The Comparison of Pitch Production Between Children with Cochlear Implants and Normal Hearing Children

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ABSTRACT

This study compares the pitch production of children using cochlear implants (CI) with that of children with normal hearing. Twenty subjects from six to eight years old participated in the study. Three kinds of sentences were read and analyzed using Visi-Pitch Ⅱ(KAY Elemetrics, Model 3300). There were no considerable differences between the two groups regarding pitch, mean fundamental frequency (F0) and pitch range. In the cases of the slope value of F0 and duration, however, there were significant differences. Thus, it is concluded that duration and pitch control can be crucial factors in determining the intonation treatment of the children with cochlear implants.

Keywords: cochlear implant (CI), F0, slope value, intonation treatment

1. Introduction

The voices of severely hearing impaired children exhibit different characteristics than children with normal hearing, such as higher pitch, higher loudness, higher nasality, etc. Among these, intonation, one of the supra segmental elements, is the most important factor making it hard to deliver messages, since intonation is simple and there is not significant variation of pitch range in hearing impaired children. As children with severe hearing loss can increase their capacity to hear after CI surgery, children with cochlear implants have come into the spotlight but still have problems with intonation.

According to Tye-Murray's study (1995), significant differences in sound recognition were observed between amplified sound stimulation by hearing aids and direct stimulation of the auditory nerve through cochlear implants. There were also significant differences between these two methods in terms of language acquisition and the types of sound producing mechanisms. The degree of improvement of a child's speech and language ability vary with various factors such as the time of CI, the child's cognitive ability, etc. Although many aspects of language ability after CI surgery, intonation remains a major problem. The problem of intonation in

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language ability is still a tough issue for many children who have experienced improvement and undergone operations. Unlike hearing impaired children with hearing aids, the children with cochlear implants are able to hear intonation sounds which were not previously heard because they have a better hearing capacity than children with hearing aids. However, the reason to analyze their intonation differences in comparison with children with normal hearing is that they still experience intonation problems in spite of the improvements shown after CI surgery. The children with cochlear implants will have different patterns of intonation and other speech characteristics which will make their intonation sound strange.

Therefore, the purpose of this study is to examine the differences in intonation between a CI group and a normal group, both consisting of children aged 6 to 8 years old, by analyzing the characteristics of each group's pitch production, in both acoustical and phonological terms, in declarative sentences (D1 and D2), interrogative sentences (In1 and In2) and imperative sentences (Im1 and Im2).

Firstly, the differences in P1, P2, P3, slope value, duration, pitch range (from the maximum pitch to the minimum pitch), and mean fundamental frequency (mean F0) will be examined while the CI group and the normal group read declarative, interrogative, and imperative sentences. Secondly, P1, P2, P3 and slope values in the declarative sentences 1 and 2 read by the CI group will be compared. Finally, P1, P2, P3 and slope values in the declarative sentences 1 and 2 read by the normal group will be compared.

2. Methods

2.1 Subjects

20 participants, including 10 children with cochlear implants and 10 children with normal hearing, who live in Seoul and Gyeunggi-do, were selected for the study. Subjects were asked to read three different type of sentences five times. Two declarative (D1, D2), two interrogative (In1, In2), and two imperative (Im1, Im2) sentences with different lengths were used in this experiment.

2.2 Analysis

Visi-Pitch II (model 3300, KAY Elemetrics) was used to analyze voice samples and the voice recorder was a TASCAM DA-P1 model Digital Audio Recorder. The microphone was a SENNHEISER e815s and the recording tapes were DT-120's from Sony. 70Hz was set as the minimum analysis value and 1000Hz as the maximum analysis value in the pitch analysis range. The values of peaks in each sentence were measured, and F0 slopes were analyzed based on the following formula.

F0 slope m = P1-Pn / T1-Tn

where P1 = peak 1, Pn = last peak, and T1-Tn = duration of time

T-tests were conducted for each sentence to compare P1, P2, P3, and the slope values of the CI group and the normal group while declarative sentences, interrogative sentences and imperative sentences were read.

3. Results

1. Comparison of the slope values of P1, P2 and P3 for the CI and normal group

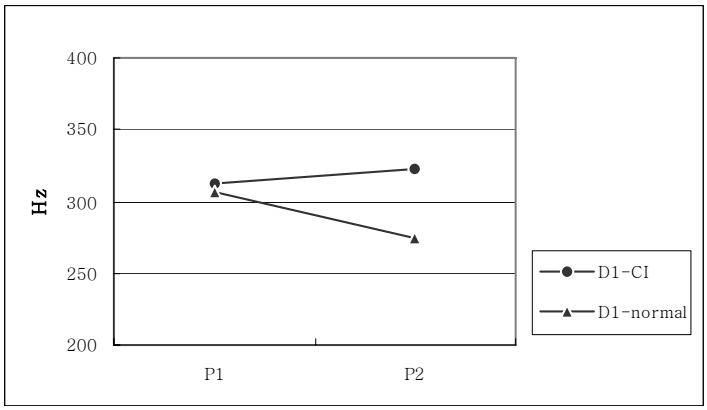

Figure 1. Peaks in the first declarative sentence

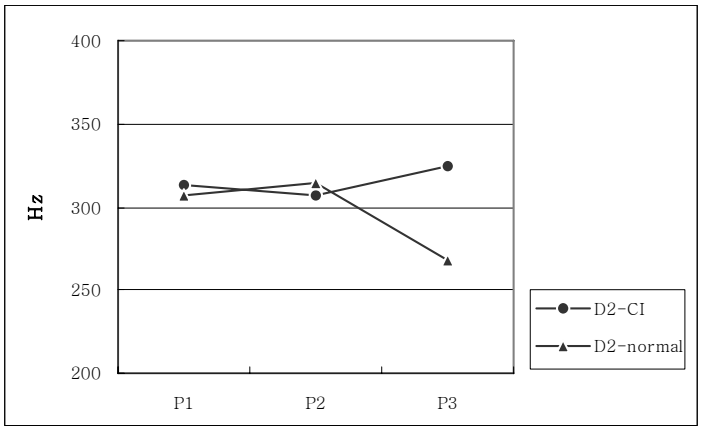

Figure 2. Peaks in the second declarative sentence

Table 1. The results of t-test for P3 of the declarative sentences for each group

sentences	group	N	P3 (Hz)	SD	t	p
D2	CI	10	323.95	72.62	2.138	.046*
	Normal	10	267.49	41.21		

*p<.05

As seen in <Figure 1>, there were no notable differences in the values of P1 and P2 in D1 and D2. However, as seen in <Figure 2> and <Table 1>, there was a meaningful difference in P3, the final peak value of D2, for the CI group. As shown in <Table 2>, there were significant differences between the slope values of both D1 and between the groups after conducting a t-test.

Table 2. The results of a t-test in each group for the slope values of declarative sentences.

sentences	group	N	slope	SD	t	p
D1	CI	10	6.07	21.66	5.766	.000*
	Normal	10	-51.09	22.66		
D2	CI	10	2.13	22.91	.621	.005*
	Normal	10	-25.68	14.74		

*p<.05

There were only minor differences between the groups for the values of P1 and P2 in Im1. There were also no noticeable differences in the peak values for the groups in Im2. However, as seen in <Figure 3>, P3, the final peak, the CI group produced a gradually rising pattern, yet the normal group produced a rapidly rising pattern for the final peak value.

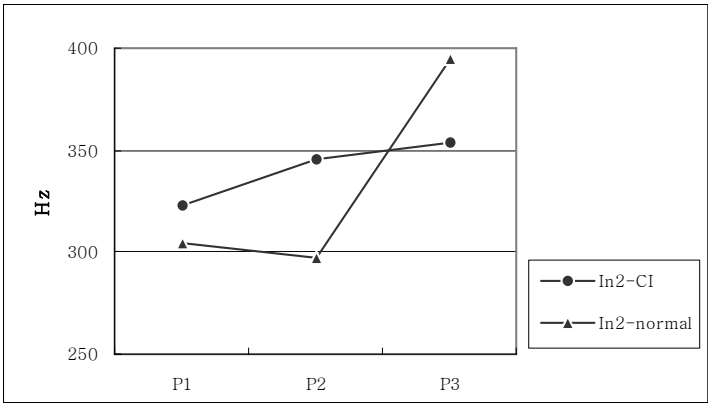

Figure 3. Peaks in the second interrogative sentence

2. The comparison of duration, pitch range, and mean F0 for the CI and the normal group

As seen in <Table 3 and 4>, and <Figure 4>, major differences in duration were observed in all six sentences.

Table 3. the results of t-test for duration in declarative sentences

sentences	group	N	duration (sec)	SD	t	p
D1	CI	10	2.18	.50	5.381	.000*
	Normal	10	1.27	.15		
D2	CI	10	3.20	.80	4.896	.000*
	Normal	10	1.92	.17		

*p<.05

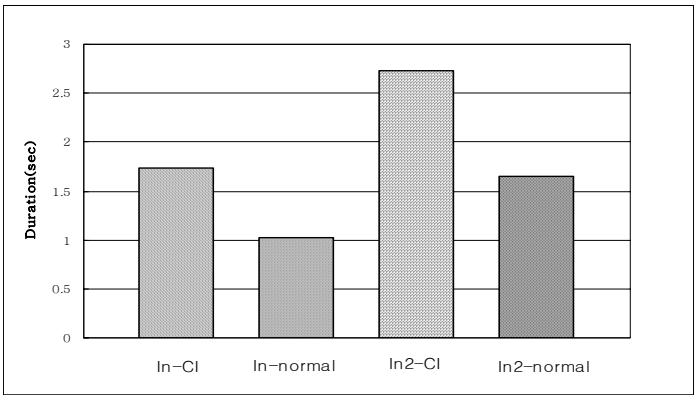

Figure 4. Duration in the interrogative sentences between the two groups

Table 4. The results of t-test for duration in imperative sentences

sentences	group	N	duration(sec)	SD	t	p
Im1	CI	10	2.23	.50	4.362	.000*
	Normal	10	1.48	.21		
Im2	CI	10	2.90	.92	3.457	.003*
	Normal	10	1.83	.33		

*p<.05

For the pitch ranges of the two groups, as seen in <Table 5>, differences in D2 were observed in declarative sentences and significant test results in both In1 and In2 were observed in interrogative sentences.

Table 5. The results of t-test for the pitch ranges of the groups for declarative sentences

sentences	group	N	pitch range (Hz)	SD	t	p
D1	CI	10	111.82	53.10	-5.71	.575
	Normal	10	124.01	41.63		
D2	CI	10	144.45	68.80	15.617	.001*
	Normal	10	157.93	71.87		

*p<.05

In mean fundamental frequency (mean F0), there were no statistical differences between the CI group and the normal group.

4. Discussion

In studies conducted in a variety of language zones, there was a general tendency for a declination of F0 when sentences were produced (Vaissiere, 1983; Cruttenden, 1997; Ladd, 1996), and Vaissiere (1983) argued that such tendencies could differ depending on the length of the sentences and according to whether the sentences are produced in a natural environment or by reading texts. In addition, Cooper & Sorensen (1981) explained that the weakness of subglottic air pressure and muscles related to speech, including vocal cords, cause the pattern of declination of F0. According to Ko (1988) and Koo (1986), which dealt with intonation in Korean declarative sentences, there was a general tendency for the value of the final peak in declarative sentences to show a declination in comparison with the value of P1. In these latter two studies, for the normal group, P2, the final peak value in D1, declined and P3, the final peak value in D2, declined in comparison with P1 in each sentence. Therefore, the results were similar to previous studies, showing a declination of F0 overall. However, when comparing the values of P1 in D1, the CI group exhibited different characteristics from the normal group, showing patterns for P2 that inclined steeply or were close to horizontal and showing a similar value of P1. Cho (2003), who studied the intonation of hearing impaired children, insisted that they showed a mid-level or falling meter while producing declarative sentences and this was reflected in the results of D1, in which a mid-level meter was seen. But D2, which showed a slight inclination, yielded different results from Cho's study on hearing impaired children with hearing aids because the participants for this study had cochlear implants, not hearing aids. Hearing impaired children with hearing aids speak with simple tones, failing to hear and produce the declining intonation patterns in the last part of declarative sentences due to a lack

of ability to accept sound in comparison with the CI group. However, although the CI group could recognize the intonation patterns in interrogative sentences since they have a better acoustic ability, they still had difficulties controlling intonation delicately in the declination patterns seen in the last part of declarative sentences. Therefore, even though the CI group recognized the different intonation between the beginnings and ends of sentences, their pitch increased slightly while they raised their voices in the last part of sentences due to their difficulties with delicate control, rather than speaking in natural declining patterns due to their difficulties with delicate control.

O'Halpin's study (2001) mentioned that hearing impaired children had difficulties controlling breathing and F0, observing that their F0 values did not have declining patterns and explaining the characteristics of hearing impaired children. These include speaking with expanded syllables, excessively long pauses when producing sentences and other characteristics. Based on the imperative sentences which hearing impaired children produced, the values of P2 showed a horizontal intonation pattern instead of a declining pattern because the values of P1 and P2 in Im 1 were similar and the values of P3 in Im2 represented a slightly declining pattern, as with the declarative sentences. That indicated that, although the CI group understood the meanings of declarative sentences and imperative sentences, they had difficulties distinguishing subtle intonation differences when reading each type of sentence. In interrogative sentences obviously different from declarative sentences, the final peak values in both In1 and In2 increased in the CI group. However, unlike the normal group, in which P2 increased rapidly to the final peak value, hearing impaired children showed only a slightly increasing pattern. In addition, the graph of peak values showed a steady upward curve in In2 rather than In1. Overall, the CI group demonstrated a rise in pitch values in the last part of interrogative sentences, but these rising rates were small and the patterns of inclination and intonation were different in comparison with the normal group. This matched the results seen in Allen & Ardorfer's study (2000), in which the value of F0 rose less in the CI group than in the normal group.

The significant differences in the declination values between D1 and D2 reflected the results of Ladd's study (1996) in which sudden declination values were observed in short sentences. The declination of the values of F0 measured in declarative sentences was significant as the declinations produced by the two groups obviously differed when the mean results of each group were compared. The mean declination value in D1 and D2 which the normal group produced was -38.39 while the mean declination value in the same sentences for the hearing impaired group was 4.1. Further, whereas the normal group tended to have a negatively inclined F0 pattern, the hearing impaired group did not show an declined pattern, exhibiting a positive value. These results coincided with O'Halpin's study (2001) in which an incline of F0 in declarative sentences was not observed in a hearing impaired group. This indicates that the voices of hearing impaired children sound simple and strange when we hear them speaking, due

to a lack of variation in their pitch. Furthermore, hearing impaired children showed a tendency to raise their pitch in the last part of the declarative sentences by speaking loudly, and such inappropriate selections of tones and difficulties in controlling strength may result in strange sounds.

It was also noticed that while the sentence peak values were very different in both groups, in D1 "-ga", a function word, was determined to be the P1 value for the normal group, as it showed the highest pitch value, rather than "Young-Hee", a content word, in the phrase "Young-Hee-ga." However, "Young" was determined to be the P1 value for the CI group because "young," the first syllable, was emphasized in the sentence "Young-Hee-ga." "l̈il" was selected as the P1 value because "-l̈il," a function word, was emphasized rather than "Chul-Su," a content word, while the normal group read D2. But, the CI group read monotonously, putting emphasis equally on each syllable, "Chul-Su-l̈il", rather than the naturally emphasized "-l̈il," an accusative postpositional word. Therefore, "Chul," the first syllable was determined as the P1 value in most cases. So, the CI group read declarative sentences with similar tones, failing to show distinctive pitch variations, emphasizing content and function words equally, and failing to show natural intonation patterns. Thus, the specially emphasized part was designated the peak value. The normal group had a tendency to put heavy emphasis on "-l̈il," a function word, as well as "-yo?," the last part of the interrogative sentence In2 "no-rae-l̈il-haet-seo". Therefore, that word became the peak value. However, the hearing impaired children read "no-rae-l̈il" with similar tones for all three syllables, failing to put emphasis on a function word, showing simple patterns of wave forms and a lack of rhythmic sense. For this reason, the peak value was not always fixed on "-l̈il," the function word. Considering this point, the CI group might be able to learn natural intonation patterns close to those of the normal group if they are taught to emphasize postposition words rather than content words for natural intonation, and to control their low pitch on content words.

Duration should be mentioned here. The results showed that the CI group had significantly longer duration than the normal group when reading given sentences. Upon examination, the causes of their longer duration were reasons such as difficulties in respiratory control as well as the CI group's tendency to read postposition words, and function words, at the same speed as content words. In addition, while the normal group read "Young-Hee-ga", leaving a space between the final two syllables, the hearing impaired group typically read each single syllable independently: "Young-Hee-ga". This study supports Yun's opinion (1994) that hearing impaired children have abnormally long pronunciation of syllables and that they pronounce vowels at the same slow speed in meaningless postposition words, at the ending of words or in every syllable.

Although no meaningful statistical differences were observed in pitch range except for D2, there were generally more narrow pitch ranges in the CI group than the normal group. These

results reflected the findings of Allen & Ardorfer's study (2000) on intonation in a hearing impaired group, that the ranges of intonation were less than those of a normal group. Allen & Ardorfer (2000) argued that such narrow pitch ranges when producing sentences made it hard for hearing impaired people to deliver messages due to their limited tone variations. Furthermore, this study's results coincided with Calvert's observation (1962) that a deaf speaker had fewer variations in voice tones than a normal person due to his/her simple speaking characteristics. However, since those previous studies were also conducted with hearing impaired children with hearing aids, and this study focused on the CI group, it can be understood that no meaningful differences were observed between the pitch ranges of the two groups due to the subjects' different equipment.

5. Concluding Remarks

When examining the differences in intonation between the CI group and the normal group, there were no meaningful differences in phonetic standards such as pitch or mean fundamental frequency, yet there were differences in the subtle intonation needed to deliver messages effectively. While this could be explained by examining the slope patterns of each group, F0 declination seen in declarative sentences from the normal group was not observed in the CI group. Different patterns were observed, including the steadily rising patterns in interrogative sentences shown by the CI group. The differences in intonation factors and the length of production were considered to be mutually related, the most significant observation of this study. Duration should therefore be considered a crucial factor to offering effective intonation treatment to CI patients.

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Appendix 1

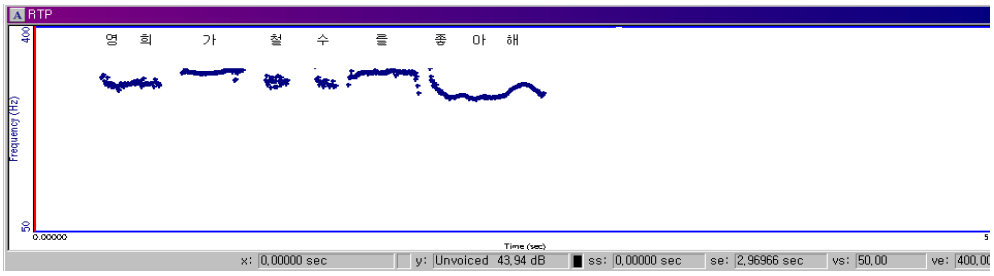
Sentences

Declarative sentences
D1 - Young-Hee-ga jo-a-hae
D2 - Young-Hee-ga Chul-Su-lil jo-a-hae

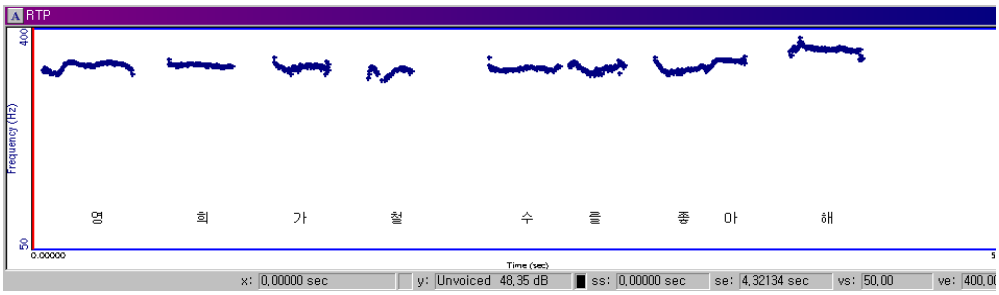
Interrogative sentences
In1 - no-rae-lil haet-seo
In2 - Young-Hee-Ga no-rae-lil haet-seo

Imperative sentences
Im1 - Chul-Su-ya suk-jae-hae
Im2 - Chul-Su-ya ppal-li suk-jae-hae

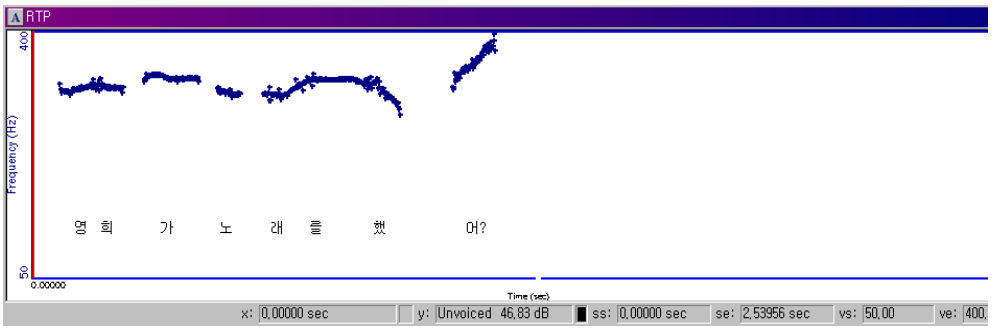
Appendix 2



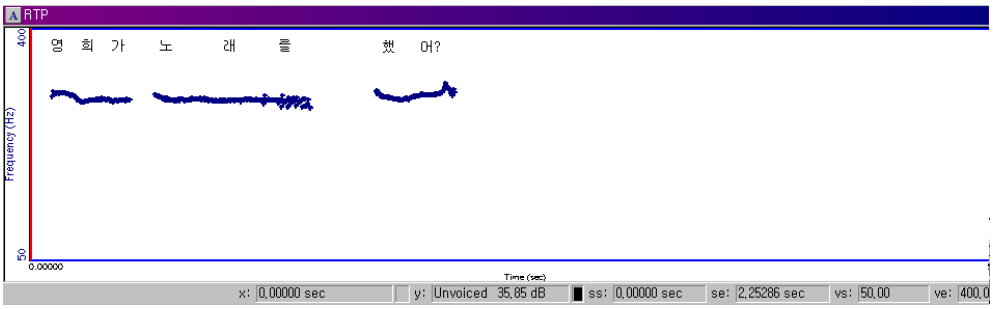
Normal Group-D2



CI Group-D2



Normal Group-In2



CI Group-In2