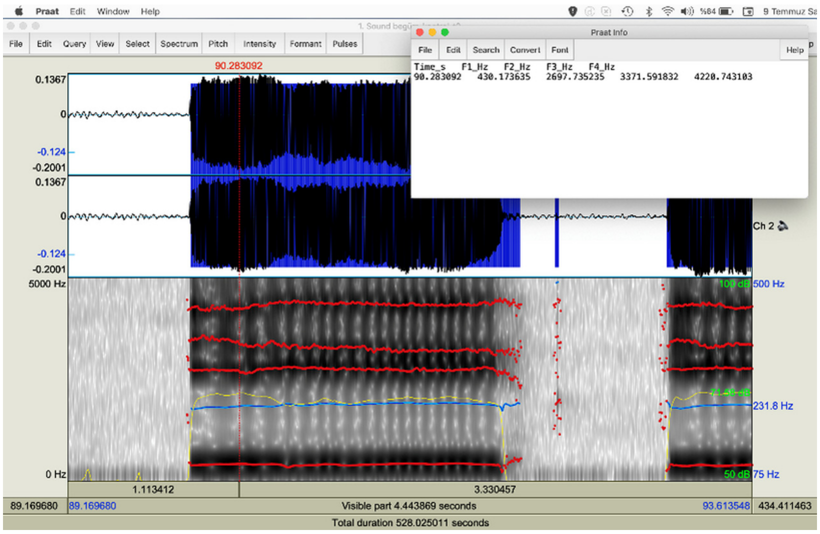

Fig. Analysis of the formant frequencies of the [i] sound with the Praat software.

patients for at least 3 seconds each and repeated 5 times; ([a], [ɛ], [ɯ], [i], [ɔ], [œ] [u], [y]).

The voice records were transferred from the Logic X software to the Praat software (version 6.0.43; University of Amsterdam, Amsterdam, the Netherlands) for the acoustic analysis. The formant frequencies (F0, F1, F2, F3, and F4) and the shimmer %, jitter %, and noise-to-harmonics ratio (NHR) parameters were considered.

For the analysis of the formant frequencies, magnification was made on the time point when the relevant sound had the most intense appearance on the spectrogram, and the red-colored vertical time cursor was placed onto the moment when the formant frequency to be analyzed was expressed. From the toolbar of the software, the formant list option was clicked on, and the F0, F1, F2, and F3 values were obtained (Figure). To determine the shimmer, jitter, and NHR, in contrast with the formant frequencies, the time interval in which the relevant sound was observed on the spectrogram was selected instead of a time point. By clicking on the voice report option from the pulses tab on the toolbar, the numerical values of the shimmer, jitter, and NHR parameters were recorded. This procedure was repeated 5 times, and the mean values were calculated for each sound parameter at T0 and T1.

Statistical analysis

The sample size of the study was calculated by using the G*Power (version 3.1.9.2; Universität Düsseldorf, Düsseldorf, Germany) software, on the basis of the mean change in the F2 frequency of the vowel [i] in a previous study.[15] It was found that a minimum of 16 patients should be included with a 1-tailed effect size of 0.90, 95% power, and 5% type I error rate. Considering the possible patient dropouts, 19 patients were included in the SARME and the control groups. The data were analyzed using the SPSS (version 25.0; IBM, Armonk, NY) software. Kolmogorov-Smirnov test was used to test the distribution of the data. The changes in the normally distributed variables within groups in time were analyzed by paired-samples *t* test. Mann-Whitney U test was used to compare the control and treatment groups in terms of the changes that took place in time. $P < 0.05$ was accepted to be statistically significant.

RESULTS

Table I shows the comparison of the F0, F1, F2, F3, shimmer, jitter, and NHR values in the SARME group before (T0) and after the procedure (T1). Statistically significant differences were observed in the F1 frequency of the [a] sound ($P = 0.005$), F2 frequency of the [ɛ] sound ($P = 0.008$), and F2 frequency of the [œ] sound ($P = 0.004$). Lower values were recorded after the procedure. In contrast, the F1 frequency of the [y] sound ($P = 0.02$), F2 frequency of the [u] sound ($P = 0.01$), the jitter parameter of the [ɯ] and [i] sounds ($P = 0.04$ and $P = 0.002$), and the NHR value of the [ɛ] sound ($P = 0.04$) were found to be significantly higher than the baseline values.

The number of changes in the SARME and the control groups between T0 and T1 was expressed as delta values (eg, ΔF0), and the comparison between 2 groups is shown in Table II. The SARME group exhibited

Table I. Time-based comparison of the F0, F1, F2, F3, shimmer, jitter, and NHR parameters in the SARME group

		F0		*F1*		*F2*		*F3*		*Shimmer*		*Jitter*		*NHR*	
Vowel	*Measuremet time*	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P
[a]	T0	817 ± 138	0.9	1270 ± 97	0.005*	3107 ± 297	0.23	3933 ± 450	0.92	3.16 ± 1.4	0.31	0.28 ± 0.12	0.72	0.0088 ± 0.0059	0.24
	T1	816 ± 140		1226 ± 109		3175 ± 347		3940 ± 433		3.68 ± 1.5		0.29 ± 0.144		0.0127 ± 0.0138	
[ϵ]	T0	603 ± 90	0.65	2134 ± 248	0.15	2973 ± 314	0.008*	3964 ± 488	0.06	3.15 ± 1.38	0.46	0.28 ± 0.101	0.25	0.0072 ± 0.0026	0.04*
	T1	608 ± 84		2013 ± 298		2744 ± 290		3731 ± 509		2.85 ± 1.5		0.34 ± 0.24		0.0171 ± 00.2	
[ɯ]	T0	470 ± 97	0.46	1672 ± 373	0.08	2966 ± 259	0.07	3951 ± 304	0.86	3.04 ± 1.75	0.4	0.21 ± 0.13	0.04*	0.0119 ± 0.0255	0.29
	T1	456 ± 71		1540 ± 227		2896 ± 264		3964 ± 417		3.34 ± 1.83		0.29 ± 0.16		0.0061 ± 0.008	
[i]	T0	390 ± 61	0.43	2395 ± 352	0.43	2051 ± 726	0.66	4090 ± 384	0.19	2.74 ± 1.6	0.12	0.21 ± 0.07	0.002*	0.0038 ± 0.0025	0.17
	T1	443 ± 298		2293 ± 551		3176 ± 351		3975 ± 443		3.29 ± 2.28		0.34 ± 0.13		0.0081 ± 0.0136	
[ɔ]	T0	565 ± 100	0.27	953 ± 148	0.37	3098 ± 332	0.43	3801 ± 365	0.65	2.97 ± 1.52	0.13	0.27 ± 0.16	0.31	0.0054 ± 0.0069	0.15
	T1	548 ± 86		953 ± 108		3065 ± 339		3779 ± 352		3.89 ± 2.21		0.35 ± 0.26		0.0124 ± 0.019	
[œ]	T0	541 ± 94	0.71	1594 ± 185	0.43	2771 ± 260	0.04*	3847 ± 448	0.98	3.25 ± 2.06	0.57	0.31 ± 0.47	0.72	0.0218 ± 0.0672	0.4
	T1	546 ± 86		1526 ± 382		2709 ± 246		3849 ± 346		2.98 ± 1.01		0.35 ± 0.28		0.0082 ± 0.0115	
[u]	T0	425 ± 52	0.12	910 ± 136	0.41	2907 ± 304	0.01*	3673 ± 328	0.12	2.85 ± 1.57	0.98	0.24 ± 0.11	0.13	0.0044 ± 0.0051	0.58
	T1	405 ± 54		881 ± 142		3006 ± 287		3773 ± 369		2.86 ± 1.39		0.32 ± 0.22		0.006 ± 0.0108	
[y]	T0	379 ± 54	0.83	1726 ± 180	0.02*	2540 ± 243	0.28	3683 ± 362	0.1	2.96 ± 1.97	0.19	0.29 ± 0.21	0.75	0.0042 ± 0.0049	0.52
	T1	377 ± 54		1830 ± 210		2579 ± 234		3739 ± 334		3.63 ± 1.49		0.27 ± 0.23		0.0059 ± 0.0111	

X, mean; *SD*, standard deviation.
*$P < 0.05$ statistically significant (paired-samples *t* test).

Table II. Comparison of the SARME (T) and control (C) groups on the basis of the ΔF0, ΔF1, ΔF2, ΔF3, ΔShimmer, ΔJitter, and ΔNHR values

		ΔF0		*ΔF1*		*ΔF2*		*ΔF3*		*ΔShimmer*		*ΔJitter*		*ΔNHR*	
Vowel	*Groups*	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P	*X* ± *SD*	P
[a]	T	1.47 ± 51.26	0.544	1.47 ± 51.26	0.03*	−68.47 ± 244	0.311	−68 ± 244	0.624	−0.52 ± 2.17	0.297	−0.013 ± 0.163	0.223	−0.003 ± 0.014	0.191
	C	−1.94 ± 6.41		−1.94 ± 56.4		−47.05 ± 699		−47 ± 699		0.57 ± 1.97		0.024 ± 0.193		0.002 ± 0.016	
[ϵ]	T	−5.31 ± 50.34	0.253	121.4 ± 354	0.603	228.5 ± 336.7	0.037*	233 ± 507	0.603	0.29 ± 1.74	0.163	0.298 ± 1.74	0.046*	−0.009 ± 0.2	0.057
	C	16.05 ± 75.06		60.94 ± 423		9.73 ± 324.2		55.8 ± 616		1.29 ± 1.82		1.29 ± 1.82		0.002 ± 0.006	
[ɯ]	T	13.73 ± 79.58	0.603	131.2 ± 308.5	0.116	70.3 ± 163.7	0.435	−12 ± 311	0.817	−0.3 ± 1.55	0.191	−0.3 ± 1.55	0.544	0.005 ± 0.023	0.624
	C	32.17 ± 115.5		64.35 ± 378.7		256.2 ± 932		143 ± 1158		0.43 ± 1.79		0.43 ± 1.8		0.0004 ± 0.031	
[i]	T	−52.8 ± 288.2	0.624	101.8 ± 555.5	0.817	−124 ± 801.4	0.13	115 ± 368	0.234	−0.55 ± 1.5	0.017*	−0.126 ± 0.14	0.017*	−0.004 ± 0.013	0.012*
	C	4.47 ± 32.2		42.52 ± 474.8		83.7 ± 164.2		−17 ± 346		1.09 ± 2.32		0.023 ± 0.19		0.003 ± 0.006	
[ɔ]	T	17.3 ± 66.6	0.954	0.631 ± 81.233	0.977	32.4 ± 179	0.506	21.6 ± 205	0.07	−0.9 ± 2.58	0.002*	−0.074 ± 0.31	0.271	−0.00 ± 0.02	0.009*
	C	11.63 ± 77.09		63.36 ± 348.4		−40.8 ± 373		51.9 ± 491		1.32 ± 1.83		0.059 ± 0.15		0.003 ± 0.007	
[œ]	T	−4.94 ± 58.5	0.863	67.31 ± 366.1	0.84	61.9 ± 123.7	0.773	−1.8 ± 315	0.506	0.26 ± 2.07	0.506	−0.04 ± 0.54	0.116	0.013 ± 0.069	0.116
	C	−3.63 ± 52.3		−17.4 ± 87.1		64.2		90 ± 172		0.31 ± 1.75		0.02 ± 0.123		−0.0004 ± 0.005	
[u]	T	19.52 ± 52.1	0.025*	28.31 ± 148.5	0.046*	−98.6 ± 162.1	0.212	−99 ± 269	0.138	−0.008 ± 2.1	0.138	−0.081 ± 0.22	0.954	−0.001 ± 0.012	0.729
	C	−20 ± 47.96		−98.7 ± 204.2		−17 ± 293.1		35 ± 229		0.89 ± 1.8		−0.058 ± 0.13		−0.0003 ± 0.004	
[y]	T	1.89 ± 38	0.931	103.8 ± 186.8	0.234	−39.1 ± 155	0.435	−56 ± 143	0.538	−0.6 ± 2.18	0.163	0.019 ± 0.327	0.664	−0.001 ± 0.012	0.603
	C	2.57 ± 24.83		59.73 ± 235.4		−79.7 ± 299		116 ± 812		0.426		−0.051 ± 0.49		0.0003 ± 0.003	

X, mean; *SD*, standard deviation.
*$P < 0.05$ statistically significant (Mann-Whitney U test).

significantly more changes compared with the control group between T0 and T1 for the F0 parameter of the [u] sound ($P = 0.025$), the F1 parameter of the [a] ($P = 0.03$) and [u] ($P = 0.046$) sounds, and the F2 parameter of the [ɛ] sound ($P = 0.037$). There was no significant difference between 2 groups in the F3 parameter for any of the vowel sounds. Similarly, the changes in the NHR parameter were significantly greater in the treatment group than the control group for the [i] ($P = 0.012$) and [ɔ] ($P = 0.009$) sounds. Surprisingly, in the comparison of the changes in the shimmer parameter, the control group showed more change than the treatment group in the [i] ($P = 0.017$) and [ɔ] ($P = 0.002$) sounds. In the jitter parameter in time between the control and treatment groups, a statistically significant difference was found in the [ɛ] ($P = 0.046$) and [i] ($P = 0.017$) sounds. The jitter parameter of the [ɛ] sound showed more difference in the control group, whereas that of the [i] sound more difference in the treatment group.

DISCUSSION

The effects of the RME on the voice have previously been investigated in growing subjects.[16,17,19] As humans age, the bone elasticity decreases, and the anatomic structures become resistant to orthopedic forces. As a consequence, in adults, the expansive orthopedic forces outcomes are limited to dentoalveolar structures rather than skeletal ones.[20-23] Although SARME is a routine procedure for correction of a maxillary transverse deficiency in adult patients, its effects on the voice are not fully investigated in the literature.

Sari et al[18] examined voice changes in 6 SARME patients and observed a decrease in the F2 frequencies of the sounds [i] and [œ]. Sari et al[18] provided no information about the hour of the day at which the voice records were collected. However, Evans et al[24] suggested that a person's voice is affected by the cyclic hormone level changes that occur at different hours of the day. They observed that in the samples taken at 9 AM, the level of testosterone was high, and the fundamental frequency of the voice was low, whereas the samples taken at noon and in the afternoon revealed decreased testosterone levels and increased fundamental frequency in a gradual manner. Considering the negative correlation between the testosterone levels and the F0 frequency, all records in our study were taken at 12:00 AM.

The effects of the microphone types and positions on the sound records were investigated using microphones with different qualities positioned at different distances and angles.[17] Different records were taken at 4, 3, and 1 cm distances, with varying angles: 0°, 45°, and 90°. It was reported that condenser microphones provided more reliable recordings than dynamic microphones. The authors reported that the perturbation values were affected mostly by microphone sensitivity and the mouth-microphone distance, and the angle was less influential at short distances.[25] In our study, high sensitivity condenser-type Telefunken Ar-51 tube microphones were placed at 15 mm constant distance between the patient and the pop-up filter.

In a study by Bilgiç et al,[19] the voice changes induced by rapid maxillary expansion were evaluated on 30 patients with the mean age of 12 ± 0.75 years. Bilgiç et al[19] evaluated the changes on the F0 only among the formant frequencies of the isolated [a] sound using audio recordings taken at 2 time points; before and after RME. The F0 formant frequency, which is also known as the fundamental frequency, is formed in the glottis region. However, the palate shape, the nasal cavity, the tongue position, and dentoalveolar units are the structures that are mainly affected by the maxillary expansion procedure. These anatomic structures are called resonator areas because the sound gains its characteristics by resonating on them. Because the maxillary expansion affects mainly the resonator structures, most of its effects are expected on the formant frequencies such as F1, F2, and F3, rather than the F0 fundamental formant frequency. In other words, after rapid maxillary expansion or SARME, it will be more reasonable to expect voice changes in the F1, F2, and F3 formant frequencies. Bilgiç et al[19] observed changes in F0, jitter, and shimmer parameters, and they reported that these changes were highly correlated with nasal cavity width increase. In our study, although there was no significant change in the F0 value of the [a] sound, the F1 value of the treatment group showed significantly more change than the control group. The intragroup comparison showed higher F1 values than the pretreatment values. Considering the reduction in the maximum F0 parameter by Bilgiç et al,[19] it might be hypothesized that the voice might have turned low-pitched by hormonal changes rather than as a result of the rapid maxillary expansion.

Biondi et al[26] used expansion appliances with 2- and 4-arms on children with the mean age of 9.3 and examined the effects of the expansion on the voice. This study was performed without a control group, and the audio recordings were made at 6-time points for the [i] vowel only. The sound analysis was carried out using both the Praat and BioVoice (GitHub Inc, San Francisco, Calif) programs. The authors reported that the speech impairment was greater with a 4-arm expansion appliance, although this difference was meaningful only during the first 3 months of application. Biondi et al[26] also reported a reduction in the F0 frequency of the [i] sound and an increase in the F1 and F2 formant frequencies. In our study, no significant change was observed in the formant frequencies of the [i] sound. This might be related to the fact that we collected the voice samples after the critical 3 months of the adaptation period mentioned in the study by Biondi et al.[26] Moreover, this difference might also be related to the differences in age groups in the 2 studies.

Niemi et al[27] examined the sound changes in 8 vowels in 5 male patients in which the mandible was surgically advanced. They examined the formant frequencies (F0, F1, and F2) and sound duration parameters. They observed no long-lasting, significant changes in vowel production. In their study, it was made sure that the patients who were included did not have noticeable speech defects. Therefore, the authors suggested that repeating the study with patients who have speech defects and examining the effects of repairing the malocclusion on voice formation would be valuable.

Vähätalo et al[28] investigated the effects of stretching the genioglossal muscle by chin osteotomy with the purpose of preventing the collapse of the tongue floor. They included 5 male patients with sleep apnea in the study and performed the sound analysis on 8 vowels. They reported that this surgical intervention had no significant effect on the F0, F1, and F2 parameters of the voice.

Macari et al[16] examined the effects of rapid maxillary expansion on the F0, F1, F2, and F3 frequencies of isolated [a], [i], [ɔ], and [u] sounds in 14 patients with ages ranging from 8 to 15. They observed statistically significant reductions in the values of the first and second formant frequencies of the [a] vowel, and they recommended to professional voice artists candidates for rapid maxillary expansion to consider this change in voice characteristics.[16] However, this study had no control group even though the evaluated patients could experience hormonal changes in a short period, even in 2 weeks, because of adolescence. Another important limitation of this study was that the records were collected immediately after the removal of the expansion appliance. Adaptive functional muscular changes related to the presence of the expansion appliance could also have affected the voice parameters with the onset of its removal. In our study, the study group was composed of adults, and a comparison was made to a control group. The youngest patient in our treatment group was aged 17 years 8 months, and it was assumed that hormonal voice changes had already occurred at this age. Significant reductions were observed compared with the baseline values in the F1 frequency of the [a] and the F2 frequencies of the [ϵ] and [œ] sounds in the treatment group. In contrast, the values recorded at T1 in the F1 frequency of the [y] sound and the F2 frequency of the [u] sound were significantly higher than those recorded at T0. In contrast, neither in the study by Macari et al[16] nor ours, the amount of alveolar bending or the amount of true skeletal expansion amounts were correlated to the observed voice changes.

Within the scoop of our study, we considered the pretreatment records and the records taken approximately 5.8 weeks after the appliance removal. All the patients had passive long-armed transpalatal arches fabricated the same day with the appliance removal to maintain the transverse dimension. We provided a scientific, evidence-based retention protocol, but we did not calculate the relapse amount after the procedure. This might be considered as a limitation of the present study.

During the study, some of our patients reported improvement in their articulation, but none of them reported worsening. We found no reference data to decide whether the changes that we found were noticeable by laypeople or not. In the literature, there is no threshold value regarding the clinical perceptibility of the determined differences. Future studies may check if the patients' self-notice or voice changes are perceived by others and at which quantitative level.

CONCLUSIONS

The present study is the first in the literature to prove that some changes occurred in voice characteristics as a result of the SARME. Significant differences were recorded in the F1 frequency of the [a] sound, the F2 frequency of the [ϵ] sound, and the jitter value of the [i] sound in the treatment group, compared with the control group and intergroup comparison based on time. However, there is no threshold value based on scientific evidence regarding the clinical perceptibility of these differences that were determined. However, it may be recommended for clinicians to provide the necessary information for patients who are candidates to have the SARME procedure, especially for those who use their voices professionally.

AUTHOR CREDIT STATEMENT

Onur Erdem Erdur contributed to conceptualization, methodology, investigation, resources, data curation, and original draft preparation; Berza Sen Yilmaz contributed to conceptualization, methodology, formal analysis, data curation, reviewing & editing, visualization, supervision, and project administration.

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