Original Article

Fundamental frequency (F0) comparison based on demographic features in post-lingual hearing loss people after cochlear implant

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ABSTRACT

Background and Objective: Any change in the auditory system can affect the proper use of speech and audio productions structures. The reason of this negative effect is the lack of auditory feedback. Voice changes caused by hearing impairment are connected to breathing, voice phonation and speech production. The aim of this study was comparing One of the voice parameters (F0) based on demographic features of post lingual people after cochlear implantation. Methods: The study included 38 (19 male, 19 female) post-lingual hearing-impaired adults who underwent cochlear implantation. The required data are based on information that was provided in the cochlear implant center by patient's file, these data includes demographic information and audiogram that's collected after cochlear implant. Results: According to the results, we found the most important effected was usage time of cochlear implant on the pronunciation of vowel /a/. It can be said that the implant type of the cochlear implant and the ear that's taking prosthesis has no significant impact on the performance of the pronunciation of this vowel. Also, we measured the effective factors associated with deafness (i.e. type of hearing loss, duration of deafness and aetiology of deafness) in the participants. These factors cause no significant difference in pronunciation performance of this vowel. Also, the main effect and interaction of these factors did not indicate a significant difference on result of the F0 of this vowel ($F<0.842$, $P=0.486$, $\eta 2 <0.096$, Observed power<0.206). Conclusion: On comparing the variation of results, the most important effect is usage time of cochlear implant on the pronunciation of vowel /a/ and other factors such as implant type and implant side have no significant relationship with this vowel. On the other hand, type of hearing loss, duration of deafness and aetiology of deafness have no significant relationship with vowel /a/.

Keywords: Cochlear implantation, Fundamental frequency, Post-lingual deafness

Introduction

Normal hearing provides good feedback for voice and speech control.[1] The "Audio Feedback" mechanism gives us the ability to monitor and calibrate speech acoustic features.[2] It is also responsible for controlling instant and delay of speech, and voice generation.[3] Therefore, the health of acoustic features of voice is highly dependent on the function of the auditory system. Through a healthy auditory system and normal hearing feedback, people can control important aspects of speech including sound, production, rhythm or speech fluency, and correct their errors.[4, 5]

Any change in the auditory system can affect the proper use of speech and audio productions structures. The reason of this

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negative effect is the lack of auditory feedback. voice changes caused by hearing impairment are connected to breathing, voice phonation and speech production.[3, 6] People suffering Hearing loss caused by the lack of normal auditory feedback and auditory control, are unable to control muscle movement associated with speech mechanisms and speech production.[7]

Limited auditory feedback has a negative impact on deaf persons speech indices, such as deviation at fundamental frequency (F0), fundamental frequency variation (vF0), changes in sound intensity, resonance (sound amplification), and speech length and duration.[2, 8] In people with severe to deep hearing loss, the average fundamental frequency is increased and its reason is lack of auditory feedback.[1]

The vocal and speech characteristics of pre lingual deaf people indicate more pronounced changes than those of the post lingual deaf people.[6, 9] Pre lingual deaf people have had no hearing experience for proper development of speech, while post lingual deaf people has auditory experience and used hearing and speech in part of their life as a primary means of communication [9] and phonation control has reached maturity, which involves controlling the muscles involved in the production of voice.[10] But when these patients experience hearing impairment at each stage of their life, they cannot develop vocal voice changes due to lack of monitoring through auditory feedback.[9, 11]

Some studies have reported that the time of hearing loss extent longer, some similar abnormalities with pre lingual deaf people may occur in the voice and speech characteristics of the post lingual deaf people, including deviations in treble and bass of voices, speech rate, length of vowels, nasal dependency, pronunciation and speech production, voice intensity, and language placement.[12] However, with the introduction of cochlear implant and its ability to manage hearing impairment, post lingual deaf people report significant improvements in communication abilities, including voice and speech abnormalities.[2, 9] (Cochlear) implant is a computer electronic device that directly stimulates the auditory nerve through the small electrodes in the earworm; then the auditory nerve transmits these signals to the brain.[2] With the development of hearing technology, more deaf people will benefit from cochlear implantation.[7]

Improvements in speech production and voice quality criteria after cochlear implantation are the results of auditory feedback recovery, enabling the listener to resume listening and modifying speech. However, several factors determine the extent of this improvement, such as the duration of hearing loss and the effect of post-cochlear implant therapy.[13-15]

Possible effects of auditory feedback reconstruction through cochlear implantation on hearing and speech parameters of deaf people have been studied in various studies.[14-18] Some of these studies have raised the issue of hearing in post lingual deaf people before and after implantation, but the conclusions were not always consistent and the results related to controlling and reducing fundamental frequency (F0), pitch, acoustic and other aspects of Audio has been contradictory. The number of samples studied in these studies are low and this may have caused these differences in results.[11, 14, 15]

Some studies did not indicate any significant differences fundamental frequency and its changes after cochlear implantation.[10, 11] However, in other studies, the in fundamental frequency after implantation was significantly reduced.[2, 19, 20] Leder et al. [20] reported that the fundamental frequency is one of the first voice parameters that are almost normal after implantation. Increasing the number of channels in the low frequency (F0) will improve the detection of fundamental frequency in cochlear implant.[21] Six months after cochlear implantation, 62% of adults reported a significant reduction in base frequency, and 38% of adults showed a significant decrease in the fundamental frequency after implantation of the cochlear implant.[15, 19] In some studies, significant changes in fundamental frequency were reported, this incident happened 5 to 24 months after implantation of post lingual deaf people.

Finally, although a lot of studies has been done to check the voice in deaf people after cochlear implantation, the results are in contrast. Different studies use different techniques and tools for evaluation. In addition, the age of cochlear implant and the strategy of it are important factors that influence voice quality, but few studies considered these factors in them.

Speech acoustic analysis provides an objective criteria of the speech production differences that can be effective in treatment plan.[22] There is a reason that makes demographic indicators of deafness time and patient cochlear implant time effective factors; different result of the studies in changes of fundamental frequency in the post lingual patients is the reason that confirms those factors. Therefore, this study aimed to compare fundamental frequency on demographic features of post lingual people after cochlear implantation.

Methods:

Patients with severe to profound post lingual deafness who have undergone cochlear implants at Ahwaz Imam Khomeini Hospital between years 2013 and 2018 are called. The required data are based on information that was provided in the cochlear implant center by patient's file, these data includes demographic information and audiogram that's collected before and after cochlear implant. After collecting these data, they are recorded in information check list. Only people that received similar audio therapy or intervention after surgery, are studied.

The demographic and clinical data examined are: Age, gender, underlying diseases, deaf etiology, deafness, age of cochlear implantation, cochlear implant type, clinical signs (vertigo, tinnitus). Auditory sensitivity thresholds are evaluated using an audiometric test and middle ear function using a tympanometry test. Otoscopy, tympanometry and pure tone audiometry (PTA) are performed at speech frequencies and the corresponding results are recorded.

In order to analyze the acoustic voice parameters, the voice of the people who have taken part in this study are recorded in the

acoustics room. This acoustics room has gotten some features that includes: using sound intensity meter to get and confirm less than 31 decibels background noise and putting the microphone at a distance of 11 cm from the mouth of the subject at 45 degrees. Calibrate the microphone before recording. Subjects were asked to produce vowels /a/ for at least 5 seconds. To be sure, they repeat it 3 times. It should be noted that the subject is given a description of how to proceed before recording the sound. We used AKG microphone C1000s model and TASCAM voice recorder US122MK mode after that Praat (version 5.3.13) sound analyzer system is used to study fundamental frequency (F0), finally, the measured acoustic criteria (F0) is analyzed and evaluated based on demographic characteristics extracted by mixed model three-way ANOVA. The regional ethics committees approved the current study protocol (Registration Code: IR.AJUMS.REC.1398.175).

Inclusion criteria:

- Severe to profound bilateral sensory hearing loss after verbal development (post lingual) in the audiometric test
- Lack of other side disabilities
- Normal Throat examinations
- The desire to participate in the study

Excluded Criteria:

- Repetitive cochlear implantation
- The presence of interfering factors that can affect the sound, for instance respiratory diseases, neuromuscular diseases, crashes and injuries to the head and neck, History of head and neck surgery, anatomical impairment in the vocal cavity, pharyngeal abnormalities, lips and oral cavity, history of tracheostomy, systemic diseases, hypothyroidism, mental defects, use of drugs that affect hearing and voice.
- Patients with surgical complications

Results and Discussion

We present the findings of this study in the form of two vowel /a/ and a sentence that you will see below and then reviewed and reported factors affecting of the Vowel /a/.

1. Implementation Vowel /a/

Surgical Factors:

The results of the Vowel /a/ evaluation of the experimental groups are shown in Table 1.

Table 1. Mean and standard deviation of Fundamental frequency vowel /a/ by type of implant type, implanted side and prosthesis term in subjects

	Implant Type	Implant Side	Prosthesis term(yrs)	Frequency	Means± SD
Vowel /a/	MED.EL	Right	<1	12	174.33±88.47
			1-2	9	150.21±40.42
			>2	11	202.37±32.86
		Left	<1	3	189.35±90.55
			1-2	3	151.22±51.39
			>2	3	166.33±89.99
	Other Prosthesis	Right	<1	9	167.37±90.37
			1-2	9	159.35±72.22
			>2	8	199.40±25.21
		Left	<1	3	182.42±75.21
			1-2	3	147.29±93.29
			>2	3	160.43±48.41

As described in the table above, the average and standard deviation related to the Fundamental Frequency of vowel /a/ are indicated based on the implant type, implant side and prosthesis term in post-lingual people that has taken cochlear implantation. The highest F0 values with an average and standard deviation of 202.37±32.86 Hz refers to those who have used MED.EL prosthesis in their right ear for more than two years. The lowest F0 with an average and standard deviation of 147.29±93.29 Hz is for those who have used other prostheses other than the MED.EL model for one to two years in their left ear.

Table 2. Determine the main effects and the effect of the Implant Type, Implant Side and Prosthesis Term of the fundamental frequency vowel /a/ in subjects

Analyzed Factors	df	F	P-value	η^2	Observed power
Implant Type	1	0.003	0.957	0.001	0.050
Prosthesis Term	2	4.289	0.032	0.280	0.399
Implant Side	1	1.07	0.309	0.036	0.170
Implant Type* Prosthesis term	2	1.01	0.375	0.065	0.209
Implant Type* Implant side	1	0.32	0.576	0.011	0.085

Implant side*prosthesis term	2	0.005	0.945	0.001	0.051
Prosthesis term* implant side* implant type	2	1.09	0.303	0.072	0.151

As it's indicated in the table above, there are 3 factors related to the conditions of the cochlear implant on the vowel pronunciation function /a/. According to this table, it can be said that the implant type of the cochlear implant and the ear that's taking prosthesis has no significant impact on the performance of the pronunciation of this vowel. The interaction effect of these factors did not make a significant difference on the results ($p < 0.05$).

Deafness factors:

In the descriptive table below, the average and standard deviation related to the fundamental frequency of the vowel /a/ are defined. Its according to the effective factors associated with deafness (ie type of hearing loss, duration of deafness and aetiology of deafness) in the post-lingual deaf people who has taken cochlear implant. The highest fundamental frequency values with average and standard deviation of 172.75 ± 42.11 Hz was for those who gradually had a history of deafness due to infection for less than two years. The lowest fundamental frequency voice with average and standard deviation of 139.48 ± 29.83 is related to those who have experienced a history of hearing loss due to unknown causes for more than two years (Table 3).

Table 3. Mean and standard deviation of Fundamental frequency vowel /a/ by type of hearing loss, duration of deafness and aetiology of deafness in subjects

	Type of hearing loss	Duration of deafness (years)	Aetiology of deafness	Frequency	Means ± SD
Vowel /a/	Abruptly	<2	Infection	10	152.38±90.82
			strike	10	158.37±81.90
			Unknown	12	159.32±40.95
		>2	Infection	4	154.26±90.18
			strike	2	160.22±51.85
			Unknown	3	162.33±73.90
	Gradual	<2	Infection	9	149.41±66.67
			strike	7	150.55±93.70
			Unknown	10	166.50±82.26
		>2	Infection	3	172.42±75.11
			strike	3	163.35±35.29
			Unknown	3	139.29±48.83

Table 4. Determine the main effects and the effect of the type of hearing loss, duration of deafness and aetiology of deafness of the fundamental frequency vowel /a/ in subjects

Analyzed Factors	df	F	P-value	η^2	Observed power
Type of hearing loss	1	0.568	0.457	0.023	0.112
Duration of deafness	1	0.842	0.486	0.096	0.206
Aetiology of deafness	2	0.554	0.582	0.044	0.131
Type of hearing loss * Duration of deafness	1	0.311	0.736	0.025	0.094
Type of hearing loss * Aetiology of deafness	2	0.394	0.679	0.032	0.106
Duration of deafness * Aetiology of deafness	2	0.521	0.672	0.061	0.140
Type of hearing loss * Duration of deafness * Aetiology of deafness	2	0.416	0.515	0.053	0.090

As mentioned in the table above, the effect of three factors related to deafness of individuals on the pronunciation of vowel /a/ is indicated. According to this table, it can be said that factors such as type of hearing loss, Duration of deafness and aetiology of deafness, cause no significant difference in pronunciation performance of this vowel. Also, the main effect and the combined effect of these factors did not indicate a significant difference on result of the fundamental frequencies of this vowel ($F<0.842$, $P=0.486$, $\eta^2 <0.096$, Observed power<0.206).

2. **Express Declarative sentences**

Surgical factors

As described in table below, the average and standard deviation of the fundamental voice frequency of people during the telling predicative sentences with separation of implant type, implant side and the prosthesis term in post-lingual deaf people using cochlear implant, is indicated. The highest fundamental voice frequencies with an average and standard deviation of 32.21 ± 28.13 Hz is for those who have used MED.EL prosthesis in their right ear for more than two years. The lowest fundamental voice frequency with an average and standard deviation of

162.51 ± 27.88 Hz refers to those who have used MED.EL prosthesis in their left ear for one to two years (see table).

Table 5. Mean and standard deviation of Fundamental frequency of predicative sentence by type of implant type, implanted side and prosthesis term in subjects

	Implant Type	Implant Side	Prosthesis term(yrs)	Frequency	Means ± SD
Predicative sentence	**MED.EL**	Right	<1	12	181.30±80.91
			1-2	9	166.29±76.67
			>2	11	190.28±32.13
		Left	<1	3	168.32±99.34
			1-2	3	162.27±51.78
			>2	3	170.35±70.05
	Other Prosthesis	Right	<1	9	175.19±58.67
			1-2	9	181.24±72.04
			>2	8	171.31±73.75
		Left	<1	3	168.34±75.21
			1-2	3	166.29±18.19
			>2	3	177.30±63.39

Table 6. Determine the main effects and the effect of the implant type, implanted side and prosthesis term of fundamental frequency of predicative sentence in subjects

Analyzed Factors	df	F	P-Value	η^2	Observed power
Implant type	1	0.003	0.900	0.002	0.057
Prosthesis term	2	3.277	0.041	0.195	0.430
Implant side	1	1.01	0.221	0.024	0.130
Implant type * Prosthesis term	2	1.11	0.150	0.101	0.317
Implant type * Implant side	1	0.44	0.515	0.011	0.085
Implant side * Prosthesis term	2	0.009	0.867	0.003	0.059
Implant side * Prosthesis term * Implant type	2	1.19	0.290	0.099	0.149

Deafness factors:

As described in table below, the average and standard deviation of the fundamental voice frequency of people during the telling predicative sentences with separation of implant type, implant side and the prosthesis term in post-lingual deaf people using cochlear implant, is indicated. The highest fundamental frequency of voice with average and standard deviation of 170.1 ± 11.66 Hz is for those who have experienced a history of deafness gradually due to infection for less than two years. The lowest Fundamental frequency of voice with average and standard deviation of 144.33 ± 33.33 Hz is for those who have experienced a history of deafness gradually due to blows for more than two years (Table 7).

Table 7. Mean and standard deviation of Fundamental frequency of predicative sentence by type of implant type, implanted side and prosthesis term in subjects

	Implant Type	Implant Side	Prosthesis term	Frequency	Means ± SD
Predicative sentence	**MED.EL**	Right	<1	10	150.36±88.82
			1-2	10	155.33±90.11
			>2	12	160.30±12.11
		Left	<1	4	157.28±56.18
			1-2	2	162.28±66.99
			>2	3	166.35±73.11
	Other Prosthesis	Right	<1	9	170.36±10.67
			1-2	7	159.47±67.16
			>2	10	160.43±82.43

	Left	<1	3	152.39±11.27
		1-2	3	144.33±35.33
		>2	3	156.31±44.12

Table 8. Determine the main effects and the effect of the implant type, implanted side and prosthesis term of fundamental frequency of predicative sentence in subjects

Analyzed Factors	df	F	P-Value	η^2	Observed power
Type of hearing loss	1	0.668	0.400	0.043	0.132
Duration of deafness	1	1.142	0.386	0.196	0.105
Aetiology of deafness	2	0.550	0.580	0.044	0.129
Type of hearing loss * Duration of deafness	1	0.330	0.717	0.029	0.095
Type of hearing loss * Aetiology of deafness	2	0.404	0.660	0.038	0.109
Duration of deafness * Aetiology of deafness	2	0.500	0.672	0.060	0.144
Type of hearing loss * Duration of deafness * Aetiology of deafness	2	0.400	0.515	0.051	0.091

As mentioned in the table above, the effect of three factors on how sentences are performed is indicated. According to this table, it can be said that factors such as type of hearing loss, duration of deafness and the aetiology of deafness have not caused any significant differences on fundamental frequency of predicative sentences. Also, the main effect and the combined effect of these factors did not indicate a significant difference in the fundamental frequency of the sentences ($F<1.142$, $P=0.386$, $\eta2 <0.196$, Observed power<0.144).

In this study we find that, the most important effect is usage time of cochlear implant on the pronunciation of vowels. As it was indicated in Bonferoni's follow-up tests, regardless of other factors, those who had used cochlear implant for more than two years had significantly higher fundamental frequencies than those who used a prosthesis less than a year ($P=0.03$).

Hocevar-Boltezar et al. [11] reported, in the post-lingually deafened adults, only a slight improvement was detected in some voice parameters after the implantation. The deaf adults generally have a higher F0 than normal hearing speakers. Therefore, the results of the preimplantation acoustic analysis partially confirmed the results of Leder et al.,[20] Who found that after a few years of deafness in adults with postlingual deafness an unusually high F0 value was found. Most researchers examined the usual F0 of a standard speech sample in small groups of patients. They found a significant decrease in F0 after several hours or months of CI experience [14, 16-18, 20]. According to the results of Campisi et al.,[23] F0 was not altered by implant activation or experience with CI application in a group of 21 deaf children. In the other study, Monini et al. [24] rated F0 in the isolated vowel voice samples / a / in six adults and three children. They found a significant decrease in F0 after the first CI adjustment. Their results differ from the results of this study, probably due to a smaller number of patients included in their study. The result of our study, which is closed to the result of Hassan et al,[12] they reported patients who received rehabilitation significantly improved more than those who did not.

Conclusion

The results in our sample showed, the most important effect is usage time of cochlear implant on the pronunciation of vowel /a/ and other factors such as implant type and implant side have no significant relationship with this vowel. On the other hand, type of hearing loss, duration of deafness and aetiology of deafness have no significant relationship with vowel /a/. Also, we found that the type of hearing loss, duration of deafness and the aetiology of deafness have not caused any significant differences on fundamental frequency of predicative sentences.

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Disclosure of interest

The authors report no conflicts of interest.

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