SOME EFFECTS OF COCHLEAR IMPLANTATION ON SPEECH PRODUCTION

ANNE-MARIE ÖSTER

Dept. of Speech Communication & Music Acoustics
Royal Institute of Technology (KTH), Box 70014
S-100 44 Stockholm, Sweden

ABSTRACT

A new method for the treatment of acquired total deafness in adults is under probation in Sweden since 1983. The Vienna Cochlear Prosthesis is an extra-cochlear system comprising a single-channel implant with its active electrode placed in the round-window niche. The device functions on the basis of electrical stimulation of the cochlear nerve.

The present study reports on acoustical analyses of fundamental frequency of two patients' recorded readings of a familiar text consisting of 89 words and an unfamiliar text of 56 words. The recordings were made pre-implant and post-implant after 1, 3, 6, 12 and 24 months. We have also made recordings of the patients when they read the text without and with the implant.

The analyses made included the speech rate, phonation time as well as the mean and the standard deviation of the fundamental frequency. The results are shown in forms of F0-histograms. The main effect found is an improvement in F0-control which means a lowering in mean F0 and a more normal F0-distribution. A shift towards a more normal rate of articulation is also found.

INTRODUCTION

A cochlear implant is a new technical aid for the deaf based on direct electrical stimulation of the auditory nerve. An implant provides only limited auditory information but still most implanted patients report benefits by the implant. Hochmair-Desoyer /1/ gives details about a questionnaire to patients with one year's experience of a single-channel implant. The patients derived benefits in:

1) Provision of environmental (non-speech) sound.
2) Provision of speech sounds as an aid to lip reading.
3) Improved speech production.
4) Reduced awareness of tinnitus through distraction and/or suppression effects.

There are only a few reported studies which deal with aspects of speech production rather than speech perception of cochlear implantation with deafened adults. One reason to this research orientation is perhaps that.."many persons with an acquired hearing loss, as the result of an infection or through accident, continue to have great problems in receptive communication even after extensive training and the selection and fitting of prosthetic aids. In contrast the effects of acquired deafness on speech quality are far more subtle... Changes when they do occur tend to be acquired gradually." /2/. Nevertheless, those studies in the cochlear implant literature dealing with adventitiously deaf patients' speech production have reported some improvements in speech production after implantation.

CHANGES IN SPEECH WITH USE OF AN IMPLANT

In a study of four patients Iler-Kirk and Edgerton found that an improvement in voice parameters and fundamental frequency had taken place after implantation /3/. Waters studied the speech production of three cochlear implant wearers /4/. He assessed their speech pre-therapy and post-therapy and post-therapy while using the implant for six months. All three patients were judged to have improved production of speech after using their implants for six months. Not only the voice quality, which became less harsh and tense, improved but also overall timing and pitch control. Ball and Ison reported on a patient that showed a frequency range that approached normal with marked reduction in irregularity after electrical stimulation /5/. East and Cooper used a questionnaire one year following implantation for assessing the device /6/. The implant wearers and their families remarked that the improved modulation of speech volume when using the implant led to increased self-confidence. Plant and Öster (ref. /2/) found in a case study of a Swedish female speaker two years after implantation that ..."a number of changes had occurred after implantation. At the prosodic level these included a more normal range of fundamental frequency, improved F0-control in signalling emphatic stress contrasts and improvements in durational aspects."

An interesting and important question is, however, whether this improvement is attributable to speech training effects or to the information provided by the implant. Iler-Kirk and Edgerton (ref. /3/) analyzed speech samples of two men and two women reading a standard passage with and without their implants. The aided condition for the male patients resulted in a lower mean F0 and reduced variability in intensity level. The female patients showed a higher mean F0 and an increase in intensity variability. These results represent positive changes for all patients compared to normally hearing persons of the same sex.

METHOD

Subjects

A cochlear implant is of interest only to those patients who are deaf but still have an active cochlear nerve. No benefit from hearing aids is a criterion for operation as well as a strong motivation. The implanted patients must have auditory memories which exclude those who are born deaf. The two patients in this paper are a man born in 1930 and a woman born in 1955. They were both deafened post-lingually, the man at the age of 17 and the woman at the age of 26. Both had used their extra-cochlear implants for two years at the time of the last recording of their speech. Since the operation, they have obtained speech training one hour weekly including breathing and phonation exercises.

Materials

The recordings were made when the patients read a standard passage of 89 words. This text became over time very familiar to them since they read it at the time of recurrent testing that occurred prior to operation and 1, 3, 6, 12 and 24 months after operation. The two patients were recorded when they read the standard passage and an unfamiliar text of 56 words two years after implantation in order to study the direct feedback effect of the implant.

Recordings

The recordings were made in a sound-treated test room. A TEAC A-3340 four-channel tape recorder was used. A contact microphone attached to the patients' trachea recorded the synchronous larynx signal.

DATA ANALYSIS

Instrumental analysis

The fundamental frequency behavior was analyzed by using a computer program developed by S. Ternström of the Dept. of Communication and Music Acoustics. This fundamental frequency distribution analysis uses the tape-recorded signal from the contact microphone placed at the patient's larynx. The program gives graphic printouts of F0-contours as a function of time (pitch contour), mean F0, the most common frequency, standard deviation and F0-histograms with statistics.

RESULTS AND DISCUSSION

Fundamental frequency analysis

The results of the F0-analysis of the pre-implant reading and the three readings up to two years after implantation are presented in Table I for the female patient and Table II for the male patient. The measures show a considerable lowering in mean F0 for both patients. The pitch becomes more correct compared to normally-hearing persons of the same age and sex. There is also an noticeable decrease in standard deviations (SD) that, especially for the male patient, means that his intonation has improved. His intonation pre-implant was uncontrolled and extremely lively.

F0-histograms obtained for the standard passage pre- and post-implant of the female patient are presented in Fig. 1A. Fig. 2A shows the F0-histograms of the male patient. In Fig. 1A the pre-implant histogram is more positively skewed than the post-implant histogram two years after operation. A positive skewness is typical for normal distribution (see ref. /2/, p. 71). The post-implant histogram is more symmetrical due to a tendency towards instability and unperiodicity in the vocal cords that can be seen in the area around 100-150 Hz. Fig. 2A presents a post-implant histogram that is more peaky than the pre-implant histogram that is more diffuse indicating a wider range of commonly occurring frequencies.

	Mean F0	SD (Hz)
Pre-implant	265.39	53.40
6 months post-impl.	221.72	43.93
12 months post-impl.	238.65	45.81
24 months post-impl.	219.67	46.15

Table I. F0-measures for the female patient.

	Mean F0	SD (Hz)
Pre-implant	161.48	36.38
6 months post-impl.	141.71	23.95
12 months post-impl.	138.49	23.92
24 months post-impl.	144.40	27.72

Table II. F0-measures for the male patient.

Durational aspects

The F0-analysis also calculates the total duration of the speech sample, the per cent of pauses over 200 msec and the per cent of pauses under 200 msec. From these measures, the phonation time can be estimated which is done in Tables III and IV.

	Duration, sec	Phon.time, sec
Pre-implant	38.43	22.60
6 months post-impl	40.22	20.12
12 months post-impl	36.05	17.71
24 months post-impl	34.78	17.87

Table III. Duration time for the female patient's readings of the standard passage.

	Duration, sec	Phon.time, sec
Pre-implant	27.24	14.46
6 months post-impl.	37.69	20.45
12 months post-impl.	33.01	16.21
24 months post-impl.	36.64	17.31

Table IV. Duration time for the male patient's readings of the standard passage.

The results show that the two patients' phonation times 24 months after implantation have moved towards normal values. Their results can be compared with that obtained by a normally hearing 40-year old female, native speaker of Stockholm Swedish. In this case the phonation time was 16.77 sec. The results obtained two years after implantation for both patients indicate, therefore, a shift towards a more normal rate of articulation. The male patient's speech pre-implant was very fast and mechanical. Already after 6 months' post-implant, an extension in duration and phonation time can be observed. Over time he manages to control pausing and phrasing that improves his intonation considerably.

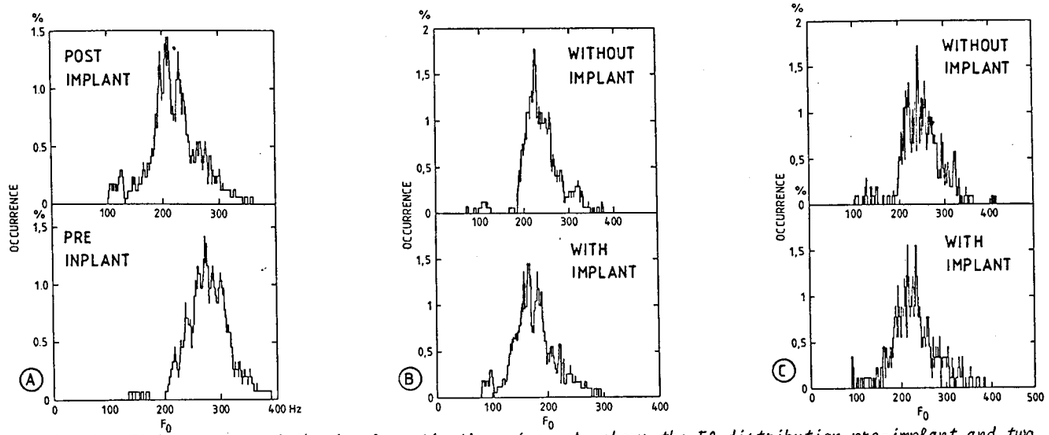

Fig. 1. F0-histograms of the female patient's voice. A: shows the F0-distribution pre-implant and two years after implantation. B: shows the patient reading a familiar text without and with the implant. C: shows the patient reading an unfamiliar text without and with the implant.

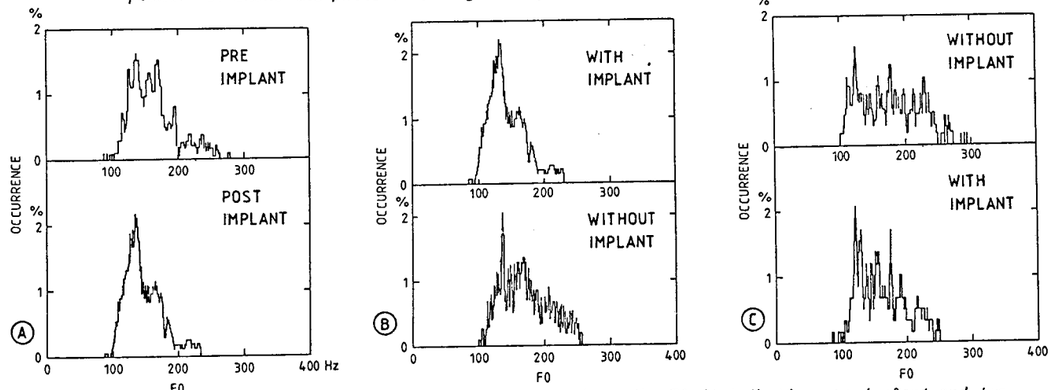

Fig. 2. F0-histograms of the male patient's voice. A: shows the F0-distribution pre-implant and two years after implantation. B: shows the patient reading a familiar text without and with the implant. C: shows the patient reading an unfamiliar text without and with the implant.

FAMILIAR TEXT	Mean F0 (Hz)	SD (Hz)
Without implant	239.58	41.95
With implant	219.67	46.15
UNFAMILIAR TEXT		
Without implant	252.55	46.07
With implant	229.61	50.01

Table V. Female patient's readings.

FAMILIAR TEXT	Duration, sec	Phon.time, sec
Without implant	37.90	18.76
With implant	34.78	17.87
UNFAMILIAR TEXT		
Without implant	25.61	11.23
With implant	22.87	9.53

Table VI. Female patient's readings.

FAMILIAR TEXT	Mean F0 (Hz)	SD (Hz)
Without implant	170.58	38.23
With implant	144.40	27.72
UNFAMILIAR TEXT		
Without implant	176.86	45.45
With implant	163.97	39.50

Table VII. Male patient's readings.

FAMILIAR TEXT	Duration, sec	Phon.time, sec
Without implant	36.09	11.96
With implant	36.64	17.31
UNFAMILIAR TEXT		
Without implant	20.95	7.07
With implant	21.00	6.27

Table VIII. Male patient's readings.

Direct feedback effect of the implant

The implant gives the subjects a direct feedback of their own voice production. To study this effect an analysis was made on the readings with and without implant, both on familiar text and unfamiliar text. The day of recording the patients came in the morning without their implants on. They read both texts without implants before they put them on and adjusted them to an appropriate level. After half an hour when the patients chatted with the experiment leader, the aided readings were recorded. In Tables V-VI the results for the female patient are shown and in Tables VII-VIII for the male patient. Fig. 1B and 1C shows the different histograms for the female subject's readings of the familiar and the unfamiliar texts. The histograms of the male subject's readings are presented in Fig. 2B and 2C.

The results from Tables V-VIII and Figs. 1B and 1C and 2B and 2C show that both patients' fundamental frequencies decrease when the implants are switched on. There are also changes in duration and phonation time for both patients in the aided readings that indicate more normal values. The histograms of the man's voice show in the two aided readings a more peaky distribution that indicates a more controlled behavior. The histograms of the woman's voice, Fig. 1B, however, shows distributions that in the aided readings become more symmetrical that indicates that her voice sometimes becomes unstable and creaky.

FINAL DISCUSSION

The results of the F0-analyses in this study show that both patients derived benefits in improved speech production thanks to their single-channel implant. The follow-up recordings show that the improvements are immediate and permanent. The most noticeable change seems to be a lowering in mean fundamental frequency to a more normal value considering age and sex. The implant provides some limited spectral information especially in the low frequencies, timing and intensity. The female patient s voice becomes sometimes with the implant very pressed and creaky. This is probably due to the fact that she strains her voice in order to get some low-frequency feed-back.

The most positive changes, however, occur in the male patient's speech. The benefits for this patient appear to derive from timing information provided by the implant. The pre-implant recording reveales a high tempo together with an uncontrolled intonation. In the part of the experiment when the implant is switched off, he returns to this way of speaking. After implantation it is obvious that the patient modifies and plans his speech production consciously. The possibility that the improvements in speech production is a result from the training provided can probably be excluded. All the measures and the histograms show that the implants have a direct feedback effect on both patients' speech production.

The implant is superior to ordinary speech-training devices, as for instance visual indicators, which are big, heavy and limited to clinical use. The patient will very often relapse into old habits as soon as he leaves the clinic. As the implant is wearable, it is always present and offers continuous training and monitoring to the patients.

Like previous studies dealing with the speech production of cochlear implant wearers, this study shows that improvements in durational aspects, a more normal range of fundamental frequency and an improved F0-control occur with an implant. The implant is an effective speech device as it offers feedback and voice control.

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