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An Analysis on Aerodynamic and Acoustic Changes After Thyroidectomy

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The purpose of this study was to investigate the aerodynamic and acoustic changes after thyroidectomy without laryngeal nerve injury by using objective methods. Voice samples of sustained /ɑ/ recorded from 44 adults preoperatively and nearly 1 week and 3 months after thyroidectomy were analyzed for mean vocal fundamental frequency (Mean Fo, Hz), maximum fundamental frequency (Max Fo, Hz), minimum fundamental frequency (Min Fo, Hz), jitter, shimmer, glottal to noise excitation ratio (GNE), irregularity, noise, overall severity, S time, Z time, S/Z ratio, and maximum phonation time (MPT). Voice samples were analyzed using the lingWAVES software. The comparisons of preoperative and early and late postoperative acoustic parameters revealed significant differences in Mean F0, Max F0, MPT, and S Time between the early and late postoperative periods. The voice changes after thyroidectomy were not affected by age, sex, or surgical procedure, but they differed between the benign and malignant nature of the tumor. Patients with malignant tumors showed a greater decrease in Mean F0 and Max F0 compared with the patients with benign tumors, and this difference was statistically significant. Voice changes may occur after thyroidectomy even in the patients with no evidence of laryngeal nerve damage, and these changes can be assessed with objective measurement methods. This information should be explained to the patients during the preoperative counseling, and proper informed consent is ethically and legally required for all planned thyroidectomies.

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Thyroidectomy is a commonly performed surgical procedure in otorhinolaryngology and general surgery clinics, and it mostly leads to voice changes in the postoperative period. As the vocal tract includes the glottis, where voice is produced, and the resonator, which produces the unique voice for every individual, any intervention made in this anatomical site may lead to changes in voice.

Voice changes may happen after thyroidectomy and are generally caused by damage to the laryngeal nerve. Inferior laryngeal nerve damage has been a well-known reason, and many surgical procedures to prevent this problem have already been defined in detail. Lately, the paralysis of the external branch of the superior laryngeal nerve has been progressively accepted, and procedures have been defined to decrease the risk of damage to this nerve.[1,2] However, voice changes may occur even without laryngeal nerve damage, but the specific mechanism remains unknown; however, different reasons have been provided, including intubation,[3] modification of venous drainage of the larynx,[4] cricothyroid dysfunction,[3–5] laryngotracheal fixation with impairment of vertical movement,[3,6,7] strap muscle dysfunction due to nerve damage or direct injury (section),[6,7] local pain in the neck, and/or a psychologic rebound to the postoperative conditions.[4]

Voice changes can be assessed both by subjective and objective methods. Currently, objective voice analyses have a growing importance for phoniatrics because they support diagnosis and have a central role both in detecting voice disorders and in patient follow-ups. Computerized acoustic analysis is an objective method and contributes to the objective assessment of potential voice changes.[5,8]

The purpose of this study was to analyze the aerodynamic and acoustic changes after thyroidectomy in the patients with no evidence of laryngeal nerve injury by using objective methods. In addition, we pursued whether these changes are affected by patient characteristics including age, sex, surgical procedure, and histopathologic diagnosis.

Methods

Forty-four patients who underwent thyroid surgery due to thyroid pathology at the departments of Ear, Nose, and Throat, and General Surgery, between July 2013 and July 2014, were evaluated prospectively. The study was certificated by the local ethics committee and applied in pursuance of the Declaration of Helsinki as changed in 2013. Exclusion criteria included the following: prior thyroidectomy, radiotherapy history, surgery to the neck, detection of a pathology in the videolaryngostroboscopy (VLS) examination before the surgery, and systemic or neurogenic diseases that affected voice quality and pathology. VLS examinations were performed using a Storz 8010 machine (Karl Storz GmbH & Co, Tuttlingen, Germany) with a 70° angled rigid endoscope. All the patients were euthyroid at the time of operation, and the preoperative VLS examinations were normal. The effect of thyroidectomy on voice was examined by recording the voices of the patients preoperatively and 1 week and 3 months postoperatively.

Aerodynamic and acoustic analysis

Voice records were achieved using Adobe Audition CS6 version 5 software (Adobe Systems Inc, San Jose, California) with a professional microphone (AKG C1000; AKG, Vienna, Austria). The microphone was placed at a distance of 30 cm from the oral cavity, and a vowel of "a" was recorded for 5 seconds. The voice records were evaluated using the lingWAVES software (version 2.6; Wevosys, Forchheim, Germany).

The lingWAVES software is a program used for voice and speech analysis, biological feedback, and documentation. The lingWAVES evaluates a number of acoustic parameters including fundamental frequency (F0), jitter, shimmer, glottal to noise excitation ratio (GNE), irregularity, noise, and overall severity parameters. In this software, the Vospector module can measure the voice quality, and the Voice Protocol module evaluates the aerodynamic parameters such as S Time, Z Time, maximum phonation time (MPT), and S/Z ratio (Fig. 1).

The statistical analysis was based on the 13 parameters assessed by the lingWAVES software, including mean vocal fundamental frequency (Mean Fo, Hz), maximum fundamental frequency (Max Fo, Hz), minimum fundamental frequency (Min Fo, Hz), jitter, shimmer, GNE, irregularity, noise, overall severity, S Time, Z Time, S/Z ratio, and maximum phonation time (MPT).

Thyroidectomy technique

All patients underwent lobectomy and subtotal or total thyroidectomy as indicated by the primary

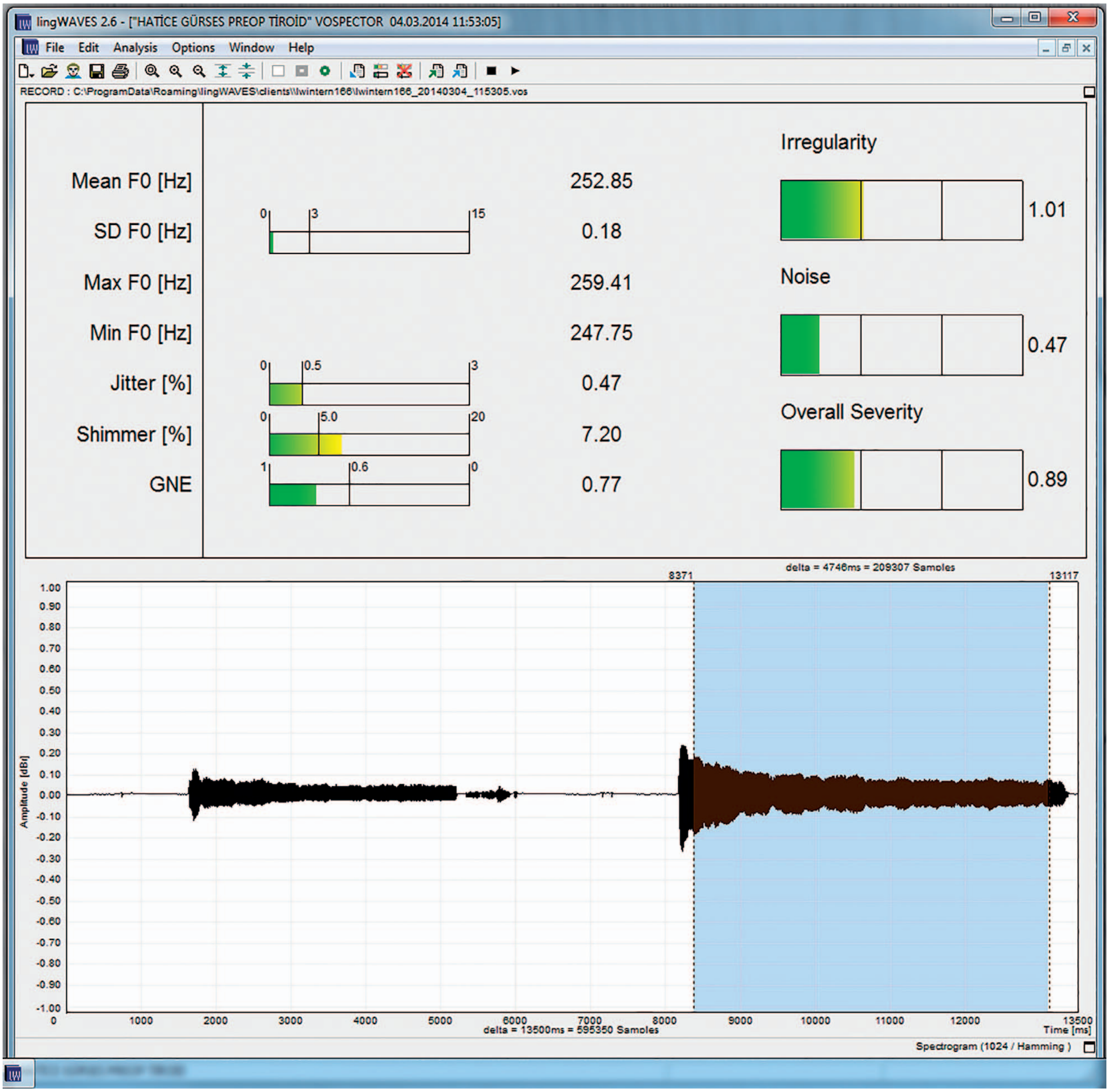

Fig. 1 Evaluation of acoustic parameters (top) with lingWAVES Vospector Module and the evaluation of aerodynamic analysis (bottom) with lingWAVES Voice Protocol Module.

condition. The surgical procedures were grouped as total and subtotal thyroidectomy for statistical evaluation, and the lobectomy cases were included in the subtotal thyroidectomy group. The histopathologic diagnoses were grouped as benign and malignant; the patients with multinodular goiter, solitary nodule, and Basedow's disease were included in the benign group, and the ones with papillary carcinoma and follicular carcinoma were included in the malignant group.

Statistical evaluation

Statistical analyses were performed using the SPSS 15.0 software for Windows (SPSS Inc, Chicago, Illinois). The averages and the frequency distributions were examined. The normality of the intergroup distribution was checked. Statistical comparisons of normally distributed data were performed using the Student *t* test and one-way analysis of variance, and non-normally distributed

Table 1 Characteristics and pathological profiles of the patients

General characteristics	n	%
Age	44	46.25
Sex		
Male	9	20.5
Female	35	79.5
Benign diagnosis	33	75
Solitary nodule	4	9.1
Basedow's disease	3	6.8
Multinodular goiter	26	59.1
Malign diagnosis	11	25
Papillary carcinoma	9	20.5
Follicular carcinoma	2	4.5
Type of operation	34	77.3
Total thyroidectomy	7	15.9
Subtotal thyroidectomy lobectomy	3	6.8

n, number of patients.

data were evaluated using the Kruskal-Wallis and Mann-Whitney *U* tests. A *P* value of <0.05 was considered statistically significant.

Results

The 44 patients comprised 9 (20.5%) male and 35 (79.5%) female patients, with a mean age of 46.25 (range, 14–73) years (Table 1). In our patients, multinodular goiter was the most frequent indication for thyroid surgery (59.1%), and total thyroidectomy was the most common surgical procedure (77.3%), followed by subtotal thyroidectomy (15.9%). Lobectomy was performed in only 3 patients (6.8%). No intraoperative or postoperative complications occurred, and all patients were discharged on the first or second day after surgery. In histopathologic analysis, 75% of the tumors were benign, and 25% were malignant. Table 1 presents the clinical and pathologic profiles of our patients.

In the comparisons of preoperative and early and late postoperative acoustic parameters, significant differences were found in Mean F0, Max F0, MPT, and S Time between the early and late postoperative periods. The comparisons revealed that Mean F0, Max F0, and MPT decreased in the early and late postoperative periods compared with the preoperative period, whereas the S Time was prolonged. Table 2 presents the comparison of parameters assessed in the preoperative, early postoperative (1 week after surgery), and late postoperative (3 months after surgery) periods.

An analysis was performed to determine the interaction between the voice changes after thyroidectomy and the patient characteristics including age, sex, surgical procedure, and histopathologic diagnosis. The analysis was based on the comparison of preoperative and postoperative assessments of the voice parameters, and significant differences were found in Mean F0, Max F0, MPT, and S Time. The evaluation of these parameters revealed that the voice changes after thyroidectomy were not affected by age, sex, and surgical procedure; however, they differed between the benign and malignant nature of the tumor because a significant decrease was detected in Mean F0 and Max F0 in the malignant group compared with the benign group. Although Mean F0 and Max F0 were affected by the benign or malignant nature of the tumor, no correlation was established by MPT and S Time (Fig. 2). This result

Table 2 Comparison of the objective acoustic voice measurements among preoperative and early and late postoperative periods

Variables	Preoperative mean	Early postoperative mean	Late postoperative mean	P^a	P^b
Mean F0	218.68	196.56	202.78	0.01	**0.01**
Max F0	231.38	208.26	213.7	**0.02**	**0.01**
MPT	12.618	10.017	11.63	**0.01**	**0.02**
S Time	7.932	9.235	8.893	**0.01**	**0.01**
Min F0	189.84	178.43	189.81	0.19	0.99
Shimmer	6.723	7.62	6.758	0.25	0.93
Jitter	0.17	2.5	1.44	0.25	0.33
GNE	0.7875	0.755	0.81	0.28	0.106
Irregularity	2.467	0.932	0.9	0.34	0.33
Noise	0.445	0.535	0.457	0.19	0.75
Overall severity	0.736	0.824	0.775	0.11	0.14
Z Time	9.877	10.021	10.019	0.74	0.71
S/Z Time	0.39	0.51	0.35	0.59	0.6

Bold values show the significant difference between the values of Mean F0, Max F0, MPT, and S time, according to the variable groups.

[a]Comparison of preoperative and early postoperative periods.

[b]Comparison of preoperative and late postoperative periods.

Fig. 2 Comparison of preoperative and postoperative values of Mean F0, Max F0, MPT, and S Time between benign and malign tumor groups.

indicates that the patients with malignant tumors are more prone to the voice changes after thyroidectomy. Table 3 presents the effects of age, sex, surgical procedure, and histopathologic diagnosis on the acoustic parameters.

Discussion

Voice changes can be assessed both by subjective and objective methods. In the literature, a number of

Table 3 Effectivity of patient sex and age, surgical procedure, and histopathologic diagnosis on the acoustic parameters Max F0, Mean F0, MPT, and S Time

	P values			
Variable	Sex	Age	Operation type	Benign/malign
Max F0	0.06	0.33	0.55	0.049
Mean F0	0.14	0.31	0.72	0.018
MPT	0.68	0.89	0.95	0.66
S Time	0.45	0.37	0.33	0.56

studies have been reported that assessed the voice changes only by subjective methods,[9] only by objective methods,[5] or by both methods.[10] Acoustic analysis methods are the most common objective assessment methods. Among these, the Multidimensional Voice Program (MDVP),[11–13] Voice Range Profile Program (VRP),[13] and Praat[14] have been used in various studies. In addition, lingWAVES has also been used as a voice analysis program. For instance, Torrejano and Guimarães[14] compared the voice qualities of the patients who underwent supracricoid laryngectomy and total laryngectomy by using the lingWAVES software. However, to the best of our knowledge, no study has used the lingWAVES software for analyzing the voice changes after thyroidectomy. Therefore, this is the first report in the literature analyzing the voice changes after thyroidectomy by using the lingWAVES software.

Subjective assessment of voice changes is achieved using the quality-of-life measurement tests. In the literature, a number of questionnaire-based tests including the Voice Handicap Index (VHI)[9], Voice-Related Quality of Life (V-RQOL),[14] Voice Activity and Participation Profile (VAPP), and Vocal Performance Questionnaire (VPG) have been suggested for the assessment of quality of life. However, although we attempted to use these tests in our study, we failed to administer them because the socioeconomic profile of the patients was low, and the variety of the linguistic profiles of the patients was a real challenge for the applicability of these tests.

Perceptual analysis method is another subjective analysis method. In perceptual analysis, hoarseness, roughness, and breathiness levels, as well as pitch, loudness, and resonance qualities of the voice are evaluated perceptually. The most frequently used perceptual scale is called The Grade, Roughness, Breathiness, Asthenia, Strain (GRBAS) Scale,[15] which was developed by the Japanese Logopedia and Phoniatrics Association. However, in 1994, this method was simplified to The Roughness, Breathiness, Hoarseness (RBH) Scale through the omission of Asthenia and Strain by Hussein Gaber *et al*.[16] In 2002, another scale called The Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V) was developed by the American Speech-Language-Hearing Association.[17]

Perceptual tests have been used for a long time. However, perceptual evaluation has some difficulties, and an experienced staff is mandatory for appropriate application of the test. To overcome these difficulties, the relationship between hoarseness level and acoustic-aerodynamic parameters has been investigated by working on extensive databases, and as a result, new objective parameters enabling perceptual evaluation have been developed, including the Dysphonia Severity Index[9,18] (DSI), Gottingen Hoarseness Diagram[19] (GHD), and Vospector.[14]

The lingWAVES software has a number of objective parameters such as irregularity, noise, and overall severity, which enable perceptual evaluation through the Vospector module of the software. The irregularity parameter assesses roughness, the noise parameter assesses breathiness, and the overall severity parameter assesses the general hoarseness level of voice, and all of these assessments are shown on a visual analogue scale. Therefore, additional use of perceptual analysis tests such as GRBAS, RBH, and CAPE-V was not needed in our study.

In literature, the total number of preoperative and postoperative voice analyses performed in a study is reported to vary between 2 and 4. Akyildiz *et al* performed a total of 2 analyses in the preoperative and early postoperative periods and reported that a significant reduction was observed in the postoperative parameters including highest fundamental frequency, standard deviation of average fundamental frequency, phonatory average fundamental frequency range in semitones, and degree of subharmonics parameters. Celestino *et al*[13] administered 3 questionnaires preoperatively and 1 week and 1 month postoperatively to compare the voice and swallowing changes. They observed significant changes in swallowing but no significant changes in voice. Similarly, Leonard *et al*[9] compared the functional voice changes by administering the DSI preoperatively and 4 weeks and 6 months postoperatively, and they reported that significant changes were detected at postoperative week 4, but the changes disappeared at month 6. Sinagra *et al*[5] performed a total of 4 objective voice analyses preoperatively and at months 2, 4, and 6 to compare the fundamental frequency and shimmer in preoperative versus postoperative periods, in smoking versus nonsmoking patients, and in malignant versus benign pathologies. It was revealed that no significant change was observed in any of these comparisons, but the patients reported voice fatigue and alterations in the pitch of voice in the postoperative period. In our study, a total of 3 voice analyses were performed preoperatively and 1 week and 3 months postoperatively. In light of the studies mentioned above, we consider that performing 2 voice analyses appears to be inadequate in terms of the assessment of long-term results. Moreover, the studies with 4 voice analyses have shown that the long-term results do not differ after the postoperative third month. Therefore, we maintain that performing 3 voice analyses would be an ideal alternative in terms of less work load both for the patients and the health care staff.

Postoperative acoustic parameters are likely to differ from the preoperative acoustic parameters. Although the studies conducted by Celestino *et al*[13] and Sinagra *et al*[5] did not find any significant differences between the preoperative and postoperative results, the studies by Debruyne *et al*[4] and Leonard *et al*[9] found significant changes in some acoustic parameters between the preoperative and early postoperative periods, but these differences disappeared at long-term comparisons. On the other hand, Soylu *et al*[20] found differences between the preoperative and long-term postoperative results and reported that these differences did not disappear and also the changes in some acoustic parameters still persisted in the long term. Similarly, we also found significant in the preoperative and postoperative acoustic parameters, and these changes did not disappear in the long term and the changes in some acoustic parameters were still present at the end of the third month. These changes were represented as a decrease in Mean F0, Max F0, and MPT parameters and as a prolonged time in S Time in the early and late postoperative periods compared with the preoperative period. Because the acoustic changes are irreversible and persist in the long term, the patients should be informed about these complications during preoperative counseling and postoperative care.

The analysis on the interaction between the voice changes after thyroidectomy and the patient characteristics including age, sex, surgical procedure, and histopathologic diagnosis revealed that the voice changes were not affected by age, sex, and surgical procedure, but they differed between the benign and malignant nature of the tumor. Similarly, Kark *et al*[1] investigated the effectivity of the surgical procedure in the patients undergoing thyroidectomy on the acoustic changes. They detected a significantly higher incidence of permanent voice changes in the patients managed with subtotal thyroidectomy (25%) compared with the patients who underwent lobectomy (11%). Debruyne *et al*[4] found similar results as Kark *et al*[1] and Akyildiz *et al*[10] in their study, which investigated the interaction between the acoustic parameters and sex of the patient, surgical procedure, histopathologic diagnosis, and experience of the surgeon. They found that only the surgical procedure did not affect acoustic parameters. Similarly, we also found that the surgical procedure (total or subtotal thyroidectomy) had no effect on the postoperative acoustic parameters.

Sinagra *et al*[5] compared the fundamental frequency and shimmer in patients with benign or malignant tumors, and they did not detect any significant difference. However, we found that the postoperative acoustic parameters differed between the benign and malignant nature of the tumor. Therefore, we consider that the patients with a malignant tumor have a greater risk for permanent voice changes in the postoperative period compared with the patients with a benign tumor. This information can be vital for the patients and thus should be explained during the preoperative counseling.

Conclusions

The outcomes of this study can be summarized as follows. Voice changes may occur after thyroidectomy even in the patients with no evidence of laryngeal nerve damage, and these changes can be assessed with objective measurement methods. The parameters including Mean F0, Max F0, MPT, and S Time, all of which are both acoustic and aerodynamic, were detected to change in the postoperative period. Voice changes after thyroidectomy are not affected by age and sex of the patients and the surgical procedure; however, a significant decrease was seen in Mean F0 and Max F0 in the malignant group compared with the benign group.

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References

1. Kark AE, Kissin MW, Auerbach R, Meikle M. Voice changes after thyroidectomy: role of the external laryngeal nerve. *Br Med J* 1984;**289**(6456):1412–1415
2. Page C, Laude M, Legars D, Foulon P, Strunski V. The external laryngeal nerve: surgical and anatomic considerations: report of 50 total thyroidectomies. *Surg Radiol Anat* 2004;**26**(3):182–185
3. Stojadinovic A, Shaha AR, Orlikoff RF, Nissan A, Kornak MF, Singh B *et al*. Prospective functional voice assessment in patients undergoing thyroid surgery. *Ann Surg* 2002;**236**(6): 823–832
4. Debruyne F, Ostyn F, Delaere P, Wellens W. Acoustic analysis of the speaking voice after thyroidectomy. *J Voice* 1997;**11**(4): 479–482
5. Sinagra DL, Montesinos MR, Tacchi VA, Moreno JC, Falco JE, Mezzadri NA *et al*. Voice changes after thyroidectomy without recurrent laryngeal nerve injury. *J Am Coll Surg* 2004;**199**(4): 556–560
6. Hong KH, Kim YK. Phonatory characteristics of patients undergoing thyroidectomy without laryngeal nerve injury. *Otolaryngol Head Neck Surg* 1997;**117**(4):399–404
7. McIvor NP, Flint DJ, Gillibrand J, Morton RP. Thyroid surgery and voice-related outcomes. *Aust N Z J Surg* 2000;**70**(3):179–183
8. Yeung P, Erskine C, Mathews P, Crowe PJ. Voice changes and thyroid surgery: is pre-operative indirect laryngoscopy necessary? *Aust N Z J Surg* 1999;**69**(9):632–634
9. Henry LR, Helou LB, Solomon NP, Howard RS, Gurevich-Uvena J, Coppit G *et al*. Functional voice outcomes after thyroidectomy: An assessment of the Dsyphonia Severity Index (DSI) after thyroidectomy. *Surgery* 2010;**147**(6):861–870
10. Lombardi CP, Raffaelli M, De Crea C, D'Alatri L, Maccora D, Marchese MR *et al*. Long-term outcome of functional post-thyroidectomy voice and swallowing symptoms. *Surgery* 2009; **146**(6):1174–1181
11. Solomon NP, Awan SN, Helou LB, Stojadinovic A. Acoustic analyses of thyroidectomy-related changes in vowel phonation. *J Voice* 2012;**26**(6):711–720
12. Akyildiz S, Ogut F, Akyildiz M, Engin EZ. A multivariate analysis of objective voice changes after thyroidectomy without laryngeal nerve injury. *Arch Otolaryngol Head Neck Surg* 2008;**134**(6):596–602
13. Lombardi CP, Raffaelli M, D'Alatri L, Marchese MR, Rigante M, Paludetti G *et al*. Voice and swallowing changes after thyroidectomy in patients without inferior laryngeal nerve injuries. *Surgery* 2006;**140**(6):1026–1032
14. Torrejano G, Guimarães I. Voice quality after supracricoid laryngectomy and total laryngectomy with insertion of voice prosthesis. *J Voice* 2009;**23**(2):240–246
15. Mendelsohn AH, Kiagiadaki D, Lawson G, Remacle M. CO2 laser cordectomy for glottic squamous cell carcinoma involving the anterior commissure: voice and oncologic outcomes. *Eur Arch Otorhinolaryngol* 2015;**272**(2):413–418
16. Hussein Gaber AG, Liang FY, Yang JS, Wang YJ, Zheng YQ. Correlation among the dysphonia severity index (DSI), the RBH voice perceptual evaluation, and minimum glottal area in female patients with vocal fold nodules. *J Voice* 2014;**28**(1): 20–23
17. Nemr K, Souza GV, Simões-Zenari M, Tsuji DH, Hachiya A, Cordeiro GF *et al*. Cognitive Vocal Program applied to individuals with signals presbylarynx: preliminary results. *Codas* 2014;**26**(6):503–538
18. Wuyts FL, De Bodt MS, Molenberghs G, Remacle M, Heylen L, Millet B *et al*. The dsyphonia severty index: an objective measure of vocal quality based ona multiparameterapproch. *J Speech Hear Res* 2000;**43**(3):796–809
19. Michaelis D, Fröhlich M, Strube HW. Selection and combination of acoustic features for the description of pathologic voices. *J Acoust Soc Am* 1998;**103**(3):1628–1639
20. Soylu L, Ozbas S, Uslu HY, Kocak S. The evaluation of the causes of subjective voice disturbances after thyroid surgery. *Am J Surg* 2007;**194**(3):317–322