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Increasing the speech intelligibility by the use of voice therapy in patients with profound hearing loss

Abstract

Objective: The purpose of this study is to evaluate changes in the acoustic properties of voice in patients with profound sensorineural hearing loss to determine the effectiveness of voice therapy.

Material-Method: Our study consisted of 15 individuals from the 20-25 years of age with bilateral symmetrical hearing loss (Group A), and 15 individuals in the 26-65 age group with post lingual cochlear implants (Group B). The control group (Group C) included 15 adults with the normal hearing range from the age group of 20-30. Prospective analysis methods was utilized for this research. In order to quantitatively measure the psychosocial consequences of voice-related disorders the Voice Handicap Index (VHI) was given, and, to determine the acoustic measures of the voice quality, the /ah/ sound was digitally recorded with the Multidimensional Voice Program (Kay Elemetrics) in all groups.

Conclusion: Average Fundamental frequency (F_0), jitter percentage (jitter), shimmer, noise-harmonic ratio (NHR), voice turbulence index (VTI), soft phonation index (SPI), PPQ and APQ parameters were analyzed through acoustic sound analysis program. When the data in Group A are compared with Group B, the acoustic parameters show a statistically significant higher value.

Discussion: Speech intelligibility increased in individuals with profound hearing loss who received sound therapy and who used cochlear implants. According to the results of the VHI, individuals with cochlear implants benefit from voice therapy.

Keywords: acoustic analysis, speech perception, cochlear implants, hearing impairment, voice quality, voice therapy

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Abbreviations: HL, hearing loss; CI, cochlear implantation; HA, hearing aids

Introduction

Hearing loss (HL) may cause crucial deprivation in the auditory system, especially in the first year of cortical development. Therefore, it is important to manage HL in any severity, by the use of hearing aids (HA) or cochlear implantation (CI) as early as possible. The general procedure to (re)habiliate the HL is defined as aural rehabilitation.

Upon completion of in detailed diagnostical work up which includes audiological assessment evaluation and use of proper HA and or assistive hearing instrument, aural rehabilitation basically involves following: a) Supplying variable types of treatments to patients that have difficulties in hearing and b) providing unique amplification aids to manage the patient's hearing skills (Figure 1).

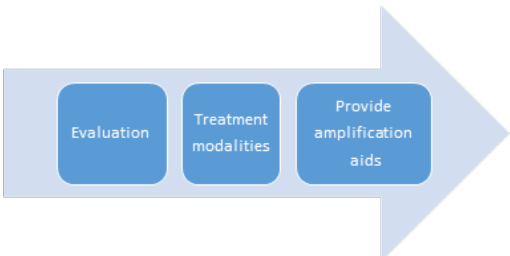

Figure 1 Aural rehabilitation process in basic framework.

Therapy procedures included in aural rehabilitation, such as speech therapy and amplification of hearing by HA or CI, are designed individually and each of them should be presented to patients to help them deal with the disability[1] caused by a HL or total deafness. Further, targets of the aural rehabilitation also involves;[2]

1. Parental or individual counselling to determine applicable therapy strategies
2. Early intervention strategies and the progression towards intelligible speech production
3. Improvement of communicative skills (auditory, speech and language, sign)
4. Improvement of literacy (reading, cognition or writing,)

Aural rehabilitation and voice

During traditional laryngoscopic examination, it is rare to find a lesion or an organic problem that causes a voice disorder in people with profound hearing loss. For the last three decades, the use of assistive voice analysis software has had an important role to assess the voice production mechanism.

Usual aural rehabilitation strategies target to improve listening skills and articulation and do not focus on alterations in voice acoustics,[3] However it has been observed that people with severe hearing loss have abnormal production of voice due to the lack of auditory feedback.[4]

Deviations in voice acoustics depend on the severity of disorder, age and gender of the patient and the hearing device.[5] Lane and Webster[6] claimed that the speakers with HL were, on the average, 43% more variable in their production of pitch than their normal hearing (NH) counterparts. Leder, Spitzer &Kirchner[7] indicated that speaking fundamental frequency (F_0) was significantly higher for the group with the HL than for normal-hearing, age-matched male speakers. Neither duration of HL nor HA usage in profound HL affected speaking F_0 values significantly. The findings of the study ensure a baseline to determine effects of rehabilitation.

Studies also indicated that male individuals with HL, had significantly higher vocal intensity and exceptional intensity variations than NH male speakers while they spoke[5,6] The duration of profound HL nor the history of HA use significantly influenced voice intensity.[7] Higgins, Carney and Shulte[8] stated that individuals with profound HL had at least one speech/voice physiology parameter outside of the normal range, and most of the patients demonstrated specific clusters of abnormal speech behaviors.

Cochlear implantation and voice acoustics

Cochlear implantation is applied to patients who have profound sensorineural HL and do not benefit from hearing aids. Cochlear implant is a device which auditory nerve directly stimulates through electrodes that fix in the inner ear. The implant itself cannot restore normal hearing but ensures significant auditory feedback cues to the cortical areas in different domains, such as timing, intensity, and frequency.[9] Individuals with cochlear implants have the capability to become aware of auditory control over their own voice production and the others, which is very critical for the development of speech control. Acoustic voice analysis and perceptual evaluation by voice experts pointed out that in great majority of variables, patients that use CI's produced better voice control than the profoundly deaf individuals treated with traditional hearing aids.[10] CI's provide auditory control on voice.

Profoundly deaf subjects even cochlear implant recipients or hearing aid users are not given in voice therapy aural rehabilitation to ensure control of their hearing. In the rehabilitation of individuals with profound HL that use hearing aids voice therapy is not included and not seen as a requirement. However, those who use hearing aids the voice therapy would be beneficial for their speech performance.

The goal of present study was to assess changes in the acoustic measures of voice in subjects with profound sensorineural HL before and after voice therapy.

Materials and methods

Subjects There were three groups included in the study. First group included 15 patients ages between 16 and 28 years old (mean 20.6 years) 3 males and 12 females with prelingually bilateral symmetric profound HL (group A). The second group included 37 postlingually cochlear implanted individuals ages between 17 – 35 years old (mean 21.97 years) 11 males and 26 females (group B). Final group consisted of 15 normal hearing adults as a control group ages between 20- 31 years old (mean 25.2 years) years 10 males and 5 females (group C).

Individuals from group A and group B were oriented from a hearing-impaired cultural society. All subjects in both groups had special education reports to utilize special education sessions but none of them had any opportunity to take a speech therapy session as their education reports only include academic support. Head of their society demanded that members of the society had important problems to communicate and find job due to the lack of speech and voice problems. Articulation evaluation was performed with Ankara Articulation Test (AAT)[10] and to evaluate voice parameters the Multi-Dimensional Voice Program (MDVP) software (Model 4305, Kay Elemetrics Corp., Lincoln Park, NJ, USA) was used.[11]

Ethical approval

The present study was confirmed by the Ethical Committee; University based hospital of a local collage (Ethical Protocol: İşitme Engelli Yetişkinlerde Formant Analizi (Formant Analysis in Hearing Disordered Adults), protocol no:6632, date, 30.01.2018). This research was conducted in accordance with the principles of Declaration of Helsinki. Written informed consent was obtained from all participants.

Inclusion and exclusion criteria's

For group A, individuals with a history of congenital hearing disorder and hearing threshold greater than 85 dB were chosen. For group B, individuals with the use of CI postlingually and a hearing threshold greater than 50 dB was chosen. Patients at Group B were implanted either with Neurelec Digisonic SP or Medel Pulsar CI 100 device. For group C, the control group, the pure-tone average (PTA) criteria (≥25 dB average hearing loss at 500, 1000, and 2000 Hz in the better ear) accepted normal and included in this study.[12] Twenty-two patients (10 females and 12 males) from group B were excluded from the study as they could not continue therapy sessions regularly. Therefore, group B included 15 patients, (8 males and 7 males). Individuals with any organic voice disorder for all groups during the laryngeal examination were also excluded in the study.

Examination methods

Complete otolaryngological assessment including laryngeal examination, pure tone audiometry testing, and auditory perception tests were used to evaluate voice, hearing and speech outcomes for all groups. Adult individuals with prelingually HL were examined before and after voice treatment to see if voice therapy improved their voice acoustics. Post-lingual hearing-impaired individuals were examined at least 4 weeks after switching on their speech processors to test the effects of rehabilitation on voice production post intervention.

Acoustic analysis

To analyze the acoustic parameters, the MDVP software was used.[11] The following parameters were chosen as they can reflect significant domains of voice assessment (with the exception of some repeated parameters): mean fundamental frequency (F_0), absolute jitter (Jit.a), Jitter percent (Jit.), relative average perturbation (RAP), pitch perturbation quotient (PPQ), fundamental frequency variation (vF0) shimmer percent (Shim), amplitude perturbation quotient (APQ), noise-to-harmonic ratio (NHR), voice turbulence index (VTI) and soft phonation index (SPI). Acoustic analysis of patients and control group were conducted before and after voice therapy. A dynamic unidirectional microphone (Shure SM58) was placed 30 cm distance from mouth and subjects produced /a/ sound for three times. All sound samples were taken in a soundproof room. Tokens with distorted sounds were excluded and the best sample was chosen by a tonemeister.

Pre-treatment and post-treatment assessment on how the individuals perceive their own voice quality was performed using the Turkish Voice Handicap Index Short form (TVHI-SF).[13] The self -perceived the TVHI-SF was completed prior and upon completion of the therapies. For each question the participants are required to rate each answer using a 5-point scale (0=never, 1= seldom, 2= sometimes, 3= often and 4= always); maximum score is being 40 and the minimum score is being 0. The scale consists of three parts, addressing functionality, physicality, and emotionality of the voice.

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Voice therapy sessions

Sessions were performed for 8 - 10 weeks. Each session was executed for 40 minutes. Each of sessions started with abdominal diaphragmatic exercise for 10 minutes. Vocal function exercises included glissando and staccato exercises and it was aimed to control the ability of laryngeal tension. Glissando and staccato exercises were performed for 15 minutes. Lax vox blowing exercises were also performed for lasting 15 minutes as the hearing-impaired subjects may modulate the laryngeal tension with the visual cue in an easier way. Cued articulation was also utilized for manner and place of the articulators for unseen sounds making sessions more like a total communication approach with sound added.[14,15]

Statistical analysis

The mean and standard deviations were defined as quantitative variables. Number and percentage were determined as qualitative variables. To evaluate whether the variables are parametric or non-parametric, the Kolmogrov test was used. In our study, parametric comparisons were performed using the independent sample t-test, while non-parametric variables were compared using the Mann–Whitney test. Parametric variables were cross - checked using the paired sample t test, and non-parametric variables were crosschecked using the Wilcoxon test when comparing variables within the same group. A one-sample t test was used to analyze the pre-operative MDVP values to the MDVP values of normal hearing Turkish subjects. For statistical analysis, SPSS (Statistical Package for Social Science) software version 17 was utilized. A statistically significant *p* value of 0.05 was determined.

Results

The comparison between groups (A and B) represented a significant difference in the acoustic measurements for the group A, specifically, Jita, RAP, VF0, NHR, VTI, and SPI (Figure 2). There is a significant improvement in MDVP results of Group A before and after voice therapy. F_0 values are especially decreased. The comparison between groups (A and B) after voice therapy showed no significant difference in the acoustic measurements in favor of group A, specifically for VF_0, Jita, PPQ, RAP, Shim, APQ, NHR, VTI, and SPI parameters. On the other hand, there was a significant difference in F_0 parameter.

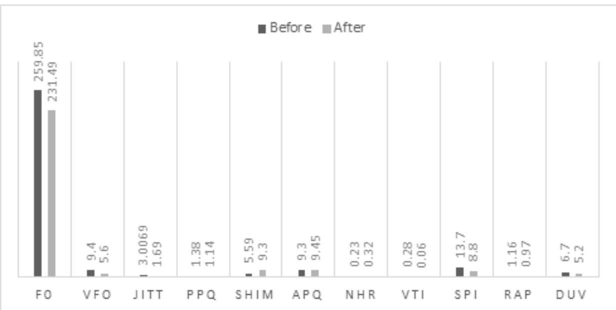

Figure 2 MDVP results of group a before and after voice therapy.

Cochlear implanted post-lingually hearing impaired adult patients showed no significant difference in the selected MDVP parameters. While both groups had no significantly different parameters, there were more different parameters in group B than group A when compared to the normal values

The TVHI-SF functional aspect showed a score median score of 9.5 for group A (SD = 4.5, variation between 4 and 18), 7.8 for group B (SD = 4.5, variation between 4 and 18), and 1 for group C (SD = 1.2, variation between 0 and 7). The TVHI-SF physical aspect showed a median score of 7.5 for group A (SD = 6.1, variation between 0 and 27), median score of 7.5 for group B (SD = 8.7, variation between 0 and 35) while in the group C, the median was 0 (SD = 3.2, variation between 0 and 14). The emotional part of the TVHI-SF had a median value of 5.5 for group A (SD = 8.9, variation between 6 and 36), median value of 4.8 for group B (SD = 7.8, variation between 6 and 28) and it was 0 for the group C (SD = 1.3, variation between 0 and 6). The comparative analysis among all the groups showed a statistically significant difference for all TVHI-SF p-value of 0.000.

Discussion

Auditory monitoring is an essential element of voice production as it modulates the use of pitch and loudness.[3] Lacking the auditory feedback of their own speech prevents those individuals monitor their own speech production.[17] Even though post-lingual deaf individuals utilizes both their hearing (as means of feedback) and speech as a means of communication during their hearing periods, their speech and voice become abnormal, especially with the parameters of intonation, pitch, rate of speech, nasality (hypo or hyper), and intensity.[18] This could be all related to lacking the auditory feedback loop during speech.

Improved auditory feedback helps HL speakers to regain the ability to control and adjust their voice output, resulting in improvements in speech production and vocal quality in the post-implantation process. Total amount of time spent with HL and the effect of auditory rehabilitation are two crucial aspects that limit the recovery on voice production.

Changes in the vocal pitch range may be considered as a primary symptom for individuals with HL. They have greater fundamental frequencies than people who have NH[16-18] Significant pitch shifts that end in voice breaks, as well as extreme vocal fluctuations were also reported.[19-20] Listeners also perceive a monotonous voice quality due to the low variation in their voice range.[21]

A comparison of group A following voice therapy was carried out to determine the influence of hearing loss on the acoustic MDVP parameters. The significant difference was in the F_0, demonstrating that hearing loss has a considerable negative impact on voice acoustics. Similar findings were found in other studies[8,22] Leder et al.[22] discovered that 21 males with post-lingually profound sensorineural HL had a greater F_0 than the hearing controls. This research corroborates previous findings.

Some researchers indicated that inability of auditory control also affects the management of voice intensity. According to Leder et al.[7], severe deafness is linked with a considerably higher voice intensity level and more intensity variation. After voice treatment, however, auditory control of voice and speech may be achieved, and voice and speech characteristics may improve.

The acoustic measures of voice samples for group A improved considerably 6 months following voice treatment in the current research (e.g. F_0, Jitter, SPI). It was expected that after voice treatment and improving listening skills over phonation; pitch and amplitude variability would decrease. The only acoustic measure that showed a significant decrease was the jitter value, which reflects pitch control. The level of shimmer, which reflects intensity control, decreased as well, although still not significantly. Leder et al.[7] reported similar findings, stating that when adequate auditory input was presented upon implantation, fundamental frequency was expected to be one of the first acoustic characteristics to be back in the normal limits.

Smoorenburg et al.[23] examined voice samples in 12 patients before and 1–4 years after implantation and observed that the abnormal pitch output, as well as the abnormal pitch modulations, return to normal levels after the CI. These data show that recovering hearing control and auditory feedback has a significant impact on pitch modulation, regardless of the duration of hearing loss.

In a review by Myzsel and Szkielkowska,[24] the voice production in hearing impaired was classified with an increasing fundamental frequency, an alteration in phonation time and voice intensity. Authors claimed that people with HL have difficulties to maintain their voice control that causes a modulation in pitch control and instability.

According to Hengen et al.,[25] patients with sensorineural hearing loss have hearing problems both for their air conduction and bone conduction. After hearing aid fitting or cochlear implantation, their air conducted hearing is amplified but bone conduction remains the same. Due to this imbalanced amplification in their hearing, people with sensorineural hearing loss experience a variability about their own voice and this causes not to control their voice parameters.[26]

Although no organic disorder was found based on the laryngeal examinations for group A and B, unusual use of voice and distorted voice parameters was observed by MDVP in the first assessment due to profound hearing loss. Similar findings also reported from different studies in the literature.[27-29] although these studies indicated that variation in auditory regulation could be a risk for dysphonia in hearing impaired, the association between hearing loss and dysphonia remains unclear due to the lack of adequate studies. [28,29]

To sum, the findings of this study show that voice treatment enhances auditory regulation of phonation, which may be reflected in long-term voice acoustic characteristics. To develop speech and language skills in people with hearing loss, speech education programs including voice therapy, hearing aid fitting, and early diagnosis are more significant.

In this study, the basic criteria for applying therapy to individuals are that these individuals who used hearing aids and cochlear implant didn't take appropriate therapy. These individuals applied our institution since they did not obtain positive results after university graduation, in their job interviews. The problem, which these individuals faced, was evaluated via AAT, MDVP, Beck Depression Questionnaire, Auditory and ENT examination and application of appropriate therapy method to these individuals was decided. The result of this study was interpreted by means of enhancing voice quality in each individual after therapy.

Conclusion

To emphasize the effect of voice treatment on the acoustic voice parameters of profound hearing loss in this study, acoustic characteristics were compared before and after voice therapy in group A. There were no significant differences between the other groups, however the group with cochlear-implanted patients had significantly deteriorated values (group B). This finding indicates the voice therapy's strong impact on hearing loss. Several acoustic voice characteristics, such as F_0, Jitt, Shim, and VF_0, as well as long-term acoustic voice parameters including NHR, SPI, and VTI, demonstrated improvement in individuals who use hearing aids with substantial hearing loss.

Traditional articulation therapies conducted in rehabilitation centers in Turkey generally aim to place targeted speech sounds without voice therapy. As the speech sounds are basically harmonics of fundamental frequency, which is generated in glottal region, use and regain of lacking speech sounds may not last permanently. Voice therapy could be a better solution to help patients to control their voice and speech production.

The TVHI-SF analysis in individuals with hearing loss could influence treatment options especially for individuals with a higher TVHI-SF scores have to an earlier speech and voice therapy with bio feedback even though decisions may alter on a case-by-case basis. TVHI-SF assistance enabling a greater chance of treatment to be success full by improving voice quality and individual satisfaction. However, the need for what others (listeners of these individuals) perceive the voice quality of these individuals also needs to be addressed.

Finally, acoustic voice analysis soft wares can be used as an assistive tool in ENT clinics as generally no organic voice problem was detected in laryngeal examination in most of the time in people with hearing disorders, although patients may have voice parameters outside the normal range.

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Conflicts of interest

The authors declared no potential conflict of interest.

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References

1. Adult aural/audiologic rehabilitation. ASHA. 2007.
2. Alpiner JA, McCarthy PA. Rehabilitative audiology: children and adults. Williams & Wilkins, Baltimore. 1993.
3. Coelho AC, Medved DM, Brasolotto AG. Hearing loss and the voice. Update on Hearing Loss. 2015.
4. Kumar S, Paul N, Basu S, et al. Effects of hearing loss on vocal fold vibrations: an electroglottographic analysis. Eastern J Med. 2012;17(1):17–23.
5. Hassan SM, Malki KH, Mesallam TA, et al. The effect of cochlear implantation on nasalance of speech in postlingually hearing–impaired adults. J Voice. 2012;26(5):669.e17–22
6. Lane H, Webster JW. Speech deterioration in postlingually deafened adults. *J Acoust Soc Am*. 1991;89(2):859–866.
7. Leder S, Spitzer J, Kirchner JC, et al. Speaking rate of adventitiously deaf male cochlear implant candidates. *J Acoust Soc Am*. 1987;82:843–846.
8. Higgins MB, Carney AE, Schulte L. Physiological assessment of speech and voice production of adults with hearing loss. *J Speech Hear Res*. 1994;37(3):510–521.
9. Kirk K, Edgerton B. The effects of cochlear implant use on voice parameters. *Otolaryngologic Clinics of North America*. 1983;16:298–292.
10. Ege P, Acarlar F, Turen F. Ankara articulation test user manual, ankara university publications. 2004.
11. Multi-Dimensional Voice Program (MDVP) software (Model 4305, Kay Elemetrics Corp., Lincoln Park, NJ, USA.
12. Clark JG. Uses and abuses of hearing loss classification. *ASHA.* 1981;23(7):493–500.
13. Kılıç MA, Okur E, Yıldırım İ ve ark. Reliability and validity of the Turkish version of the voice handicap index. Kulak Burun Bogaz Ihtis Derg. 2008;18(3):139–147.

14. Horga D, Liker M. Voice and pronunciation of cochlear implant speakers. *Clin Linguist Phon*. 2006;20:211–217.
15. Ball V, Ison KT. Speech production with electro cochlear stimulation. *Br J Audiol*. 1984;18:251.
16. Hirschberg J, Dejonckere P, Hirano M, et al. Voice disorders in children. *Int J of Pediatr Otorhinolaryngol.* 1995;32:109–125.
17. Angelocci AA, Kopp GA, Holbrook A. The vowel formants of deaf and normal-hearing eleven- to fourteen-year-old boys. *J Speech Hear Disord.* 1964;29:156–160.
18. Higgins MB, McCleary EA, Carney AE, et al. Longitudinal changes in children's speech and voice physiology after cochlear implantation. *Ear Hear*. 2003;24(1):48–70.
19. Nickerson R. Characteristics of the speech of deaf persons. Volta Rev. 1975;342–362.
20. Abberton E, Fourcin A. Visual feedback and acquisition of intonation. Academic Press, New York. 1975.
21. Hood R, Dixon R. Physical characteristics of speech rhythm of deaf and normal hearing speakers. *J Commun Dis*. 1969;2(1):20–28.
22. Leder SB, Spitzer JB, Milner P, et al. Voice intensity of prospective cochlear implant candidates and normal hearing adult males. *Laryngoscope*. 1987;97:224–227.
23. Smoorenburg G, Huiskamp T, Langeries M, et al. Effects of cochlear implantation on voice quality and speech production. 1994;374–379.
24. Myzsel K, Szkielkowska A. Development of voice in hearing-impaired individuals: overview of physiopathological aspects. *J Hear Sci*. 2020;10(3):19–23.
25. Hengen J, Hammarström IL, Stenfelt S. Perceived voice quality and voice-related problems among older adults with hearing impairments. *J Speech Lang Hear Res*. 2018;61(9):2168–2178.
26. Stenfelt S. A model of prediction of own voice alteration with hearing aids. *Speech processing and perception*. 2011;3.
27. Cohen SM, Turley R. Coprevalence and impact of dysphonia and hearing loss in the elderly. *Laryngoscope*. 2009;119(9):1870–1873.
28. Das B, Chatterjee I, Kumar S. Laryngeal aerodynamics in children with hearing impairment versus age and height matched normal hearing peers. *ISRN Otolaryngology*, 2013;1–7.
29. Selleck MA, Sataloff RT. The impact of the auditory system on phonation: A review. *Journal of Voice*. 2014;28(6):688–693.