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# Bilateral Cochlear Implantation: Auditory Outcome Depending on the Time Between Two Operations

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**KEYWORDS**

Cochlear Implant (CI), bilateral cochlear implantation, auditory outcome, EARS (Evaluation of Auditory Responses to Speech), time between two cochlear implantations.

**A B S T R A C T**

The aim of this study was to compare the auditory outcome between two groups of patients with bilateral cochlear implantation depending on the time of placement of the second cochlear implant – less and more than one year after the first one. 14 patients with bilateral cochlear implantation were enrolled and they were divided into two groups depending on the time of placement of the second cochlear implant – less and more than one year after the first one. All participants have been evaluated with LiP test (Listening Progress Profile), MTP tests 3, 6, 12 (Monosyllabic-Trochee-Polysyllabic test), MSW test (Monosyllabic Word test), MSW-Phonemes test (Monosyllabic Word-Phonemes test), SLS test (Spoken Language Skill test), SLS-Words test (Spoken Language Skill-Words test), GASP test (Glendonald Auditory Screening Procedure). Follow-up period was at least 36 months. Mean score results of both groups were compared for the major EARS (Evaluation of Auditory Responses to Speech) battery tests. Statistical analysis demonstrated that children's scores improved significantly over time in both groups. There was statistical significant difference between mean scores of both groups only for the 1st month of MTP3 test ($mean_{groupI}$=2,57; $mean_{groupII}$=9,00; p=0,006). In all other tests (LiP, MTP6, MTP12, MSW, MSW-Phonemes, SLS, SLS-Words, GASP) we obtained comparable results in the observed groups. This is the first study that evaluates the auditory outcome after bilateral cochlear implantation in Bulgarian patients depending on the time between two operations – less and more than one year after the first one. The results have shown that both groups made progress and achieved substantial improvement, but we did not find any statistically significant difference in the auditory outcome between these two groups. Additional studies in larger group of patients with bilateral cochlear implants and long-term follow-up period would confirm or rejected this.

## Introduction

Hearing loss is the most frequent sensory disorder in humans. Cochlear implantation is the only way to help patients with severe to profound sensorineural hearing loss. In the past, implantation was performed only in one ear, despite the fact that binaural hearing is superior to unilateral, especially in noisy conditions. (Kronenberg *et al*., 2010) The primary effects ascribed to binaural listening are: the head shadow effect; the binaural summation effect; and the binaural squelch effect, which produce benefits ranging from improved speech recognition in noise to the ability to localize direction of sound (Papsin and Gordon, 2008).

Cochlear implantation may be performed simultaneously or sequentially (the time interval between the two operations ranging from months to years). The "sensitive period" of time between hearing loss and implantation and between the two implantations, when performed sequentially, significantly influences the results. (Kronenberg *et al*., 2010)

Ramsden *et al*., show that sequential implantation with long delays between ears limited the amount of bilateral benefit sequentially implanted subjects might receive (Ramsden *et al*., 2005). A closer look at subjects who received the second CI relatively late after the first CI is an important aspect for counseling parents as well as professionals of special education and for choosing candidates for a second CI (Vischer *et al*., 2011).

The first cochlear implantation in Bulgaria was made in 1999. Until now in our clinic were operated 380 patients. Twenty of them were implanted two-sided.

In this study we presented our experience with auditory outcome in bilateral cochlear implantation. Fourteen children with bilateral cochlear implantation were observed for 36 months period. They were divided into two groups depending on the time between operations of the two ears – less and more than one year.

## Materials and Methods

This study was conducted at the Department Of Otorhinolaryngology, University Hospital "Queen Jovanna – ISUL" Sofia, Bulgaria.

### Participants

Fourteen children aged between 11 months and 17 years were recipients of two cochlear implants (Cochlear or MED-EL). All of the children were diagnosed in our clinic by using electrophysiological measurement methods before implantation. They were divided into two groups depending on the time between two operations: group I less than 1 year (n=7) and group II over 1 year (n=7). All patients participated in individually tailored intensive audiological rehabilitation programs after receiving their implants. The follow up period was three years.

### Main outcome measures

In order to achieve audiological assessment of the two groups we used a full battery of tests – Evaluation of Auditory Responses to Speech (EARS):

Listening Progress Profile (LiP) is a profile devised to monitor changes in the early auditory performance of young implanted children. The profile covers a range of abilities from first response to environmental sounds, through discrimination of environmental sounds and discrimination of voice, to identification of own names (Nikolopoulos, *et al*., 2000).

Monosyllabic-Trochee-Polysyllabic test (MTP) is a closed-set test used to assess the ability of an individual in recognizing words with different syllabic patterns out of groups of 3, 6 or 12 words.

Monosyllabic Words test (MSW). The aim of this test is to demonstrate the ability to identify familiar monosyllabic words. Results on this test are comparable internationally.

Monosyllabic Words – Phonemes test (MSW – Phonemes) measures the ability to correctly pronounce phonemes in monosyllabic words.

Spoken Language Skill test (SLS) measures the ability to repeat a sentence. Spoken Language Skill – Words test (SLS – Words) evaluates the recreation of the actual words in a sentence.

Glendonald Auditory Screening Procedure (GASP) demonstrate the ability to recognize simple questions. Results on this test are comparable internationally with results of other cochlear implant children.

These tests were performed in a quiet room under normal ambient noise conditions. The set of this tests evaluates the following hearing habits: detection – the ability to record the presence or absence of sound; discrimination – the ability to determine the difference or similarity between two beeps (image); identification – the ability to choose/detect any sound signal from other previously known beeps; imitation – the ability to replicate or mimic the spoken sounds, including speech; comprehension – the ability to understand spoken language.

## Statistical methods

For statistical analysis was used SPSS (Statistical Package for the Social Sciences). We compared mean scores results on both groups for 36-months follow up-period using independent two-sample Student's t-test. Two-tailed distribution was used.

## Results and discussion

All of children have prelingual deafness. 64% of patients are female and 36% are male. In both groups the implantation age of the first CI is from 11 months to 4 years. In only one patient from group II the first CI was placed at the age of 13. ($mean_{groupI}$=1,43; $SD_{groupI}$=0,787) ($mean_{groupII}$= 3,71; $SD_{groupII}$=4,152). There is no statistically significant difference between the mean age of implantation of the first cochlear implant between two observed groups (p=0,064).

Time between first and second CI in group I was less than one year and only one child received two cochlear implants simultaneously. ($mean_{groupI}$=0,57; $SD_{groupI}$=0,535). The mean time between two operations in group II was 3,14 years. (SD=0,690).

The present study compared mean score results of both groups for the major EARS battery tests. For equality of means was used t-test. Results revealed that both groups made progress and substantial improvement was noticed in early auditory performance in all the patients at the end of the first year (figure 1, table1).

Analysis of MTP3, MTP6, MTP12 data revealed a significant improvement of word recognition in both groups. There is statistical significant difference between mean scores of both groups only for the 1$^{st}$ month of MTP3 test($mean_{groupI}$=2,57; $mean_{groupII}$=9,00; p=0,006)(figure 2, figure 3, figure 4) (table 2).

In all open-set tests (MSW, MSW – Phonemes, SLS, SLS – Words, GASP) we

obtained comparable results inthe both groups. We have not found statistically significant differences between mean scores of both observed groups (figure 5, figure 6, figure 7, figure 8, figure 9) (table 3).

There are many factors that influence results after bilateral cochlear implantation – etiology of hearing loss, onset of deafness, interval between onset of deafness and cochlear implantation, appropriate case selection, surgery, age at first implantation, time between two operations, post – implant rehabilitation. The time between the two operations are not reflected our results. Bilateral cochlear implantation offers advantages to all children. No difference in auditory performance (LiP, MTP3, MTP6, MTP12, MSW, MSW – Phonemes, SLS, SLS – Words, GASP tests throughout the 36-months follow-up period) was shown whether the second CI was placed – less or more than one year after the first one(except for the 1$^{st}$ month mean scores of the MTP3 test). Similar results were reported from Dunn *et al*., (Dunn, 2012)One reason for this finding might be due to the small number of subjects tested in this study. In addition, we did not find trends in our data that indicate a negative impact on performance due to longer durations between surgeries. Prior to determine the exact time of the second operations necessary to analyze the results of a large number of patients. On the other hands, research teams of Tyler and Laske have concluded that long delays between both operations may not give the full benefits of bilateral implants. (Tyler *et al*., 2007)(Laske *et al*., 2009) Scherf *et al*., reported that there were advantages from the second CI even in children who received the second implant at a considerable distance from the first (> 6 years of age): however, these results appear to be slower than those achieved by children receiving the second implant after a short delay (< 6 years). (Scherf *et al*., 2009) Anderson *et al*., suggest that cochlear-implanted children develop open-set speech recognition soon after implantation, and these skills develop over a long period of time, highlighting the need for continued therapy to maximize listening and learning. (Anderson *et al*., 2004)

**Table.1** Results from the LiP test for both groups (LiP – Listening Progress Profile)

| Test | Time between two operations | N | Mean | Std. Deviation | Sig. (2-tailed) |
|---|---|---|---|---|---|
| LiP 1st month | less than1 year | 7 | 23.14 | 12.335 | 0.059 |
| | more than 1 year | 7 | 34.14 | 6.543 | |
| LiP 3th month | less than1 year | 7 | 33.14 | 6.122 | 0.072 |
| | more than 1 year | 7 | 38.57 | 3.952 | |
| LiP 6th month | less than1 year | 7 | 36.86 | 3.532 | 0.058 |
| | more than 1 year | 7 | 40.29 | 2.498 | |
| LiP 12th month | less than1 year | 7 | 40.43 | 1.397 | 0.205 |
| | more than 1 year | 7 | 41.29 | .951 | |

**Table.2** Results from the MTP3, MTP6, MTP12 tests for both groups (MTP – Monosyllabic-Trochee-Polysyllabic test)

| | Time between two operations | N | Mean | Std. Deviation | Sig. (2-tailed) |
|---|---|---|---|---|---|
| MTP3 1st month | less than1 year | 7 | 2.57 | 3.359 | 0.006 |
| | more than 1 year | 7 | 9.00 | 3.830 | |
| MTP3 3th month | less than1 year | 7 | 6.29 | 4.855 | 0.055 |
| | more than 1 year | 7 | 10.71 | 1.704 | |
| MTP3 6th month | less than1 year | 7 | 9.00 | 3.786 | 0.128 |
| | more than 1 year | 7 | 11.57 | 1.134 | |
| MTP3 12th month | less than1 year | 7 | 10.43 | 2.699 | 0.259 |
| | more than 1 year | 7 | 11.71 | .488 | |
| MTP6 6th month | less than1 year | 7 | 12.14 | 6.517 | 0.387 |
| | more than 1 year | 7 | 14.71 | 3.861 | |
| MTP6 12th month | less than1 year | 7 | 15.14 | 5.014 | 0.950 |
| | more than 1 year | 7 | 15.29 | 3.147 | |
| MTP6 18th month | less than1 year | 7 | 17.00 | 2.236 | 0.721 |
| | more than 1 year | 7 | 16.57 | 2.149 | |
| MTP6 24th month | less than1 year | 7 | 18.00 | .000 | 0.356 |
| | more than 1 year | 7 | 17.86 | .378 | |
| MTP12 12th month | less than1 year | 7 | 14.43 | 9.607 | 0.419 |
| | more than 1 year | 7 | 18.14 | 6.744 | |
| MTP12 18th month | less than1 year | 7 | 21.14 | 4.598 | 0.733 |
| | more than 1 year | 7 | 21.86 | 2.854 | |
| MTP12 24th month | less than1 year | 7 | 23.43 | 1.512 | 1.000 |
| | more than 1 year | 7 | 23.43 | 1.134 | |
| MTP12 36th month | less than1 year | 7 | 24.00 | .000a | 1.000 |
| | more than 1 year | 7 | 24.00 | .000a | |

**Fig.1** Mean scores for the LiP test

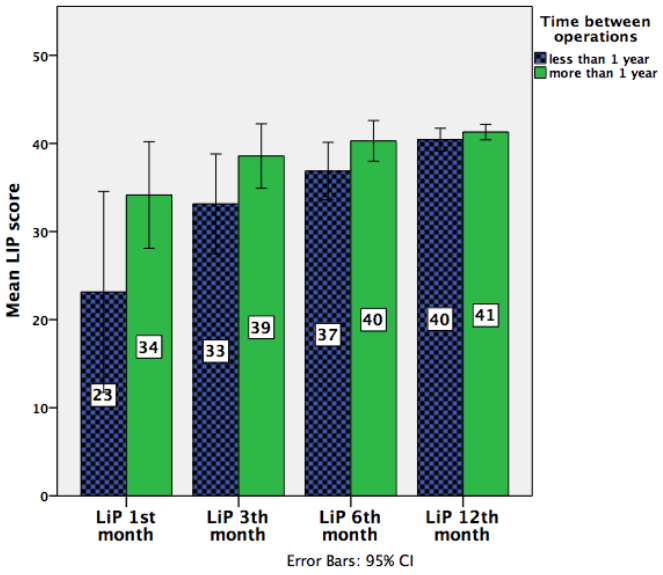


**Table.3** Results from the MSW, MSW – Phonemes, SLS, SLS – Words, GASP tests for both groups. (MSW –Monosyllabic Words test; MSW Phonemes – Monosyllabic Words Phonemes test; SLS – Spoken Language Skill test; SLS Words – Spoken Language Skill Words test; GASP –Glendonald Auditory Screening Procedure)

| Test | Time between two operations | N | Mean | Std. Deviation | Sig. (2-tailed) |
|---|---|---|---|---|---|
| MSW 6th month | less than1 year | 7 | 2.43 | 2.637 | 0.410 |
| | more than 1 year | 7 | 3.71 | 2.984 | |
| MSW 12th month | less than1 year | 7 | 4.29 | 2.498 | 0.712 |
| | more than 1 year | 7 | 4.86 | 3.132 | |
| MSW 18th month | less than1 year | 7 | 6.43 | 1.618 | 0.918 |
| | more than 1 year | 7 | 6.57 | 3.207 | |
| MSW 24th month | less than1 year | 7 | 8.29 | 1.799 | 0.649 |
| | more than 1 year | 7 | 7.71 | 2.690 | |
| MSW 36th month | less than1 year | 7 | 9.29 | 1.113 | 0.374 |
| | more than 1 year | 7 | 8.57 | 1.718 | |
| MSW-Phonemes 6th month | less than1 year | 7 | 16.29 | 5.090 | 0.242 |
| | more than 1 year | 7 | 19.86 | 5.757 | |
| MSW-Phonemes 12th month | less than1 year | 7 | 23.00 | 3.317 | 0.650 |
| | more than 1 year | 7 | 22.00 | 4.619 | |
| MSW-Phonemes 18th month | less than1 year | 7 | 26.29 | 1.604 | 0.928 |
| | more than 1 year | 7 | 26.14 | 3.761 | |
| MSW-Phonemes 24th month | less than1 year | 7 | 28.43 | 1.718 | 0.355 |
| | more than 1 year | 7 | 27.29 | 2.628 | |
| MSW-Phonemes 36th month | less than1 year | 7 | 29.14 | 1.215 | 0.626 |
| | more than 1 year | 7 | 28.86 | .900 | |
| SLS 12th month | less than1 year | 7 | 1.71 | 3.402 | 0.718 |
| | more than 1 year | 7 | 2.43 | 3.823 | |
| SLS 18th month | less than1 year | 7 | 2.29 | 3.592 | 0.380 |
| | more than 1 year | 7 | 4.14 | 4.018 | |
| SLS 24th month | less than1 year | 7 | 3.71 | 3.352 | 0.727 |
| | more than 1 year | 7 | 4.43 | 4.077 | |
| SLS 36th month | less than1 year | 7 | 5.71 | 3.352 | 0.688 |
| | more than 1 year | 7 | 4.86 | 4.375 | |
| SLS-Words 12th month | less than1 year | 7 | 14.14 | 14.017 | 0.750 |
| | more than 1 year | 7 | 16.86 | 16.985 | |
| SLS-Words 18th month | less than1 year | 7 | 15.57 | 14.797 | 0.462 |
| | more than 1 year | 7 | 22.00 | 16.803 | |
| SLS-Words 24th month | less than1 year | 7 | 22.29 | 11.056 | 0.727 |
| | more than 1 year | 7 | 25.86 | 14.147 | |
| SLS-Words 36th month | less than1 year | 7 | 26.29 | 10.095 | 0.688 |
| | more than 1 year | 7 | 30.43 | 11.356 | |
| GASP 6th month | less than1 year | 7 | 2.43 | 2.878 | 0.636 |

| | | | | | |
|---|---|---|---|---|---|
| | more than 1 year | 7 | 3.29 | 3.684 | |
| GASP 12th month | less than1 year | 7 | 3.71 | 3.352 | 0.680 |
| | more than 1 year | 7 | 4.57 | 4.198 | |
| GASP 18th month | less than1 year | 7 | 5.43 | 3.101 | 0.828 |
| | more than 1 year | 7 | 5.86 | 4.059 | |
| GASP 24th month | less than1 year | 7 | 6.71 | 1.799 | 0.580 |
| | more than 1 year | 7 | 7.57 | 3.552 | |
| GASP 36th month | less than1 year | 7 | 8.29 | 1.604 | 1.000 |
| | more than 1 year | 7 | 8.29 | 2.984 | |

**Fig.2** Mean scores for the MTP3 test

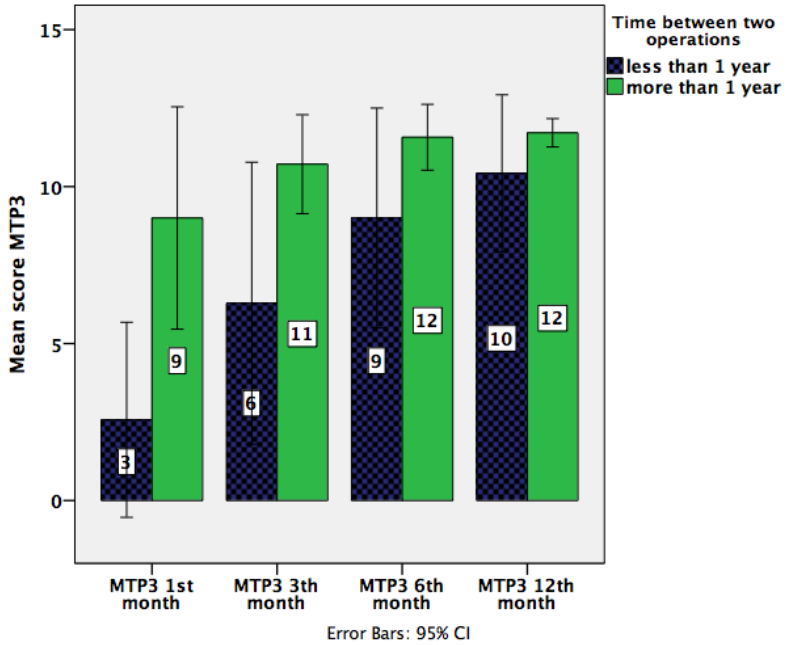



**Fig.3** Mean scores for the MTP6 test

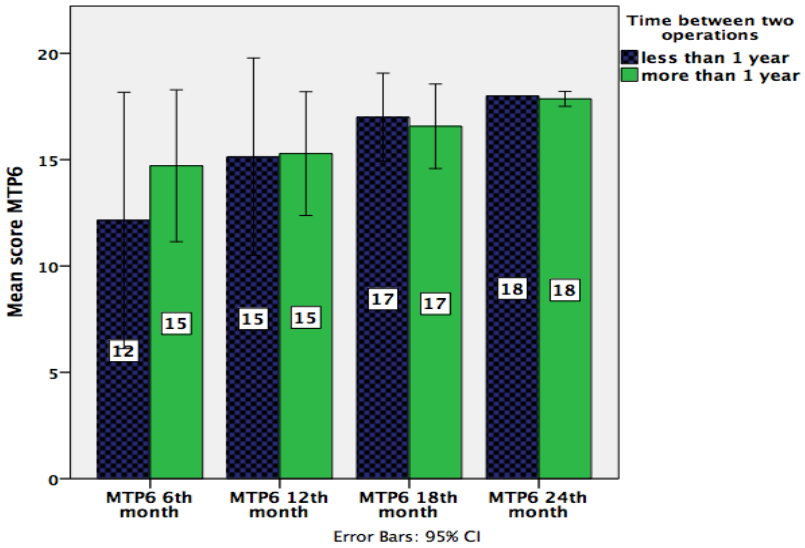


**Fig.4** Mean scores for the MTP12 test

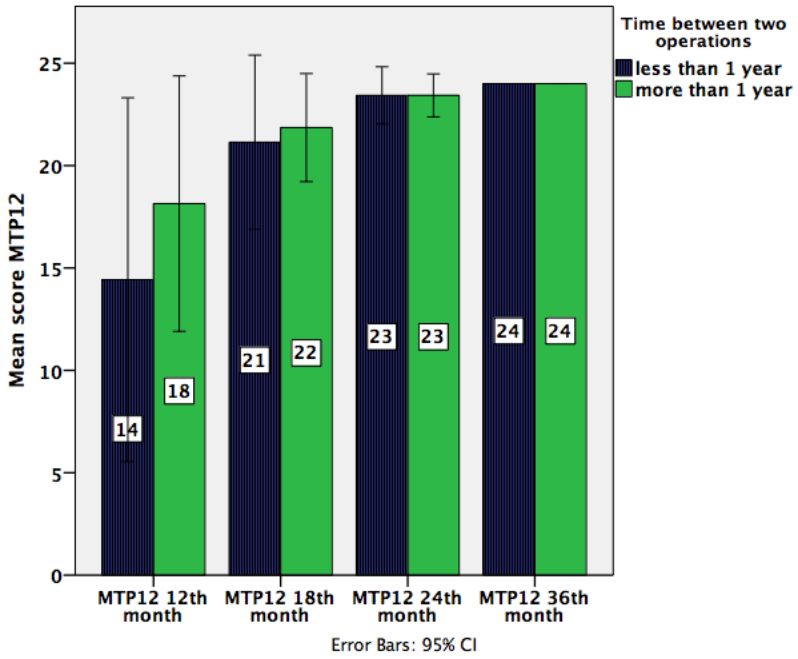



**Fig.5** Mean scores for the MSW test

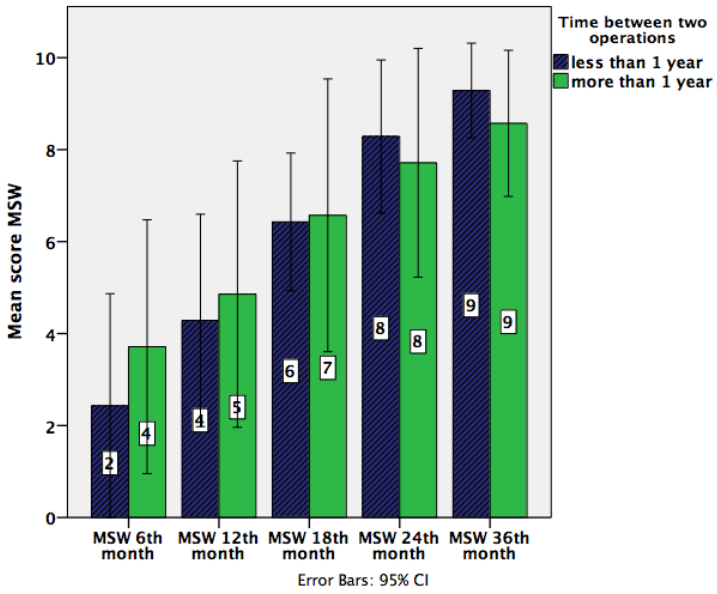


**Fig.6** Mean scores for the MSW – Phonemes test

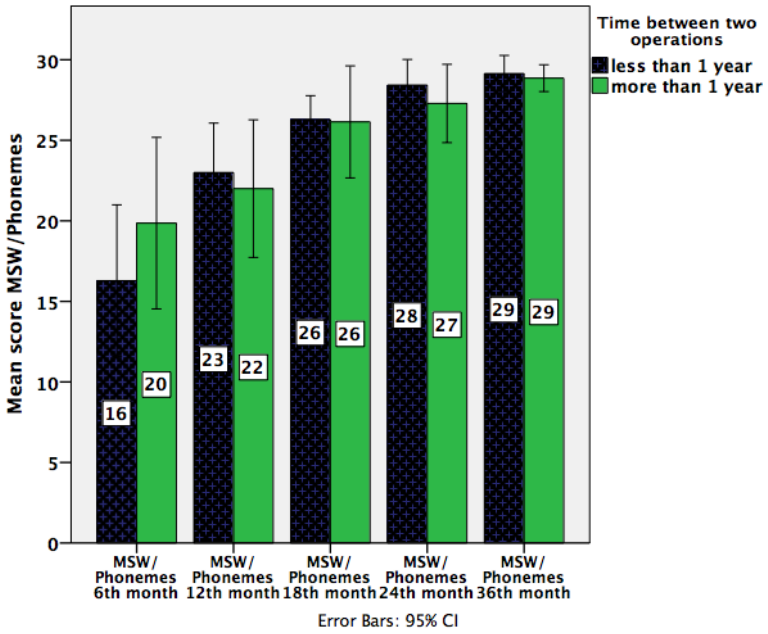



**Fig.7** Mean scores for the SLS test

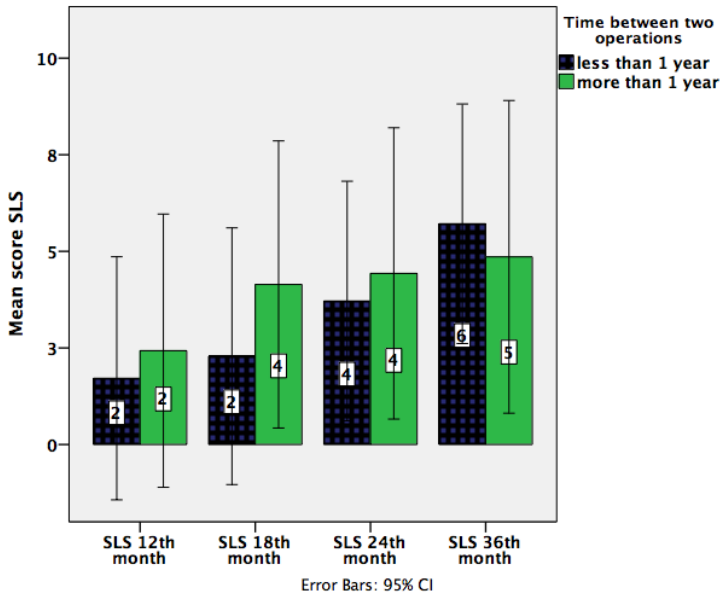


**Fig.8** Mean scores for the SLS – Words test

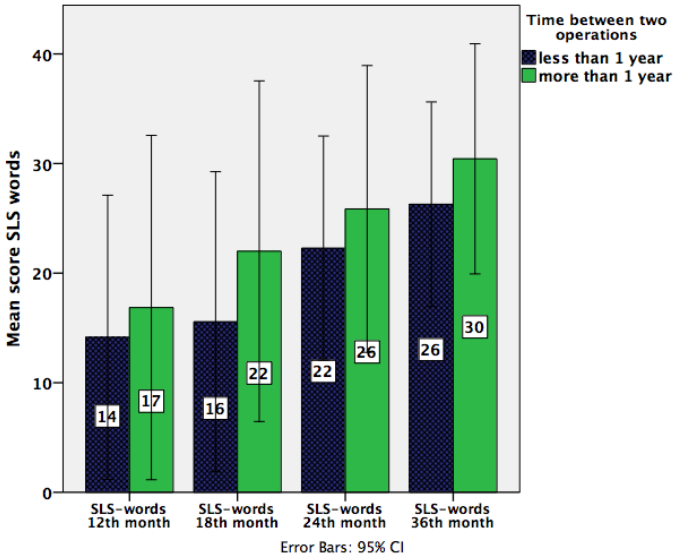
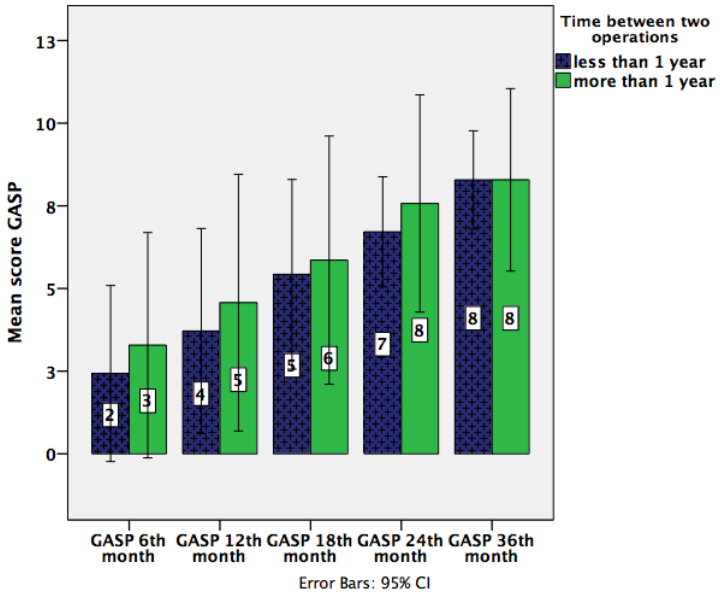



**Fig.9** Mean scores for the GASP test




Age at second implantation did not have an influence on all outcomes. From the results of Sparreboom *et al*., can be concluded that the advantages of bilateral hearing occur after sequential bilateral implantation and that age at second implantation does not influence the amount of bilateral advantage. Furthermore, they show that longer periods of bilateral implant use lead to greater bilateral advantages. (Sparreboom *et al*., 2011) Van Deun report better outcomes with bilateral CI in children who received the first implant very early (< 2 years of age) and in those with a small time interval between the two interventions. (Van Deun *et al*., 2009) Peters *et al*. also report more benefit in children who receive second CI earlier. Even in children who receive CI

within 5 years, second implant reaches same performance as first (after 1 year). (Peters *et al*., 2007)As a result of observation of 58 children with different ages of the first and second CI for 36-month period, Gordon and Papsin report benefit from second CI superior in children with shorter duration of bilateral deafness and inferior interval between the two implantations – not statistically significant. (Gordon & Papsin, 2009)

Sain's *et al*., EARS test results show that older children started at a higher performance level, but their younger peers caught up within 24 months of device use. (Sainz *et al*., 2003) Zeitler *et al*., revealed significant improvement in the second implanted ear and in the bilateral condition, despite time between implantations or length of deafness; however, age of first – side implantation was a contributing factor to second ear outcome in the pediatric population. Sequential bilateral implantation leads to significantly better speech understanding. On average, patients improved, despite length of deafness, time between implants, or age at implantation (Zeitler *et al*., 2008).

Laske *et al*. reported that although there was improvement with a second cochlear implant even after a long implantation interval, short intervals lead to better results. (Laske *et al*., 2009)Although most authors believe that early placement of the second cochlear implant has more benefits for the patients a systematic review of the literature by Smulders *et al*., shows that a second implant can be beneficial even after a substantial interval between sequential implantations (Smulders *et al*., 2011).

## Conclusion

This is the first study that evaluates the auditory outcome after bilateral cochlear implantation in Bulgarian patients depending on the time between two operations – less and more than one year. The results have shown that both groups made progress and achieved substantial improvement, but we did not find any statistically significant difference in the auditory outcome between these two groups. Additional studies in larger group of patients with bilateral cochlear implants and long-term follow-up period would confirm or rejected this.

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