A Study on Intonation Patterns of Speech Produced by Cochlear Implanted Children

Sang-Hee Park* · Tae-Yeoub Jang · Sang-Heun Lee*** ·**
Ok-Ran Jeong* · Dong-Il Seok*

ABSTRACT

The purpose of the study is to examine intonation patterns of cochlear implanted children compared with those of normal hearing children. The data tokens of three normal and five cochlear implanted children were collected and investigated. Their intonation patterns were analyzed using the speech analysis tool, *Praat*. The characteristics of the two utterance types, interrogative and declarative, were investigated. No significant difference in intonation patterns between the two subject groups was found. However, the general pitch of cochlear implanted children was higher than that of normal hearing children. In addition, cochlear implanted children showed frequent pitch breaks.

Keywords: Intonation, Pitch, Cochlear Implant, Pitch Break

1. Introduction

Cochlear implanting provides an alternative communication method for those suffering from severe sensorineural hearing loss. When electrodes are implanted into the cochlea through surgery, they stimulate hearing nerves and transmit sound signals to brain. It is devised on the same principle that electrical/mechanical energy is the medium for normal sound transmission in cochlea.

It is reported that there were 320 cases of cochlear implanting in Korea before June 2000 (Lee, 2000). Although types of the patients vary case by case, many studies have consistently reported positive results (Kim 1998, Waltzman *et al.*, 1999, Zimmerman-Phillips *et al.*, 1999, Zwolan *et al,*. 1997, among others). However, we have observed that the general speech characteristics of those with hearing aid are also shown in cochlear implanted (CI) children. They are *cul de sac* resonation, monotone, and intensive burst. This paper is focusing on their pitch characteristics. Especially, we are investigating the intonation pattern of speech produced by cochlear implanted children. It is reasonable to

* Dept. of Speech Pathology, Taegu University
** Dept. of English, Hankuk University of Foreign Studies
*** Dept. of Otolaryngology, Kyungpook National University

analyze the intonation pattern in order to explicate pitch characteristics as the most predictable and outstanding pitch fluctuations occur at the utterance of final position where intonational characteristics are mostly determined. We will especially focus on the intonation patterns of *declarative* and *interrogative* sentences assuming they had the most distinguishable intonation characteristics between each other.

The specific topics for the current study can be summarized in terms of the following three questions. First, what are the general intonational characteristics of interrogative sentences spoken by cochlear implanted children compared with normal children? Second, what are the general intonational characteristics of declarative sentences spoken by cochlear implanted children compared with normal children? Third, is there any considerable intonation pattern difference between declarative and interrogative sentences produced by cochlear implanted children? Fourth, is there any considerable intonation pattern difference between declarative and interrogative sentences produced by normal children?

2. Procedure

The subjects who participated in the experiments are composed of five (three male and two female) cochlear implanted children and three (two male and one female) normal children. All the subjects can read Korean characters and speak the Kyeongsang dialect as their parents are also speakers of the same dialect. Shown in Table 1 are the individual characteristics of the cochlear implanted subjects.

Table 1. Characteristics of cochlear implanted children

	Sex	Time of hearing loss	Age (yr:mon)	Age when cochlear implanted (yr:mon)	Time elapse after surgery (yr:mon)	Type of speech strategy	Maker and type of device
1	M	innate	8;5	7;5	1;0	ACE	Nucleus CI 24
2	M	innate	7;1	3;8	4;5	ACE	Nucleus CI 24
3	M	innate	7;11	7;2	0;9	ACE	Nucleus CI 24
4	F	innate	6;6	3;8	2;10	ACE	Nucleus CI 24
5	F	innate	8;7	8;0	0;7	ACE	Nucleus CI 24

To produce speech files, we had each subject read a script which was made up of 10 declarative and 10 interrogative sentences as shown in Table 2. Each sentence is composed of three, four or five phonological words, the count of which is based on the average number of phonological words in a sentence in primary school text books. We also made each child produce a sustained [a] sound. This was to check out the individual characteristics of unintended tonal fluctuations.

Table 2. Read sentences

Interrogative	1. Yeonghi-ga hakgyo-e kass-seupni-kka? "Did Yeonghi go to school?" 2. Bakk-e bi-ga ogo iss-seupni-kka? "Is it raining outside?" 3. Cheolsu-ga san-e ol-ra-gass-seupni-kka? "Did Cheolsu climb the mountain?" 4. Chaek-eul ilk-ko iss-seupni-kka? "Are you reading a book?" 5. Eoje imo-ga wass-seupni-kka? "Did the aunt come yesterday?" 6. Bakk-ge baram-i buleoseo changmun-eul datass-seupni-kka? "Did you close the window because the wind blows?" 7. Heungbu-wa Nolbuneun hyeongje-ipni-kka? "Are Heungbu and Nolbu brothers?" 8. Cheolsu-ga gaseu naemsae-reul matass-seupni-kka? "Did Cheolsu smell gas?" 9. Gage-e gaseo yeonpil 12 jaru-reul sass-seupni-kka? "Did you buy 12 pencils at a shop?" 10. Keurepaseu-ro byeok-e geurim-eul geuryeoss-seupni-kka? "Did you draw a picture on the wall with your crayons?"
Declarative	1. Yeonghi-ga hakgyo-e kass-seupni-da "Yeonghi went to school." 2. Bakk-e bi-ga ogo iss-seupni-da "It is raining outside" 3. Cheolsu-ga san-e ol-ra-gass-seupni-da. "Cheolsu climbed the mountain" 4. Chaek-eul ilk-ko iss-seupni-da. "I am reading a book" 5. Eoje imo-ga wass-seupni-da. "The aunt came yesterday" 6. Bakk-ge baram-i buleoseo changmun-eul datass-seupni-da. "I closed the window because the wind was blowing" 7. Heungbu-wa Nolbu-neun hyeongje-ipni-da. "Heungbu and Nolbu are brothers" 8. Cheolsu-ga gaseu naemsae-reul matass-seupni-da. "Cheolsu smelled gas" 9. Gage-e gaseo yeonpil 12 jaru-reul sass-seupni-da. "I bought 12 pieces of pencil at a shop" 10. Keurepaseu-ro byeok-e geurim-eul geuryeoss-seupni-da. "I drew a picture on the wall with my crayons"

Data were obtained and analyzed using a publicly obtainable speech analysis tool *Praat (Version 3.9.35)*. For recording the voice data a unilateral microphone was used. In order to keep the input intensity constant, the distance between microphone and mouth was adjusted heuristically for each speaker. Signals were digitized with 22 kHz sample rate and 16 bit quantization.

The fundamental frequency (F0) of the last syllables of sentences were measured. Three point (start point, mid point, and end point) measurements were conducted following the intonation analysis method proposed in Lee (1996). For the convenience of such measurements, every sentence final syllable was manually segmented and labelled in advance.

For each speaker, 10 measurement values for declarative sentences and 10 measurement values for interrogative sentences were averaged respectively, resulting in two F0 values to be analysed and compared.

3. Experimental Results

The F0 measures for each speaker are shown in Table 3. We will analyse these results, trying to answer one by one the four questions asked in the introduction section (section 1).

Table 3. F0 values (in Hz) of the final syllable declarative and interrogative sentences spoken by subjects

		interrogative				declarative			
		start	mid	end	range	start	mid	end	range
Cochlear implanted children (CI)	1	288.49	263.08	250.90	37.59	296.31	268.31	244.17	52.14
	2	281.45	274.54	260.22	21.23	285.32	261.97	233.98	51.34
	3	319.64	392.88	402.94	83.3	281.11	276.58	349.80	73.22
	4	316.83	292.78	256.32	60.51	280.08	264.63	293.93	29.3
	5	380.03	310.01	325.88	70.02	405.46	340.28	325.65	79.81
Normal hearing children (N)	1	343.10	360.37	369.96	26.86	270.41	229.78	221.72	48.69
	2	253.35	252.41	260.25	7.84	230.06	222.30	201.44	28.62
	3	273.94	263.03	203.76	70.18	261.46	252.89	174.40	87.06

3.1 Interrogative intonation patterns of CI children and normal children

The F0 of the syllable 'ka[k'ɑ]' in interrogative sentences spoken by CI-1 subject, starts from 288.49 Hz, lowers down to 263.08 Hz at the mid point, and ends at 250.90 Hz. It can be said to be a falling tone. The subjects CI-2 (281.45 - 274.54 - 260.22 Hz) and

CI-4 (316.83 - 292.78 - 256.32 Hz) also have a falling tone. But this tendency does not seem to be generalized since CI-3 has a rising pattern (319.63 - 392.88 - 402.94 Hz) and CI-5 is found to have a falling-rising contour (380.03 - 310.01 - 325.88 Hz).

In cases of normal children, data of N-1 (340.10 - 360.37 - 369.96 Hz) and N-2 (253.35 - 252.41 - 260.25 Hz) show a high level tone and a slightly-rising tone, respectively. On the other hand, N-3 (273.94 - 263.03 - 203.76 Hz) has a falling tone. Consequently, it is hard to find a consistent tendency from normal children's tonal patterns as well. Figure 1 is a visualized illustration of these results.

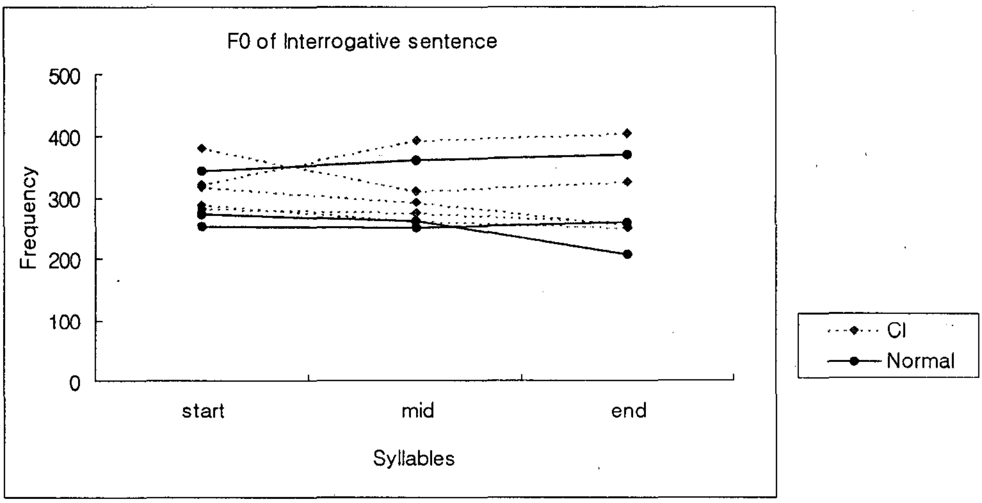

Figure 1. Interrogative sentence intonation of CI and normal children

3.2 Declarative intonation patterns of CI children and normal children

The F0 patterns of declarative sentence final syllable 'da[ta]' produced by CI children are not uniform, either. The subjects CI-1 (296.31 - 268.31 - 244.17 Hz), CI-2 (285.32 - 261.97 - 233.98 Hz), and CI-5 (405.46 - 340.28 - 325.65 Hz) have the patterns of falling tones. On the contrary, the other two CI-3 (281.11 - 276.58 - 349.80 Hz) and CI- 4 (280.08 - 276.58 - 349.80 Hz) have falling-rising tones.

As for normal hearing children, N-1 (270.41 - 229.78 - 221.72 Hz) and N-2 (230.06 - 222.30 - 201.44 Hz) end the sentences with a level or near-level tones while N-3 (261.46 - 252.89 - 174.40 Hz) with a falling tone. Figure 2 shows the graph for these results.

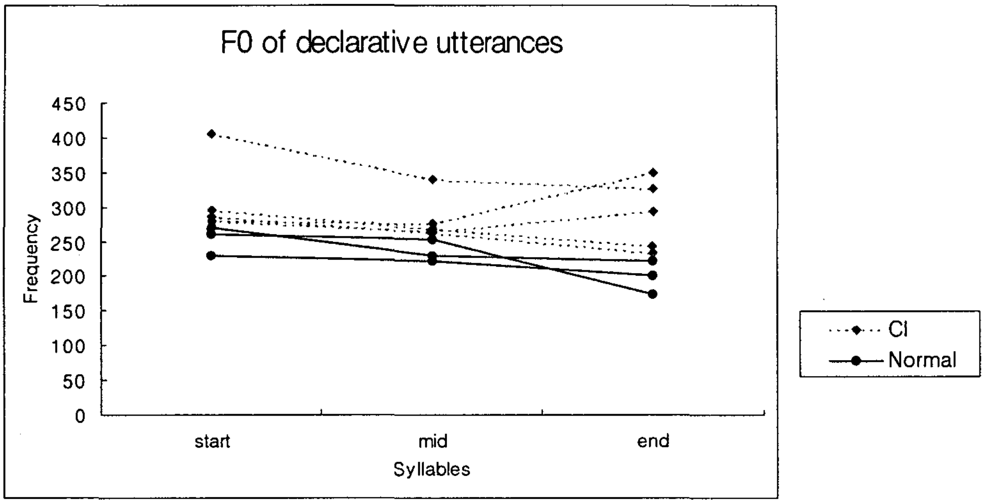

Figure 2. Declarative sentence intonation of CI and normal children

3.3 Interrogative/declarative comparison of CI children's intonation

As shown in Figure 3., the three CI children spoke with falling tones despite the sentences being interrogative. As for declarative sentences, the three children have falling contour tones, and the other two, falling-rising tones.

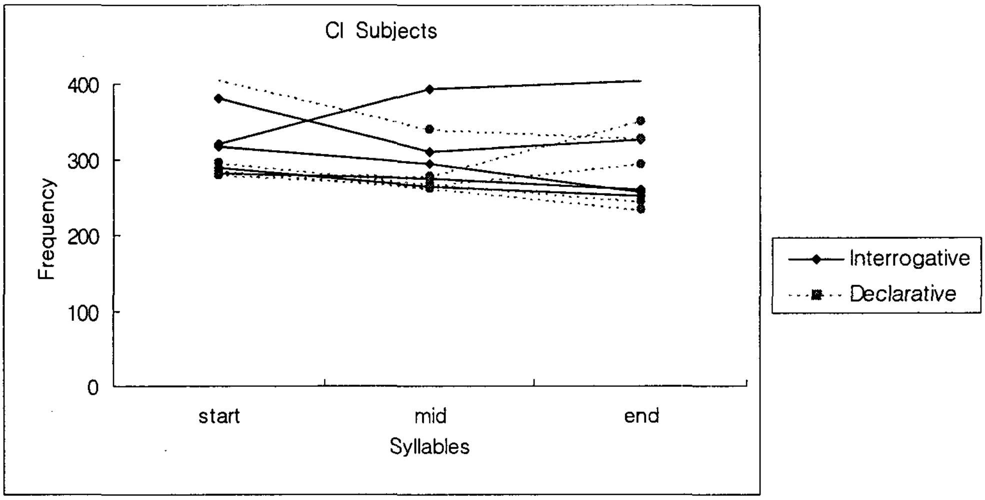

Figure 3. F0 of CI children's interrogative/declarative utterances

3.4 Interrogative/declarative comparison of normal children's intonation

Figure 4 shows that one of the three normal hearing children has a falling tone for interrogative sentences, while all three children have a falling tone for declarative sentences.

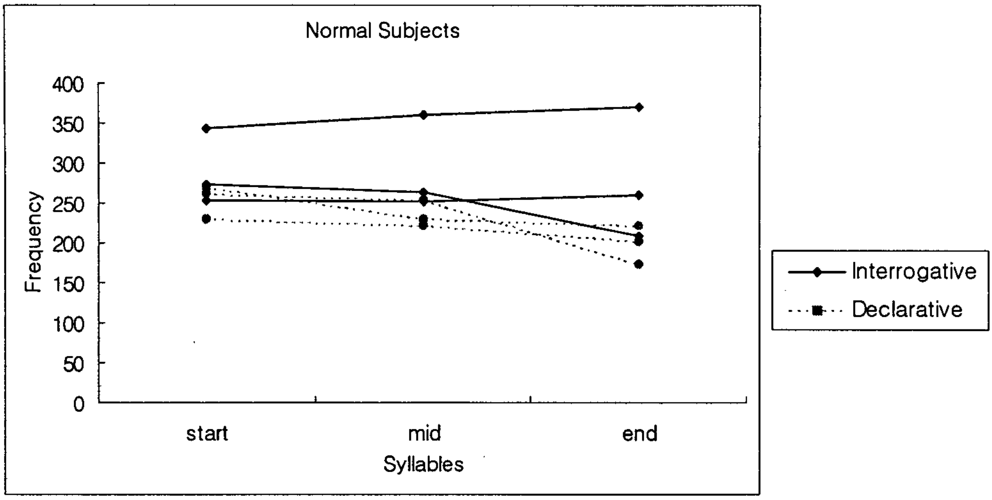

Figure 4. F0 of normal children's interrogative/declarative utterances

4. Discussion

Ladd (1996) states that intonation refers to the use of suprasegmental phonetic features to convey meanings in a linguistically structured way. Unlike other phonological systems like segments or other prosodic features, intonation has been found to be universal not only because of its existence in virtually all languages, but because of many of its functions shared by languages of widely different origins (Hirst & Cristo 1988:1). Obviously, intonation plays a significant role in Korean as well by determining pragmatic meaning of a spoken utterances. Although there is recently an increasing number of studies on Korean intonation, few of them are on the intonational characteristics of speech produced by hearing impaired speakers. Indirectly relevant studies include Huh (1996) in which general characteristics of their speech are indicated, and Yun (1990) in which slower speech rate and loss of rhythm in their speech are investigated. As a consequence, our studies are expected to encourage more active and objective research in this area.

Even though, as stated in the previous section, the shapes of intonation contour do not seem to clearly distinguish between cochlear implanted and normal hearing speakers, nor between the two utterance types such as interrogative and declarative, other aspects are considered to be important. First, the interrogative intonation of CI children is generally higher than that of normal children. This is clearer when we analyse the sustained [a] data. Four out of five CI children (318.36Hz) have higher average F0 values than normal children (239.93Hz) for interrogative sentences. This observation supports a previous study (Huh, 1996) which points out a considerable difference in average pitch values and pitch perturbation measures (frequently known as *jitter*) between normal children and hearing impaired children. The speaker CI-3, the one having a rising tonal pattern for interrogative sentences unlike the other CI children, may have been affected by the fact that his impairment was relatively lighter than the others and that he was being treated by SLP when he was put on hearing aid devices before cochlear was implanted. His falling-rising tonal pattern of declarative sentences appears to be caused by his previous training sessions in which he might have been instructed to emphasise the last syllable, that is, 'da[ta]'. Consequently, it is reasonable to conclude that the intonational characteristics of interrogative sentences uttered by CI children are different from those produced by normal children.

It should be noted that normal children's interrogative intonation tends to be falling instead of rising as is usually expected. This reflects the dialectal characteristics of Kyeongsang Korean whose general tonal shape of question sentences is a falling contour irrespective of Wh- or Yes-No questions.

For declarative sentences, the absolute F0 magnitude is found to be an additional clue to distinguish CI children's speech from normal children's. As shown in Table 1 and Figure 2, CI children's pitch is generally higher than normal children's. This observation is in agreement with the previous studies. A more interesting phenomenon is the frequent breaks of pitch curves on CI children's data. Consider arrow-marked points in Figure 5 and 6 as examples. Many data tokens only of CI children have such disconnected pitch contour. Inadequate uses of vocal folds are suspected as the cause. But further experimental studies are required to clarify the status of these pitch breaks and abrupt changes, as well as their cause.[1]

1) Too narrow a pitch-range setup of the speech analysis software (Praat) does not appear to be the cause for breaks. We attempted to display F0 of the relevant data with further extended pitch range only to have the same results.

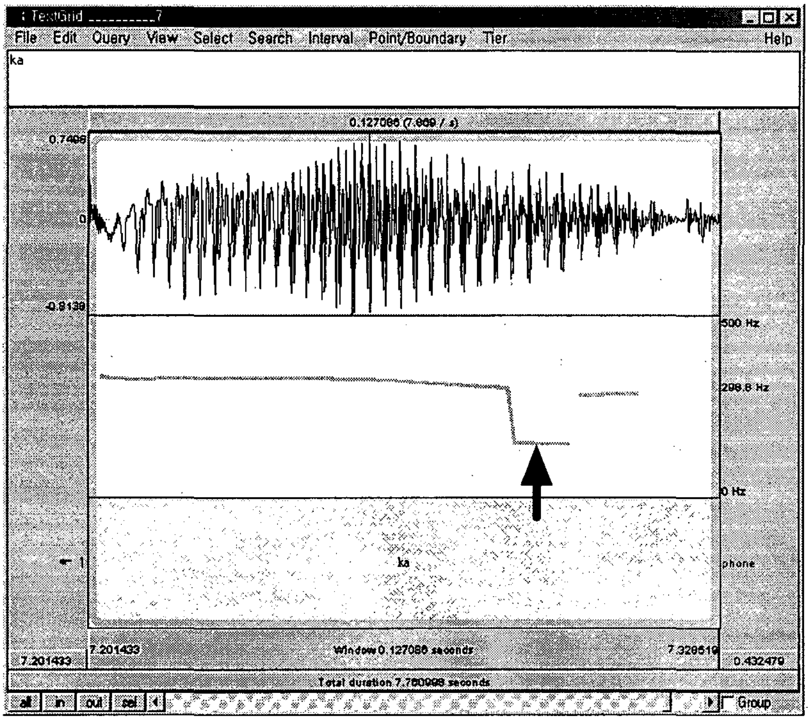

Figure 5. CI children's pitch break

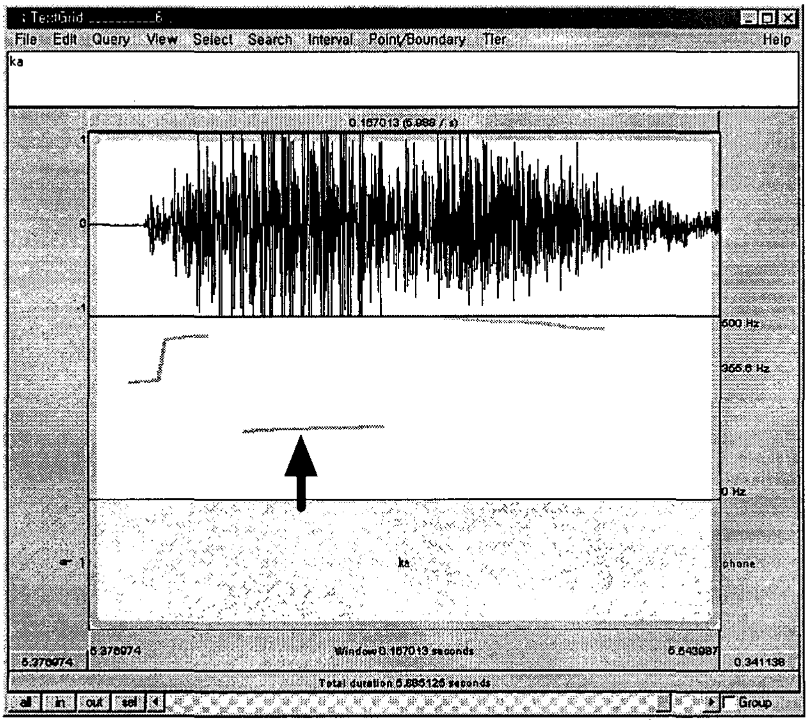

Figure 6. CI children's pitch break

5. Conclusion and Suggestions

The experimental results show that CI children's speech is hard to distinguish from normal children's speech only in terms of sentence final F0 fluctuation patterns. However, it is confirmed that CI children's average F0 magnitude is higher than that of normal children. As one of the goals of the current research is to provoke more studies on CI children's intonational characteristics, there are a number of future works to be performed. Among others, experiments with more data of various types obtained from many cochlear implanted speakers are desired in order to verify, confirm and generalize assumptions on intonation. It is certain that these studies on prosodic aspects of the spoken language will lead to a considerable improvement of the speech correction programs for cochlear implanted children and other hearing impaired people in general.

References

Hirst, D. & A. D. Cristo (Eds.). 1998. *Intonation Systems*. Cambridge University Press.

Huh, Myung Jin. 1996. *Acoustic Characteristics of Voice of Normal and Hearing Impaired Individuals*. Unpublished master's thesis, Taegu University. (in Korean)

Kim, Kee Ho. 1999. "An Introduction to English Intonational Phonology." *Korean Journal of Speech Sciences,* Vol 6, 119-143. (in Korean)

Kim, Soo Jin. 1998. *Changes of Electrical Thresholds, Dynamic Rnage, Speech Perception, and Vocabulary Aquisition in Children with Cochlear Implants.* Unpublished Doctoral Dissertation. Taegu University. (in Korean)

Ko, D. H. *et al.* 2001. *Practical Methods for Voice and Language Analysis Device*. Seoul: Hankookmunhwasa, (in Korean).

Ladd, D. R. 1996. *Intonational Phonology*. Cambridge University Press.

Lee, Sang Heun. 2000. *The Present Position and the Future Prospect of Children with Cochlear Implants*. Department of Speech Language Pathology Data (in Korean)

Park, Sang Hee & Dong Il Seok. 1999. "The Study of Auditory Sentence Comprehension Ability in Children with Cochlear Implants." *Korean Speech & Hearing Association.* Vol. 8, No. 1, 191-218. (in Korean)

Tucci, D. L., S. A. Telian, S. Zimmerman-Phillips, T. A. Zwolan & P. R. Kileny. 1995. "Cochlear implantation in patients with cochlear malformations." *Archives of Otolaryngology-Head & Neck Surgery*, 121, 833-838.

Tyler, R. S. 1993. *Cochlear implants audiological foundations.* San Diego. California: Singular Publishing Group. INC.

Tyler, R. S., B. J. Grants, H. F. B. Teagle, D. Kelsay & A. J. Parkinson. 1999. "Six-year speech-perception results of prelingually deaf children with cochlear implants." *The Second Congress of Asia Pacific Symposium on Cochlear Implant and Related Sciences,* abstracts, 86.

van Dijk, J. E., A. F. van Olphen, M. C. Langereis, L. H. Mens, J. P. Brokx & G. F.

Smoorenburg. 1999. "Predictors of cochlear implant performance." *Audiology,* 38 (2), 109-116.

Waltzman, S. B. 1999. "Factors impacting on performance of children using multichannel cochlear prosthesis." *The Second Congress of Asia Pacific Symposium on Cochlear Implant and Related Sciences,* abstracts, 22.

Waltzman, S. B., & N. L. Cohen. 1999. "Implantation of patients with prelingual long-term deafness." *Annals of Otology, Rhinology and Laryngology (supple),* 177, 84-87.

Waltzman, S. B., P. Arndt, A. Hines & S. Staller. 1999. "A comparison of coding strategies with the Nucleus 24 cochlear implant." *The Second Congress of Asia Pacific Symposium on Cochlear Implant and Related Sciences*, abstracts, 49.

Warren Otologic group. 1999. *Cochlear Implant Program.* Warren Otologic Group -pedratrics.

Weber, B. P., J. Neuburger, J. E. Goldring, T. Santogrossi, H. Koestler, R. D. Battmer & T. Lenarz. 1999. "Clinical results of the CLARION magnetless cochlear Implants." *Annals of Otology, Rhinology and Laryngology (supple),* 177, 22-26.

Young, N. M., K. M. Grohne, V. N. Carrasco & C. Brown. 1999. "Speech perception of young children using Nucleus 22-channel or CLARION® cochlear implants." *Annals of Otology, Rhinology and Laryngology(supple),* 177, 99-103.

Yun, Mi Sun. 1999. *Speech Sound, Language, Psychological Characteristics of Hearing Impairment Children.* The Korean Academy of Speech-Language Pathology and Audiology. 4, 52-64. (in Korean)

Zimmerman-Phillips, S. & C. Murad. 1999. "Programming Features of the CLARION® multi-strategyTM Cochlear Implant." *Annals of Otology, Rhinology and Laryngology (supple),* 177, 17-21.

Zwolan, T. A., S. Zimmerman-Phillips, C. J. Ashbaugh, S. J. Hieber, P. R. Kileny & S. A. Telian. 1997. "Cochlear implantation of children with minimal open-set speech recognition skills." *Ear and Hearing,* 18(3), 240-251.

Received: Jan. 30, 2002.
Accepted: Mar. 6, 2002.

▲ Sang-Hee Park
Department of Speech Pathology, Taegu University
2288 Daemyeong-dong, Nam-gu, Daegu 705-823, Korea
Tel: +82-53-650-8246
E-mail: p49811097@freechal.com

▲ Tae-Yeoub Jang
Department of English, Hankuk University of Foreign Studies
270 Imun-dong, Dongdaemun-gu, Seoul 130-791, Korea
Tel: +82-2-961-4114
E-mail: tae@hufs.ac.kr

▲ Sang-Heun Lee
Dept of Otolaryngology, Kyungpook National University

50 Samduk 2-ga Joong-ku Taegu, 700-414
Tel: +82-53-420-5784

▲ Ok-Ran Jeong, Ph. D., CCC-SLP
Department of Speech Pathology, Taegu University
2288 Daemyeong-dong, Nam-gu, Daegu 705-823, Korea
Tel: +82-53-650-8274
E-mail: oj@taegu.ac.kr

▲ Dong-Il Seok, Ph. D.
Department of Speech Pathology, Taegu University
2288 Daemyeong-dong, Nam-gu, Daegu 705-823, Korea
Tel: +82-53-650-8272
E-mail: diseok@taegu.ac.kr