Original Article / Çalışma - Araştırma

An evaluation of the effects of adenoidectomy on voice and speech function in children

Çocuklarda adenoidektominin ses ve konuşma fonksiyonu üzerine etkisinin değerlendirilmesi

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Objectives: This study aims to evaluate the possible effects of adenoidectomy on voice and speech function.

Patients and Methods: Thirty-six children (20 boys, 16 girls; mean age 8.22±1.86 years) with adenoid hypertrophy and 50 healthy children (23 boys, 27 girls; mean age 8.54±1.92 years) were included in the study. Acoustic and spectrographic analyses, voice analysis and nasalance assessment were carried out preoperatively and at one week and three months postoperatively in children who underwent adenoidectomy operation and control group.

Results: A significant change in voice nasalance and F_3 and F_4 formants was observed in children who underwent adenoidectomy. There was no significant change in F_0, shimmer %, amplitude perturbation quotient (APQ), jitter %, relative average perturbation (RAP), noise to harmonic ratio (NHR), F_1 and F_2 formant values, as assessed by objective voice analysis.

Conclusion: Our study results show that adenoidectomy may affect voice resonance and nasalance, changing the shape and size of nasopharynx and upper respiratory tract. Adenoidectomy seems to be safe without any significant change in the voice quality.

Key Words: Adenoidectomy; multidimensional voice program; nasalance; resonance; voice analysis.

Amaç: Bu çalışmada adenoidektominin ses ve konuşma fonksiyonu üzerindeki muhtemel etkileri değerlendirildi.

Hastalar ve Yöntemler: Adenoid hipertrofisi tanısı konulan 36 çocuk (20 erkek, 16 kız; ort. yaş 8.22±1.86 yıl) ve 50 sağlıklı çocuk (23 erkek, 27 kız; ort. yaş 8.54±1.92 yıl) çalışmaya dahil edildi. Adenoidektomi ameliyatı yapılan çocuklarda ve kontrol grubunda ameliyat öncesi ve ameliyat sonrası birinci hafta ve üçüncü ay akustik ve spektrografik analizler, ses analizi ve nazalans değerlendirmeleri yapıldı.

Bulgular: Adenoidektomi yapılan çocuklarda ses nazalansı ve F_3 ve F_4 formant değerlerinde anlamlı bir değişiklik gözlendi. Objektif ses analizi ile değerlendirildiği üzere, F_0, shimmer %, amplitüd pertürbasyon oranı (APQ), jitter %, rölatif ortalama pertürbasyon (RAP), harmonik gürültü oranı (NHR) ve F_1 ve F_2 formant değerlerinde anlamlı bir değişikliğe rastlanmadı.

Sonuç: Çalışma bulgularımız, adenoidektominin nazofarenks ve üst solunum yolunun şekil ve boyutunu değiştirerek sesin rezonans ve nazalansı üzerinde etkili olabildiğini göstermektedir. Adenoidektominin ses kalitesinde anlamlı bir değişikliğe neden olmadığı ve güvenle uygulanabileceği görülmektedir.

Anahtar Sözcükler: Adenoidektomi; çok boyutlu ses programı; nazalans; rezonans; ses analizi.

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Voice is a complex physiological process which occurs as a result of the interaction among respiratory, laryngeal and resonance subsystems. Surgical procedures on oral, nasal and pharyngeal cavities which change their shape and size may result in changes of voice quality by affecting resonance. Adenoid hypertrophy is very common among children and adenoidectomy is one of the most common surgeries in childhood. In the current literature, there are few studies evaluating voice changes concerning adenoidectomy.[1-4] Previous studies using generally subjective voice analysis techniques found significant changes in nasality and a decrease in nasal airway resistance.[2,4] The computerized speech lab (CSL, Kaypentax, USA) covers multidimensional voice program (MDVP), Real-Time Pitch and Real-Time Spectrogram programs separately.[5] The computerized speech lab, which is used for acoustic analysis of voice, is a program including waveform, spectrogram and formant values, energy time graphic of voice signals. This software has been used for objective analysis of voice.[6,7] It may be important to objectively determine the voice changes expressed by patients and their relatives after upper airway-related surgeries and it may be also important to assess whether these changes are permanent or not. In the present prospective study, objective acoustic analysis parameters including fundamental frequency (F_0), jitter %, relative average perturbation (RAP), shimmer %, amplitude perturbation quotient (APQ), noise to harmonic ratio (NHR), minimum and maximum pitches, F_1, F_2, F_3 and F_4 as well as a nasometer (Nasometer II, Model 6400, Kaypentax, USA) were used to evaluate voice and nasalance in the preoperative and post adenoidectomy period.

PATIENTS AND METHODS

This study was approved by Selçuk University Ethical Committee of Meram Faculty of Medicine (no: 2008/156). Informed written consent was obtained from the parents by explaining the details of the study. Children aged from 5 to 12 who suffered from adenoidal hyperplasia symptoms with grade-1 tonsil size were included in the study. A power calculation ensured that 40 patients were recruited to provide 90% power for a difference in nasalance at the 10% significance level. Four patients did not attend the postoperative follow-up and the study was completed with 36 children (20 boys, 16 girls; mean age 8.22±1.86 years) with adenoid hypertrophy. Fifty healthy children (23 boys, 27 girls; mean age 8.54±1.92 years; range 5 to 12 years) without adenoid symptoms or findings were selected as the voluntary control group. Children who had an acute or chronic voice disease, any voice-related surgery, neurological or pulmonary disease which might result in voice and speech disorders, cleft lip-palate or any nasal pathology and children with previous adenoidectomy history were excluded from the study. Adenoidal-nasopharyngeal ratio (ANR) was measured and adenoid tissue size was assessed on lateral cephalography in the study and control groups. Lateral cephalography with soft tissue exposure were obtained with mouth closed, skull in hyperextension and in the upright position. Adenoid measurement (A) was selected as the distance left between the line tangent to the union of maximal convexity and sphenobasioccipital synchondrosis on the radiography. Nasopharyngeal distance (N) was selected as the measurement of the distance between posterior border of the hard palate and sphenobasioccipital synchondrosis. ANR was obtained by calculating the ratio of A distance to N distance and the data was recorded. Forty children who had an ANR of 0.60 or more on lateral cephalography were included in the study as the adenoid group.

All recordings were conducted in a quiet room using Shure SM 58 microphone. The voice samples were obtained as follows: the subjects were requested to phonate "a" three times lasting for five seconds, in the standing position after a deep breath. The voice samples were recorded to Multi-Dimensional Voice Program (MDVP Model 5105) for acoustic analysis in CSL (Kay Elemetrics, Lincoln Park NJ, USA). The best quality data of three recorded samples were analyzed with MDVP software and mean F_0, jitter % and RAP, shimmer % and APQ, NHR acoustic parameters were examined.

For real-time pitch analysis, the subjects were asked to count from 1 to 10 and their voice samples were recorded in Real Time Pitch Model 5121 in CSL (Kay Elemetrics, Lincoln Park NJ, USA). The data were analyzed in analysis software and then minimum and maximum pitch values (Hz) were obtained.

For spectrographic analysis, the subjects were requested to phonate "a" three times lasting for five seconds after a deep breath and their voices were recorded on the Real-Time Spectrogram Model 5129 software in CSL (Kay Elemetrics, Lincoln Park NJ, USA). The best data of three recorded samples were analyzed in the analysis program and the mean values of F_1, F_2, F_3 and F_4 formants were examined.

Nasalance measurements were conducted by using Nasometer II Model 6400 (Kay Elemetrics, Lincoln Park NJ, USA) while the subjects were sitting, while separating layer was fixed to nasometer helmet straight to face layer, the microphone to record the signal to at the distance of approximately 10-15 cm to the patient's mouth. Nasometer was set before each subject was tested. Hereafter each subject was recorded by asking them to say "annemin adı emine". Nasal sentence in which there were nasal consonants such as /m/ and /n/. The data were analyzed in analysis program and mean nasalance values were examined. All cases with adenoidal hyperplasia underwent standard curettage adenoidectomy under general anesthesia. We did not perform tonsillectomy for our cases. Vocal quality was evaluated by the same otolaryngologist using grade (G), roughness (R), breathiness (B), asthenia (A), and strain (S) scale for perceptual analysis. The voice quality was scored for GRBAS scale according to four point rating system ranged from 0 (normal) to 3 (profoundly abnormal).

All measurements were recorded and analyzed for control and study groups, preoperatively. The measurements were repeated two more times for the adenoid group at one week and three months, postoperatively.

Statistical analysis

Data related to study and control groups were analyzed using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL, USA). Minimum, maximum, mean and standard deviation values of the data were calculated and findings were presented as mean ± standard deviation whether the distribution rates of the data in each group were consistent with normal distribution was determined with Kolmogorov-Smirnov consistency improvement test. If the statistical analysis of the study and control groups were found to consistent with normal distribution, Student's t-test would have been used for independent groups. However, the statistical analysis of both groups were inconsistent with normal distribution: Thus, for statistical analysis Mann-Whitney U test was performed. Preoperative, postoperative first week and postoperative third month values were compared with one-way ANOVA test and Bonferroni adjusted t-test was used post hoc. Nonparametric data was analyzed by Friedman test and for any statistically significant results, post hoc analysis was conducted by first adjusting the critical alpha value using the Bonferroni correction, with the critical alpha set at 0.017. Secondly, Wilcoxon test were used. While comparing two parametric measurements (pre- and postoperative) in the study group student's t-test, and for nonparametric measurements Willcoxon test, were used. Statistical significance rate was accepted as $p<0.05$ (in Bonferroni correction, $p<0.017$).

RESULTS

There was no significant difference for age and sex factors between the adenoid and control group ($p=0.65$, t-test and chi-square test, respectively). The mean ANR of the adenoid group was 0.79±0.96 whereas the mean ANR of the control group was 0.45±0.14. There was a significant difference for mean ANR value between control and adenoid groups ($p=0.00$). Perceptual analysis (GRBAS) values of control and adenoid group subjects are given in the Table 1. There was no significant difference for perceptual analysis of the study group ($p>0.05$).

The mean nasalance, F_0, jitter %, RAP, shimmer %, APQ, NHR, minimum pitch, maximum pitch, F_1, F_2, F_3, F_4 values for the control group and preoperative, one week postoperatively and three month postoperatively of the adenoid group are given in the Table 2.

There was a significant difference between control and preoperative measurements of the study group for nasalance ($p=0.015$). The mean nasalance measurements were significantly lower than the control group. It was determined that there was a significant increase in nasalance measurements after surgery (both 1 week and 3 months) compared with preoperative measurements ($p=0.00$). Beside, nasalance values in the postoperative third month increased significantly when compared to first week results ($p=0.00$).

There were no significant differences between controls and each measurement of the study

Table 1. GRBAS values of control and adenoid group subjects

	Control group	Adenoid group (preoperative)	Adenoid group (1 week later)	Adenoid group (3 months later)
	Mean±SD	Mean±SD	Mean±SD	Mean±SD
G (overall grade)	0.12±0.11	0.13±0.12	0.12±0.13	0.13±0.01
R (roughness)	0.21±0.01	0.21±0.11	0.18±0.12	0.21±0.13
B (breathiness)	0.01±0.01	0.21±0.1	0.14±0.01	0.18±0.13
A (asthenicity)	0.21±0.12	0.21±0.15	0.21±0.18	0.21±0.14
S (strain)	0.01±0.01	0.22±0.11	0.21±0.13	0.21±0.18

SD: Standard deviation.

group ($p>0.05$) as well as between both pre- and postoperative measurements ($p>0.017$) for F_0, jitter %, RAP, shimmer %, APQ, NHR, minimum pitch and maximum pitch.

There was no significant difference between controls and both postoperative measurements of the adenoid group for F_2 (respectively p=0.97, p=0.94, p=0.99). Although F_3 measurement of the study group was increased (2613.76±419.7) after surgery when compared to preoperative measurements (2422.98±436.41), it was not statistically significant (p=0.88). On the other hand, the three month postoperative measurement of F_3 was significantly increased when compared with the control group (p=0.012). F_4 measurement of the study group was increased after surgery compared with preoperative measurements, and was statistically significant (p=0.004). There was a significant difference between both pre- and postoperative measurements for F_4 (p=0.014).

DISCUSSION

Enlarged adenoid tissue in children causes snoring, sleeping disorders, failure to thrive, frequent upper respiratory tract infections and abnormalities in maxillofacial development.[8] Large adenoid tissue decreases nasal airflow and causes hyponasality. On the other hand, after adenoidectomy, hypernasality and

Table 2. Mean nasalance, fundamental frequency (F_0), jitter %, RAP, shimmer %, APQ, NHR, minimum pitch, maximum pitch, F_1, F_2, F_3, F_4 values of control and adenoid group subjects

	Control group	Adenoid group (Mean±SD)		
		Preoperative	Postoperative	Postoperative
	Mean±SD		1 week later	3 months later
Nasalance	58.26±8.39*	53.89±10.36*&#	60.42±5.93&	65.64±5.87#
Fundamental frequency (F_0)	297.07±35.0	295.74±45.44	286.09±41.09	283.44±40.54
Jitter (%)	1.32±0.88	1.39±0.75	1.68±0.98	1.51±0.82
Relative average perturbation	0.80±0.54	0.84±0.45	1.02±0.60	0.92±0.50
Shimmer (%)	4.11±1.81	3.94±1.39	4.84±1.68	4.47±1.17
Amplitude perturbation quotient	2.85±1.16	2.75±0.94	3.23±1.01	3.06±0.81
Noise to harmonic ratio	0.12±0.03	0.12±0.02	0.13±0.04	0.12±0.02
Minimum pitch	194.37±44.19	194.93±46.83	201.84±40.50	200.79±40.19
Maximum pitch	333.55±34.54	326.50±40.93	304.31±36.04	317.95±52.53
F_1	518.22±42.5	517.85±35.91	520.91± 61.26	529.50±34.25
F_2	1171.60±232.33	1209.69±433.21	1183.68±106.94	1195.13±452.55
F_3	2386.98±329.17∞	2422.98±436.41	2546.32±443.75	2613.76±419.7∞
F_4	3571.89±348.48∞	3628.14±357.74#	3591.72±335.51	3833.62±280.83∞#

* p<0.05; Control group and preoperative adenoid group comparison, was use the independent samples t-test; & p<0.017; Pre- and postoperative one week later adenoid group comparison, was use the one way ANOVA test in repeated measurement; # p<0.017; Pre- and postoperative three months later adenoid group comparison, was use the one way ANOVA test in repeated measurement; ∞ p<0.017; Control group and postoperative three months later adenoid group comparison, was use the one way ANOVA test in repeated measurement.

velopharyngeal failure may occur.[9] The changes in shapes and sizes of acoustic spaces related to surgical applications of the oral, nasal and pharyngeal cavities lead to variation in voice quality by changing resonance features.[9-11] In the literature, some limited studies showed that adenoidectomy and/or tonsillectomy or uvulopalatopharyngoplasty (UPPP) might affect nasalance by using subjective or limited objective analysis techniques.[2-4,12-16] Hypertrophic tonsil tissues cause air which is supposed to go out the nasal airway to pass through the oral route leading to an increase in nasalance by causing obstruction in the oropharynx. The nasalance condition improves after tonsillectomy. Results of the present study suggested that adenoidectomy did not affect voice quality in children with adenoid hyperplasia.

In the present study, laryngeal voice and nasal voice were assessed using objective and subjective acoustic analyses techniques. The parameters of /a/ vowel were examined in laryngeal voice assessment. It is known that /a/ vowel is formed phonetically without complete obstruction or extreme contraction in the vocal tract unlike other vocals. Nasal consonants (/m/ and /n/ consonants), are formed as a result of sufficient opening of the velopharyngeal tract. Whereas qualitative perceptual assessment of nasal voices such as nasality and nasalization are determined, the mirror-fogging test and nasometer device are used to calculate nasalance score objectively. The effects of surgical operations such as upper airway surgeries, septoplasty, paranasal sinus surgery, UPPP and maxillectomy on voice have been examined in various studies stating that surgeries of these areas affect nasality.[1-4,12,13,16] When nasalance values of children with adenoid hypertrophy measured with a nasometer were compared with the control group, it was seen that they were statistically significantly low ($p<0.05$). This situation suggested that adenoid hypertrophy causes hyponasality by obstructing the nasopharynx. There was a significant increase on nasalance values after surgery. After adenoidectomy, this hyponasality was improved.

Sound spectrographic analysis may be beneficial in visual assessment of the degree of hoarseness. In a normal spectrogram, harmonics are observed in smooth horizontal lines, while in the spectrogram of a pathological voice, noise components are monitored between the harmonics. As the degree of hoarseness increases, noise components in a spectrogram become dominant.[9,17] In spectrographic examination of sound, F_0 represents the fundamental frequency of the sound formed by the vocal cords. Formants are defined by shape and size of the acoustic spaces of the vocal tract. Formants are of paramount importance to the voice. In the vocal tract, there are generally four or five formants. The frequencies of the two lowest formants determine most of the vowel quality, while the third, fourth and fifth formants are of greater significance to personal voice timbre. Lips, mandible, tongue, velopharynx and posterior wall of the nasopharynx and pharynx may affect formant frequencies and amplitudes.[18] The literature in general reveals that F_1 and F_2 frequency values do not change after adenoidectomy, tonsillectomy, and UPPP surgeries as we found in our study. Different results were found for F_3 and F_4 and according to the theoretical knowledge; F_3 and F_4 frequencies may change after surgeries related to the nasal cavity and paranasal sinuses. In our opinion, this knowledge explains the increase in F_3 and F_4 frequencies after adenoidectomy in our study. On the other hand, postoperative three month measurements of F_3 and nasalance were significantly increased when compared with the control group ($p<0.017$). Although our control group was selected from healthy children, their mean ANR value was 0.45±0.14 meaning there was still adenoid tissue located in the nasopharynx posterior wall. These results may be related to that our cases had more nasopharynx space after surgery than our control group. For perceptual analysis, there was no significant difference between pre- and postoperative evaluations. This data showed us objective analysis is more sensitive then perceptual analysis for evaluation of voice quality after adenoidectomy.

Nemr et al.[19] emphasized that acoustic analysis correlated well with other methods (such as perceptual analysis, indirect laryngoscopy, laryngostroboscopy) in the examination of voice disorders and also stated that it might be used as a complementary method. Providing a place with sound insulation is important in voice analysis, because the ambient noise affects the measurement values. Carson et al.[7] in their voice analysis carried out with different hardware and software systems, found out that ambient noise particularly had significant effects on the jitter and shimmer parameters in particular.

Pitch is a term indicating the thinness or thickness of sound. There was no statistical difference between preoperative values of control and adenoid groups regarding minimum and maximum pitch values, between pre- and postoperative values of the adenoid group, and late period results of adenoid group and control group (p>0.05). İlk et al.[20] concluded that tonsillectomy does not change the values of the pitch as a result of their study. There is no sufficient data in the literature on this subject, but no change is expected to be seen in pitch values after upper respiratory tract surgeries since it is related to primitive sound which occurs in vocal cords.

Currently, acoustic and spectrographic analyses are used in organic or functional induced voice diseases in order to show the effect of treatment on voice.[5,21,22] Objective acoustic analysis parameters including F_0, jitter %, RAP, shimmer %, APQ, NHR are the basic parameters that determine the sound quality.[23,24] Measurements of jitter and shimmer parameters reflect the rough sound quality in sound signal associated with the irregularity in pitch and amplitude. Noise to harmonic ratio is expressed as the ratio of sound energy formed of F_0 and harmonics to sound energy in noise frequencies and it is also observed that it shows connection with dysphonia.[24,25] In our study, acoustic parameters of /a/ vocal (F_0, jitter %, RAP, shimmer %, APQ, NHR) in the postoperative period showed no significant change compared to the preoperative period (p>0.05). However, when patients with adenoid hypertrophy were compared with healthy children, no statistically significant difference was observed in these parameters (>0.05). Mora et al.[26] and Salami et al.[27] observed a significant decrease in F_0, jitter %, and shimmer % and NHR values and found out normalization when comparing healthy children with postoperative values after tonsillectomy with or without adenoidectomy. İlk et al.,[20] found out that no significant changes occurred in F_0 and jitter % and shimmer % values did not change, but they observed a decrease in NHR after tonsillectomy. They concluded that changes in values became apparent after tonsillectomy when tonsils were too large. Subramaniam et al.[3] found that preoperative F_0 values of children with adenotonsillar hypertrophy were lower than the healthy group but some nonsignificant changes occurred in the postoperative period and jitter, shimmer and NHR values decreased nonsignificantly. Chuma et al.[1] found that F_0 values did not change after adenotonsillectomy. F_0, jitter, shimmer and NHR values in literature were found to be variable. Although it may be thought that surgical procedures concerning the nasopharynx such as adenoidectomy must not lead to changes in acoustic parameters of sound, more studies should be made in order to decide on this issue. The results of our study and the literature make us think that surgical procedures concerning the upper airway do not cause any change in terms of sound quality and can be applied safely. Besides, while adenoidectomy decision is taken, submucosal cleft palate, velopharyngeal failure family history, developmental and neuromuscular factors should be evaluated and it should be remembered that adenoidectomy may result in complications such as velopharyngeal failure, nasal regurgitation and hypernasal speech.

In conclusions, adenoidectomy may affect resonance and nasalance by changing voice formants because this surgery changes the nasopharyngeal and upper airway shape and size. The results of our study suggest that surgical procedures concerning adenoidectomy do not cause major changes in terms of sound quality and can be applied safely. Objective voice analysis including nasalance and formants especially for F_3 and F_4 may be useful for evaluation of voice quality after upper respiratory tract surgeries.

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