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Original Research

Evaluation the Effects of RME on Turkish Vowels: A Pilot Study

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ABSTRACT
Objective: Any possible change on the quality of voice of the patient after rapid maxillary expansion (RME) treatment should be clarified at pre-treatment counseling of patients and guardians. The aim of the present study was to assess the impact of RME on the spelling of eight Turkish vowels.
Methods: Six patients whose treatment plan was approved as RME and going to wear acrylic cap-type hyrax were recruited for the study. The recordings of eight Turkish vowels (/a/, /ɛ/, /ɯ/, /i/, /ɔ/, /œ/, /u/, and /y/) were pronounced one by one by the patients. Acoustical analysis was performed using PRAAT analysis tools. Fundamental frequencies (F0), formant frequencies of F1, F2, F3, and F4, and vowel durations for Turkish vowels were measured before (T0) and after (T1) the RME.
Results: A significant difference in the mean of F2 /i/ and F3 /i/ ($p=0.001$ and $p=0.002$, respectively) and F3 /ɯ/ was found at T0 and T1 ($p=0.022$). There was no statistically significant difference between the changes in F0 values for both gender and vowel durations at T0 and T1 ($p>0.05$). There was no statistically significant difference in any of the other formants of F1, F2, F3, and F4 for vowels /a/, /ɛ/, /ɔ/, /œ/, /u/, and /y/.
Conclusion: Subject to the small sample size limitation of the present study, the spelling of vowels /i/ and /ɯ/ is lowered after maxillary expansion. The possibility of voice change after RME should be informed to the patient before treatment.
Keywords: Acoustic analyses, rapid maxillary expansion, Turkish vowels

INTRODUCTION

Rapid maxillary expansion (RME) is a widely used treatment in orthodontics that not only provides progress in patients with arch length discrepancies or crossbites but also decreases nasal resistance that in fact relieves mouth breathers. It can increase palatal volume in a statistically significant fashion (1). Any modification in the palatal morphology can affect speech by altering the area of the articulation of the tongue on the palate and change the oral resonance mechanism by enlarging the oral cavity (2).

Phonation is a complex process that involves different parts of the body, such as diaphragm, chest, lungs, larynx, vocal cords, nose, nasal passages, maxilla, teeth, and lips. Any changes at the vocal apparatus may have effects on speech whether it modifies the morphology of the resonating cavities or stiffness and other possible mechanical properties of the related tissues (3). In the literature, there are some studies investigating patients with cleft palate suffering from speech impairment primarily due to velopharyngeal insufficiency (4). In addition, articles investigating the impacts of orthognathic surgery on voice reported that surgery has effects on voice (3, 5). All this information reinforces the hypothesis that RME may have an effect on voice.

In the literature, there are orthodontic-related phonetics studies focused on the alterations caused by the RME. Stevens et al. (6) investigated the speech disturbance and adaptation of the patients wearing RME appliances with the idea of initial discomfort together with functional obstacles related with an intraoral orthodontic appliance may have impacts on patient's compliance that can be resulted with an unsuccessful result Biondi et al. (2) compared the effects of two different types of banded RME appliances on both the possible changes and/or device-related impairments in phonetic habits. In a recent study, Yurttadur et al. (7) evaluated the effects of RME on vocal function in patients with bilateral maxillary crossbite using the acoustic analysis of the /a/ vowel. To the best of our knowledge, there are no studies investigating the influence of RME on the acoustic quality of Turkish vowels. The objective of this prospective pilot study was to assess the impact of RME on the spelling of eight Turkish vowels, namely, /a/ (/a/), /ɛ/ (/e/), /ɯ/ (/ı/), /i/ (/i/), /ɔ/ (/o/), /œ/ (/ö/), /u/ (/u/), and /y/ (/ü/). It is thought that consonant sounds are influenced by dental irregularities, whereas vowels are affected by skeletal discrepancies (8, 9). Within phonetic sounds, vowels can be analyzed more simply acoustically. Owing to these two important findings, Turkish vowels were preferred for investigation

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in the present study. Formants are the major acoustic features of vowels (10). Although there are five formants for each vowel, as performed previously (11), the first four formants (F1, F2, F3, and F4) of the vowels were investigated in the present study. Any possible change on the quality of voice of the patient after RME treatment should be clarified at pre-treatment counseling of patients and guardians.

METHODS

Six patients whose treatment was planned as RME in the Orthodontic Department of Gaziantep University Dentistry Faculty were recruited for the study. The study included 4 female and 2 male patients. The mean age of the patients was 12-16 (13.68±1.4) years. All of the patients were Turkish native speakers. None of the patients have a history of speech therapy or hearing disorders. The study was approved by the ethics committee of the Sanko University (29.03.2018/15). Informed consent was obtained from all patients and their guardians.

All six RME appliances (acrylic cap-type hyrax) were made by the same laboratory technician. Appliances were fabricated with a central jackscrew and were activated as described before (2) with a less difference (0.25 mm/day). The patients wore only RME appliance throughout the study.

Speech recordings were performed at a 44-100 Hz sampling rate and 16-bit resolution. A condenser microphone (RODE NT1-A) on a laptop computer (Intel core i5 863 Mhz, 512 MB of RAM) was used. Speech samples were recorded in a quiet room in the same department. The microphone was fixed at a 10 cm distance from the mouth of the patient. The recordings of eight Turkish vowels (/a/, /ɛ/, /ɯ/, /i/, /ɔ/, /œ/, /u/, and /y/) were pronounced one by one by the patients. Patients were asked to phonate these vowels just before the insertion of the RME device and after the removal of the RME device in approximately 2 weeks.

Acoustical analysis was performed using PRAAT (version 5.3.57; Paul Boersma and David Weenink; www.praat.org) analysis tools. Fundamental frequencies (F0), formant frequencies of F1, F2, F3, and F4, and vowel durations for Turkish vowels were measured before (T0) and after (T1) the RME.

Statistical Analysis

Statistical analysis was performed using Statistical Package for the Social Sciences version 24 for Windows (SPSS IBM Corp.; Armonk, NY, USA). All descriptive statistics were expressed as mean±SD. Shapiro-Wilk test was used for normally distributed continuous variables. For each subject, the F1, F2, F3, and F4 and mean vowel duration were collected before and after treatment, and paired sample t-test was conducted. Wilcoxon signed-rank test was used for fundamental frequencies stratified by gender before and after treatment. A p value <0.05 was accepted as statistically significant.

RESULTS

A significant difference in the mean of F2 /i/ and F3 /i/ (p=0.001 and p=0.002, respectively) and F3 /ɯ/ was found at T0 and T1 (p=0.022) (Figures 1-3).

Figure 1. F2 /i/ before and after RME in subjects 1–6
RME: rapid maxillary expansion

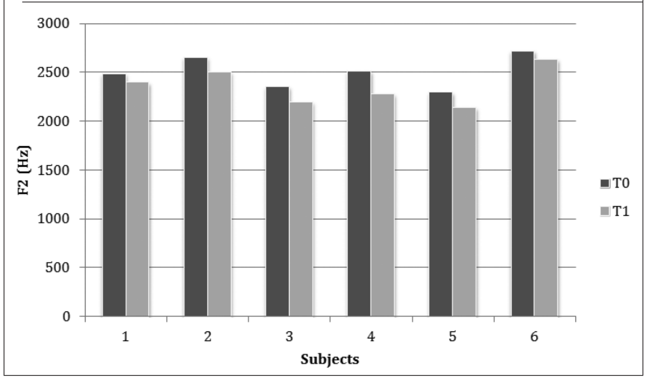

Figure 2. F3 /i/ before and after RME in subjects 1–6
RME: rapid maxillary expansion

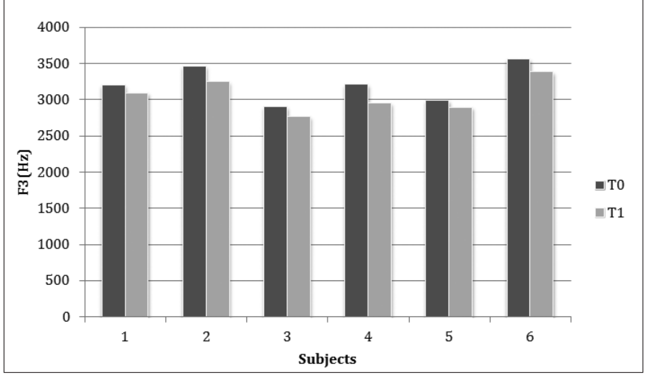

Figure 3. F3 /ɯ/ before and after RME in subjects 1–6
RME: rapid maxillary expansion

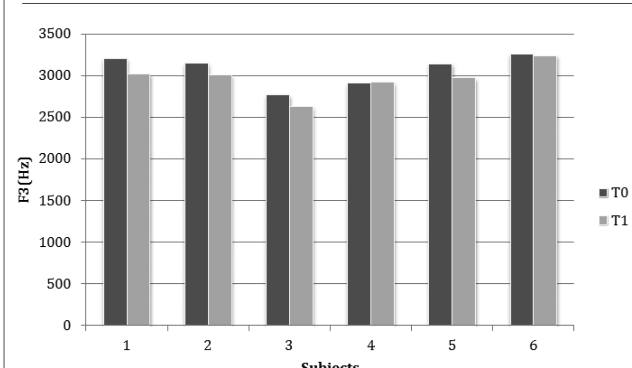

Table 1. Acoustic parameters before and after treatment

Variables (N=6)	T0 Mean (SD)	T1 Mean (SD)	p
Fundamental frequencies (Hz)	224.4 (58)	222.1 (55)	>0.05
Vowel durations (ms)	335.5 (73)	322.39 (67)	>0.05

*Wilcoxon Signed Rank Test, significant if p<0.05
T0: before expansion; T1: after expansion
SD: standart deviation

Table 2. Mean values and 95% Confidence Intervals of parameters at T0 and T1 for F1, F2, F3 and F4 frequencies (Hz) and significance values of differences (T0-T1)

Vowels	T0 Mean (SD) (N=6)	95% CI Lower - Upper Bound	T1 Mean (SD) (N=6)	95% CI Lower - Upper Bound	p
Formant 1 (Hz)					
/a/	763.8 (59)	610 - 917.6	788.8 (65)	619.5 - 958.1	>0.05
/ɛ/	586.1 (24)	522.1 - 650.1	610.3 (39)	508.6 - 712	>0.05
/ɯ/	483.6 (27)	413.1 - 554.1	502.8 (42)	392.3 - 613.2	>0.05
/i/	433.3 (32)	349.1 - 517.4	440.3 (45)	322.6 - 557.9	>0.05
/ɔ/	564.3 (31)	482.6 - 646	562.1 (64)	395.7 - 728.5	>0.05
/œ/	550.5 (19)	500.0 - 600.9	569.6 (53)	433.1 - 706.2	>0.05
/u/	467 (29)	391.6 - 542.3	455.8 (43)	344.1 - 567.5	>0.05
/y/	465.3 (29)	390.7 - 539.9	461.5 (28)	389.3 - 533.6	>0.05
Formant 2 (Hz)					
/a/	1260.1 (37)	1164.2 - 1356	1239.8 (54)	1099.9 - 1379.7	>0.05
/ɛ/	1612.6 (191)	1120.4 - 2104.8	2051.1 (71)	1867.3 - 2234.9	>0.05
/ɯ/	1324.3 (38)	1224.7 - 1423.9	1356.8 (68)	1180.7 - 1532.8	>0.05
/i/	2504 (67)	2331.1 - 2676.8	2359 (76)	2161.7 - 2556.2	*0.001
/ɔ/	1048.5 (44)	935.2 - 1161.7	1060.8 (45)	942.9 - 1178.6	>0.05
/œ/	1541.16 (90)	1307.5 - 1774.7	164 (60)	1486.8 - 1799.1	>0.05
/u/	936 (51)	804.5 - 1067.4	1227.8 (113)	937.2 - 1518.4	>0.05
/y/	1868.1 (118)	1563.2 - 2173	1772.3 (42)	1662.4 - 1882.2	>0.05
Formant 3 (Hz)					
/a/	2954.3 (210)	2412 - 3496.5	2928.5 (147)	2548.7 - 3308.2	>0.05
/ɛ/	2857.3 (125)	2534.3 - 3180.3	2922.5 (128)	2591.2 - 3253.7	>0.05
/ɯ/	3071.1 (78)	2869.1 - 3273.2	2962.3 (80)	2755.2 - 3169.4	*0.022
/i/	3220.8 (104)	2952 - 3489.6	3056 (93)	2814.9 - 3297	*0.002
/ɔ/	3106.8 (102)	2843.1 - 3370.4	3068.8 (117)	2767 - 3370.6	>0.05
/œ/	2801.5 (128)	2471.5 - 3131.4	2873.3 (68)	2698.2 - 3048.3	>0.05
/u/	3108.5 (73)	2920.1 - 3296.8	2925.1 (89)	2695.6 - 3154.6	>0.05
/y/	2811.6 (63)	2647.3 - 2976	2875 (83)	2659.2 - 3090.7	>0.05
Formant 4 (Hz)					
/a/	4036.6 (202)	3516.9 - 4556.3	3796.5 (177)	3340.6 - 4252.3	>0.05
/ɛ/	3955.1 (148)	3574.2 - 4336	3922 (246)	3289.4 - 4554.5	>0.05
/ɯ/	3901.6 (148)	3519 - 4284.2	3832.1 (99)	3575.8 - 4088.4	>0.05
/i/	4113.6 (143)	3745.6 - 4481.6	4039.1 (141)	3675.8 - 4402.5	>0.05
/ɔ/	3837.5 (128)	3507.7 - 4167.2	3851 (116)	3552.3 - 4149.6	>0.05
/œ/	3630.3 (92)	3393.6 - 3867	3854.6 (103)	3588 - 4121.2	>0.05
/u/	3964.3 (146)	3588.2 - 4340.4	3968.3 (96)	3720.1 - 4216.5	>0.05
/y/	3837 (149)	3451.9 - 4222	3954.3 (148)	3573.4 - 4335.2	>0.05

*Paired Sample t Test, significant if p<0.05
T0: before expansion; T1: after expansion
SD: standart deviation

There was no statistically significant difference between the changes in F0 values and vowel durations at T0 and T1 ($p>0.05$) (Table 1).

There was no significant difference in any of the other formants of F1, F2, F3, and F4 for vowels /a/, /ɛ/, /ɔ/, /œ/, /u/, and /y/ (Table 2).

DISCUSSION

Anatomical changes in the vocal tract may affect speech production in case of any change of the resonating cavities (12). RME may affect formant frequencies due to the altered and anteriorly replaced tongue after RME. Niemi et al. (3) reported that the facial skeleton burdens direct limitations on the morphology of the resonating vocal tract cavities and is therefore very relevant to speech acoustics or articulation. As a result of the present study, differences in the mean values of F2 /i/, F3 /i/, and F3 /ɯ/ were found to be statistically significant between T0 and T1. Vowel /i/ showed a statistically significant decrease in F2 and F3 values from T0 to T1. Although there are studies reporting no effect of RME on vowel /i/ (11), our finding is in accordance with the result of a previous study that investigated the impact of RME appliance on speech. The authors evaluated only F1 and F2 formants of the /i/ vowel and reported a centralization of the vowel by looking at the increase in F1 and the decrease in F2 (6). In another study, in contrast to our findings, vowel /i/ displayed a decrease of the F1 and an increase in the F2 and F3 (2). Meanwhile, a study investigating the effects of surgically assisted RME on voice quality reported a lowered F2 frequency and linked this finding enlargement of the size of the anterior oral cavity after surgery. Vowel /i/ is a high front vowel, meaning the position of the tongue is just behind the upper incisors, in the anterior oral cavity, during pronunciation. In case of maxillary constriction, since the tongue was unable to access the anterior oral cavity, it is not unreasonable to expect a perturbation of this vowel. In addition, the investigation of this susceptible vowel when conducting speech evaluation is recommended in a very recent study (13).

Vowel /ɯ/ is a very specific Turkish sound; it was not evaluated before except one research with no significant difference before and after surgically assisted RME (10). This difference mainly emerges from the fact that the previous researchers only investigate the F1 and F2 not F3 frequencies. Vowel /ɯ/ is also a high front vowel that can be affected by the size of the anterior oral cavity.

The changes in fundamental frequencies for both females and males before and after RME treatment demonstrated no statistically significant difference as previously reported (10, 11).

The results of this preliminary study show that no statistically significant difference was seen in the remaining Turkish vowels. For vowel /a/, our findings corroborate with other studies (7, 10). Only Macari et al. (11) reported a lowering of the F1 and F2 values of the /a/ vowel and advised that patients with narrowed maxilla who underwent RME should be aware of the possible change in speech quality.

In the present study, rather than a perceptual investigation, acoustic analysis was used to investigate speech errors just before the insertion of RME appliance and after the removal of RME. Acoustic analysis provides a more objective and reliable measurement, which may be difficult to reliably document perceptually and may not be noticeable perceptually. In the present study, acoustic analysis was performed by the PRAAT program. PRAAT program, which was also used in previous studies (2, 14), is a completely free software often used for acoustical analysis.

CONCLUSION

Despite to the small sample size limitation of the present study, it may be concluded that RME has an effect on voice acoustics. The spelling of high front vowels of /i/ and /ɯ/ is lowered after maxillary expansion. The possibility of voice change after RME should be discussed before treatment decision of patients. A larger sample of RME subjects is needed to substantiate this conclusion.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Sanko University (29.03.2018/15).

Informed Consent: Written informed consent was obtained from patients and patients' parents who participated in this study.

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Conflict of Interest: The authors have no conflicts of interest to declare.

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