Setting a New Benchmark in Hearing Performance with Slim Modiolar

Wade Colburn – Product Manager
Amy Popp, AuD – Sr. Manager Clinical Training Services

Hear now. And always

Cochlear®

Introductions

Amy Popp
AuD, CCC-A, FAAA

Current Role:
Sr. Manager Clinical Training Services

Past Experience:
-Clinical Application Specialist
-Coordinator of Cochlear Implant Center at Manhattan Eye, Ear and Throat
-AuD: Central Michigan University

Wade Colburn

Current Role:
Product Manager – Nucleus Implants

Past Experience:
-Program Leader – Cook Biotech
-Design Engineer – Cook Biotech
-BS Biomedical Engineering: North Carolina State University

Disclosure: We both work for Cochlear Americas

Learner Outcomes

After this course, participants will be able to….

- Illustrate to their colleagues the clinical evidence supporting the use and performance of perimodiolar electrode arrays.
- List all audiology considerations with the Slim Modiolar array.
- Elaborate on the new multicenter trial and the performance and bimodal benefits of the Nucleus 7 with Slim Modiolar system.

What will we cover?

PLACEMENT

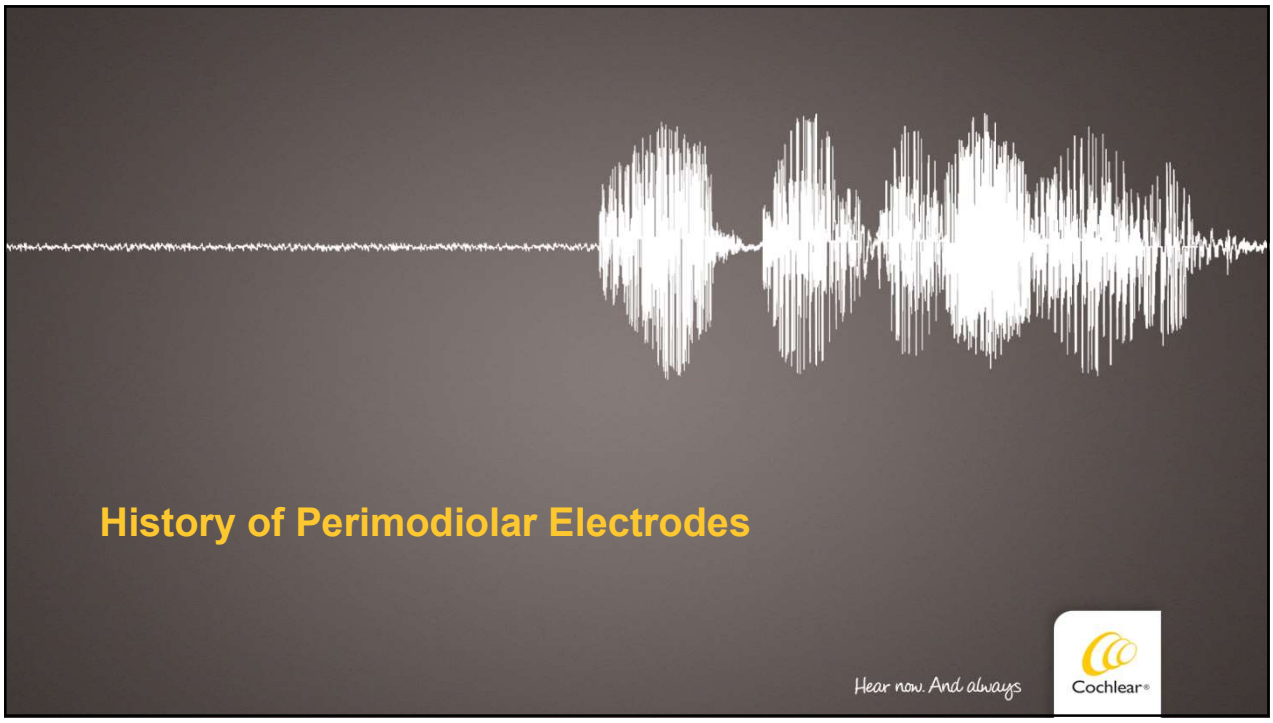
PERFORMANCE

Historical Look at Perimodiolar Electrodes

Audiological Considerations of Slim Modiolar

Slim Modiolar: An Introduction

Slim Modiolar Multicenter Trial Results



Cochlear Nucleus Implant Lifecycle

	Generation 1	Generation 2	Generation 3	Generation 4	Generation 5	Generation 6
Series Name	CI22M	CI24M	CI24R	CI24RE / CI400	CI500/Profile	CI600
Implant Body						
Year of Release	1985	1997	2000	2005	2009 / 2014	2019
Available Electrodes	Straight	Straight Double Array ABI	Straight **Contour**	Straight **Contour Advance** Slim Straight Hybrid	**Slim Modiolar** **Contour Advance** Slim Straight ABI	**Slim Modiolar** **Contour Advance** Slim Straight
Registered Implants[1]	17,665	19,520	53,495	191,252	29,891/83,755	N/A

Design Differences

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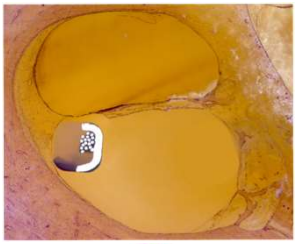
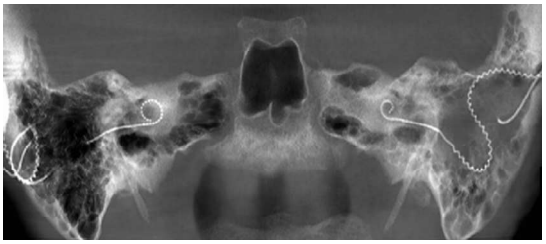
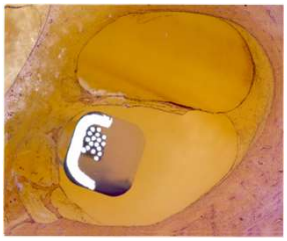
Lateral Wall Electrodes





Perimodiolar Electrodes



Lateral Wall Electrodes		Perimodiolar Electrodes	
✓	Multiple Approaches (RW, ERW, Coch)	✗	Contour Advance
✓	Thin and Soft Array	✗	
✓	Optimal Length	✓	
✓	Consistent Scala Placement	✗	
✗	Distance from Outer Hair Cells	✓	
		✓	Slim Modiolar
		✓	
		✓	
		✓	
		✓	

Does placement impact performance?

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PLACEMENT

PERFORMANCE

Lateral vs. Perimodiolar Electrodes

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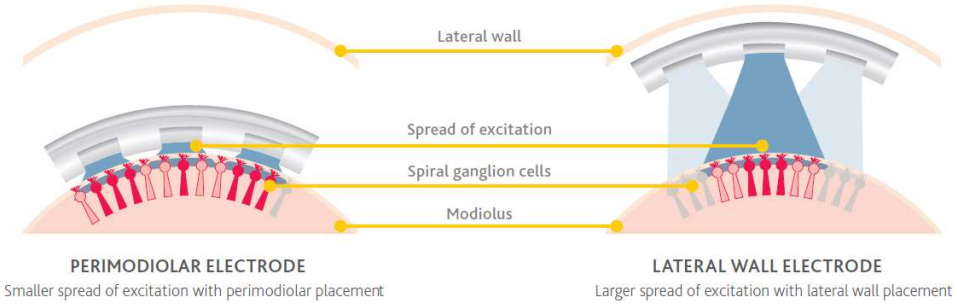
ELECTRODE POSITIONING



Predictors of Good CI Performance

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Factors Affecting Auditory Performance of Postlinguistically Deaf Adults Using Cochlear Implants: An Update with 2251 Patients

Pre-, Per- and Postoperative Factors Affecting Performance of Postlinguistically Deaf Adults Using Cochlear Implants: A New Conceptual Model over Time

Factors Affecting Open-Set Word Recognition in Adults With Cochlear Implants

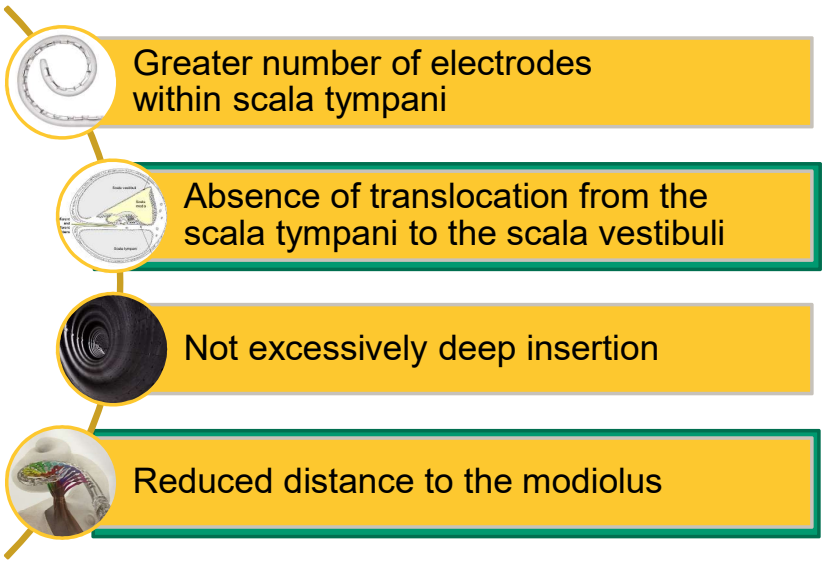
Blamey et al 2013[3] & Lazard et al 2012[4]

- Retrospective, observational design
- 15 centers
- n = 2,251

Holden, et al 2013[2]

- Single-center
- n = 114

Primary Design Factors Associated with Performance[2,3,4]



Does placement within scala tympani lead to better performance?

TABLE 3.
Overview of studies that examine speech perception in relation to scalar location of electrode arrays. UV = univariate; MV = multivariate; ST = scala tympani; SV = scala vestibuli; LW = lateral wall; MS = mid-scala; PM = perimodiolar; CT = computed tomography.

Study (year)	Method for determining electrode location	Statistical analysis	Number Implants (n)	Findings
Skinner et al (2007)	Pre- and post-operative CT	UV	15	Negative correlation between number of electrode contacts in the scala vestibuli and CNC score
Aschendorff et al (2007)	Rotational tomography	UV	43	In patients with short duration deafness, Freiburg numbers and Oldenburg sentence scores were higher for ST insertions than SV insertions
Finley et al (2008)	Pre- and post-operative CT	MV	14	Overall scalar position of the electrode array and number of electrode contacts in the scala vestibuli accounted for significant variance in CNC score
Holden et al (2013)	Pre- and post-operative CT	MV	114	The percentage of electrode contacts in the SV inversely correlated with CNC score
Wanna et al (2014)	Pre- and post-operative CT	UV	116	CNC score was higher for ST insertion (49%) than SV insertion (36%)
O'Connell et al (2016)	Pre- and post-operative CT	MV	220	CNC score was higher for ST insertion (51%) than SV insertion (39%) AzBio score was higher for ST insertion (61%) than SV insertion (50%) SV insertion associated with 12% decrease in CNC score in MV analysis

Table retrieved from O'Connell et al, 2016[5]

Does placement within scala tympani lead to better performance?

- Contour Advance
- 57 Patients
- Post-lingual matched group

Table 3. Comparison between localisation of CI512 electrodes intended for scala tympani insertion in post-lingual patients

Parameter	Scala tympani	Scala vestibuli	Translocation	*P*-value*
Patients (*n*)	41	6	10	–
Age (mean (SD); years)	66.9 (14)	64.4 (20)	69.5 (10)	0.34
Deafness duration (mean (SD); years)	17.9 (13)	15.6 (12)	10.1 (14)	0.16
Pre-op phoneme score (mean (SD); % correct)	14.2 (17)	10.5 (8)	12.6 (12)	0.35
3-mth post-op phoneme score (mean (SD); % correct)	63.6 (21)	52.7 (20)	47.3 (23)	0.11
12-mth post-op phoneme score (mean (SD); % correct)	69.1 (17)	54.2 (25)	50 (21)	0.013†

*Analyses conducted using the Kruskal–Wallis test. †$p < 0.05$. SD = standard deviation; pre-op = pre-operative; mth = month; post-op = post-operative

Table retrieved from Shaul et al, 2018[6]

Is there a benefit to placement close to the hearing nerve?

- Holden et al, 2013[2]
  - Evidence supports that a smaller wrapping factor h
    perform

Studies support there are programming and performance benefits with a perimodiolar array.[2,7,8]

- Polone
  - Focused stimulation leads to lower current levels to elicit neural responses
- Hughes et al, 2006[8]
  - Reduced channel interaction as measured with ECAP

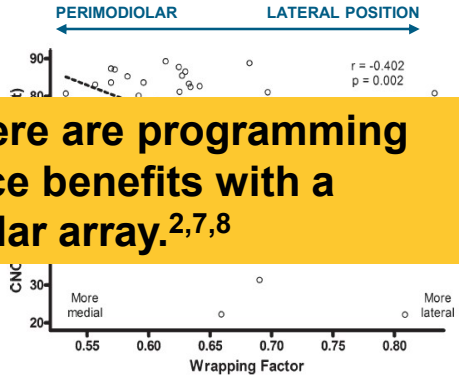


Image is a scatter plot of wrapping factor vs. CNC final score for 59 participants with electrode arrays positioned in scala tympani. [2]

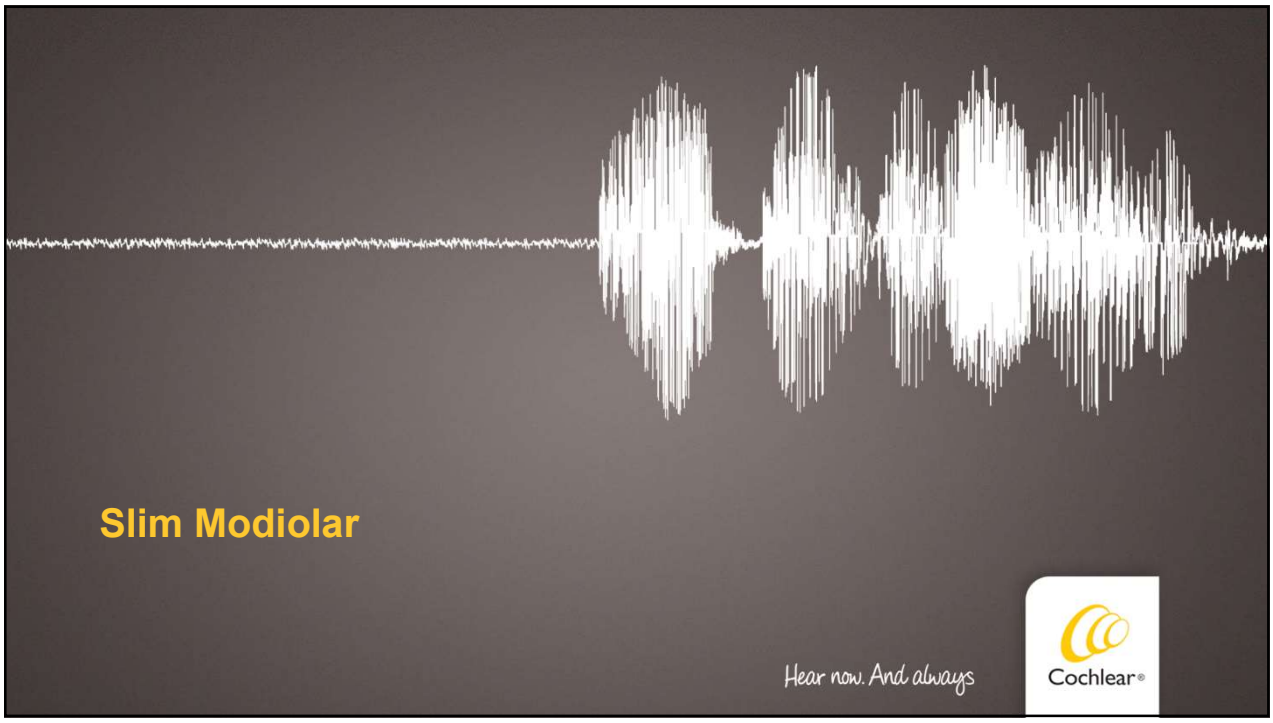
Does electrode placement matter?

Further Evidence of the Relationship Between Cochlear Implant Electrode Positioning and Hearing Outcomes

*Srijata Chakravorti, *†‡Jack H. Noble, †René H. Gifford, *Benoit M. Dawant, ‡Brendan P. O'Connell, *Jianing Wang, and ‡Robert F. Labadie

*Department of Electrical Engineering and Computer Science, Vanderbilt University; †Vanderbilt Bill Wilkerson Center, Department of Hearing and Speech Sciences; and ‡Department of Otolaryngology–Head and Neck Surgery, Vanderbilt University Medical Center, Nashville, Tennessee

Our results confirm the significance of electrode positioning in audiological outcomes. The most significant positional predictors of outcome for pre-curved arrays were <u>scala tympani insertion</u> and the <u>modiolar distance,</u> while for the later wall arrays the depth of insertion was the most significant factor. [9]



Slim Modiolar Design Goals

Cochlear

PRESERVATION

1. Thin, atraumatic electrode

PLACEMENT

2. Consistent scala tympani insertion
3. Consistent proximity to the modiolus

PREFERENCE

4. Inserted via all 3 surgical approaches

Slim Modiolar Specifications

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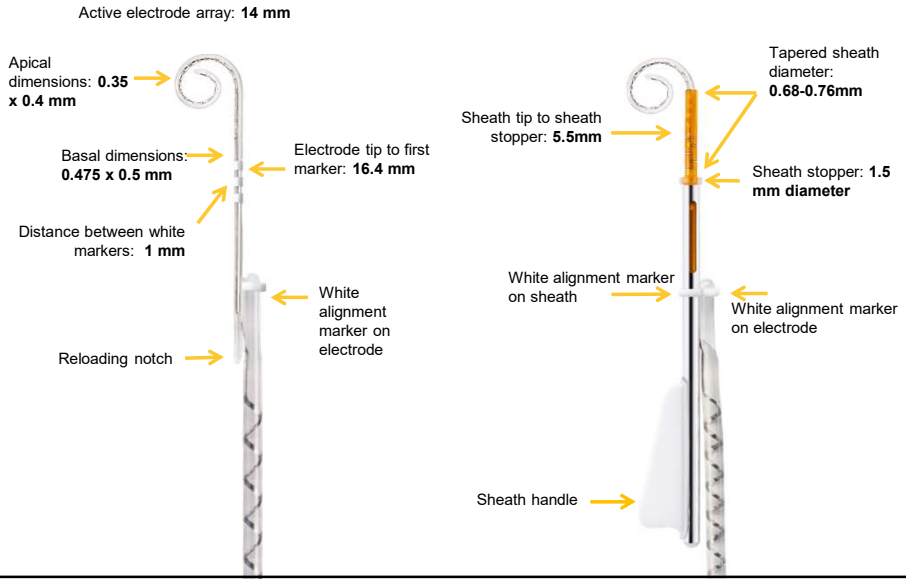


Slim Modiolar Design

Cochlear

APICAL SECTION

CI532 mm	0.35 x 0.40
CA mm	0.50 x 0.50

BASAL SECTION

CI532 mm	0.475 x 0.50
CA	0.80 x 0.80 mm

- **60% reduction in volume** compared to previous generation Contour Advance.
- In our largest ever temporal bone study (n=56) **no intracochlear trauma was evident in 98% of specimens.**

- Perimodiolar design places the electrode away from the functional structures of the lateral wall and basilar membrane.

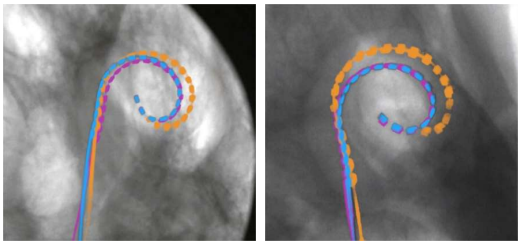
Slim Modiolar Design

Cochlear

(n=25 reloading attempts)

PROTOCOL: Same bone, insert Slim Modiolar, Insert Contour Advance, Reload & Insert Slim Modiolar

RESULTS: 92% of Slim Modiolar electrodes had more contacts positioned medially compared to CA[10]

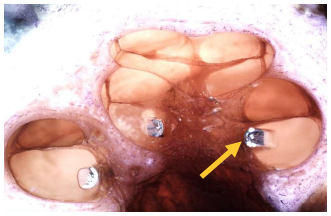


Slim Modiolar 1st insertion
CA insertion
Slim Modiolar 2nd Insertion (same electrode)

Images courtesy of A/Prof. Briggs & Hearing CRC, Melbourne, Australia

ANGULAR INSERTION DEPTH:

- **No difference in 1st & 2nd insertions** using Slim Modiolar => successful reload and insertion
- Length of Slim Modiolar and Contour Advance are identical **=> greater angle with Slim Modiolar due to closer- and more consistent perimodiolar positioning**



Shaul et al, 2018[6]

- Speech Performance:
  - In matched group,12 month mean post-op phoneme scores were significantly different (p value= .017):
    - Matched group (post-lingual, non-significant difference in pre-op scores) with a full scala tympani insertion
    - CI512 (n=31): 69.4%
    - CI532 (n=18): 79.5%

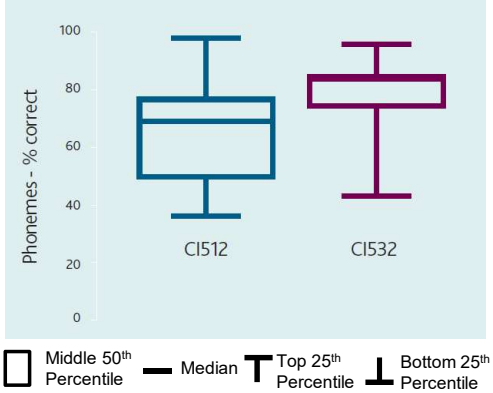


Figure 1: Twelve-month post-implantation phoneme scores in matched groups

With a compared dataset with scala tympani location, CI532 patients performed significantly better at 12 months.[6]

Slim Modiolar Design Goals

PRESERVATION

1. Thin, atraumatic electrode

PLACEMENT

2. Consistent scala tympani insertion[11]
3. Consistent proximity to the modiolus[10]

PERFORMANCE

PREFERENCE

4. Inserted via all 3 surgical approaches

Data on Slim Modiolar

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Matched Cohort Comparison Indicates Superiority of Precurved Electrode Arrays

*Jourdan T. Holder, †Robert J. Yawn, †Ashley M. Nassiri, *Robert T. Dwyer, †Alejandro Rivas, †Robert F. Labadie, and *René H. Giffo

*Department of Hearing and Speech Sciences; and †Department of Otolaryngology–Head and Neck Sur Medical Center, Nashville, Tennessee

Scalar localisation of peri-modiolar electrodes and speech perception outcomes

C Shaul[1,2], A S Dragovic[1], A K Stringer[1], S J O'Leary[1,2] and R J Briggs[1,2]

[1]Department of Otolaryngology, Royal Victorian Eye and Ear Hospital, East Melbourne and [2]Otolaryngology, Department of Surgery, University of Melbourne, Australia

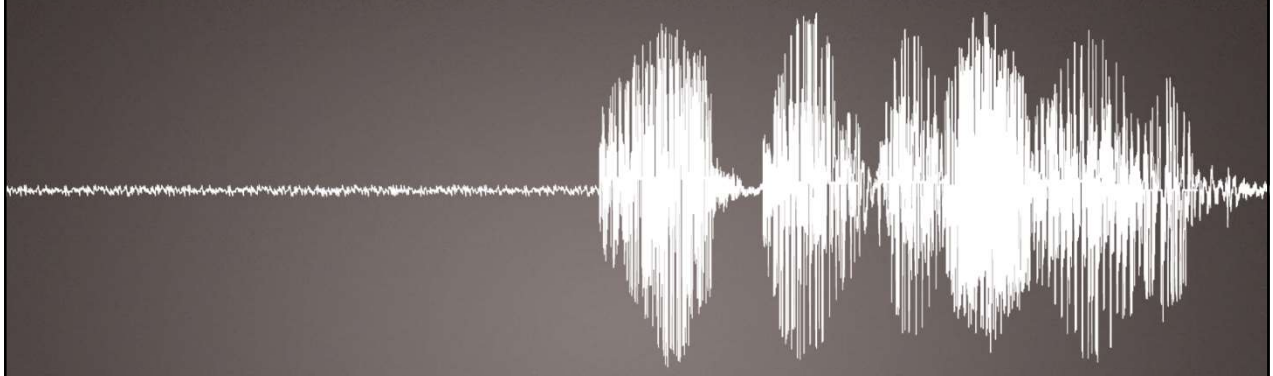
Surgical Experience and Early Outcomes With a Slim Perimodiolar Electrode

David R Friedmann, Emily Kamen, Baishakhi Choudhury, anc

Department of Otolaryngology-Head & Neck Surgery, NYU Cochlear

Objective, audiological and quality of life measures with the CI532 slim modiolar electrode

Matthias Hey, Thomas Wesarg, Alexander Mewes, Silke Helbig, Joachim Hornung, Thomas Lenarz, Robert Briggs, Mathieu Marx, Angel Ramos, Timo Stöver, Bernard Escudé, Chris J. James & Antje Aschendorff



Audiological Considerations with Slim Modiolar

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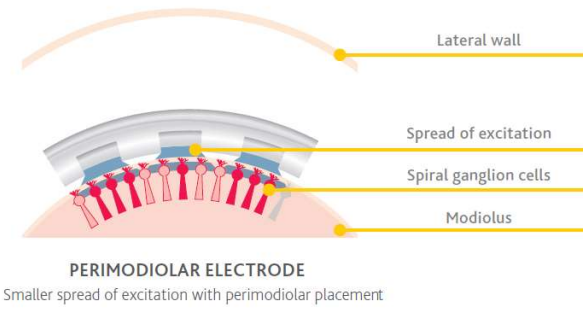
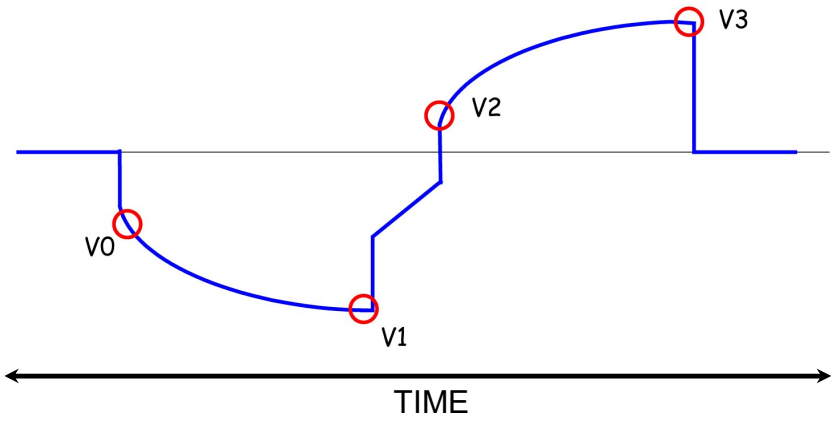
Considerations of Perimodiolar

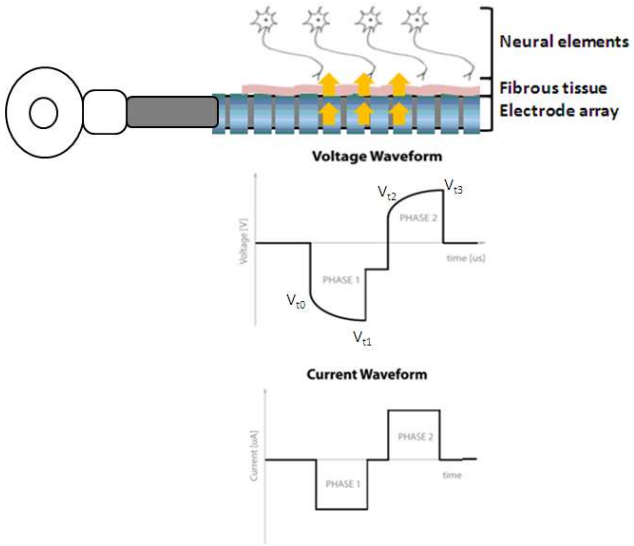


1. Focused stimulation with 22 electrode contacts
   a) Reduced channel interaction[8]
2. Lower and stable impedances[19]
   a) Less charge and improved battery life
3. Lower T's and C's
   a) More likely to stay within compliance

How are electrode impedances measured?



How are electrode impedances measured?



Some Reasons Impedances Change

Electrode impedance can increase significantly during certain medical conditions, such as:

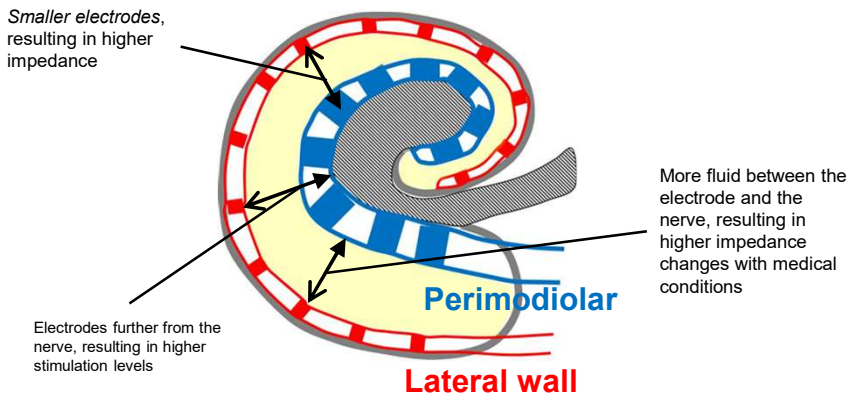
- Implant site infection
- Middle ear infection
- Bladder infection
- Autoimmune disorder
- Hormonal change (puberty, menopause, thyroid disorders)
- Dizziness or Vertigo
- Stroke
- Meningitis
- Otosclerosis
- Shingles
- Post-operative acoustic hearing loss

Summary of Key Factors

Factor	Impact on electrode impedances
Environment - fluid contact, proximity to bone etc	If there is not good fluid contact or there is fibrosis or ossification in the area there will be more resistance to the current (therefore higher impedances).
Medical, pharmaceutical (drugs), hormonal changes	Medications, drugs and hormonal fluctuations change the conductive nature of the fluid the current passes through (and therefore may change the resistance or impedance value).
CIS (unused channels) Disabled channels	Due to conditioning of the electrode with the surrounding environment, unused or disabled channels will typically have higher impedance values.
Time of day measurement taken	Impedance values will typically be lower after a period of stimulation due to conditioning of the electroneural interface.

Lateral Wall vs Periomodiolar Electrodes

Lateral Wall Electrodes	Perimodiolar Electrodes
CI422/522/622 & Hybrid L24	CI24RE/CI512/612/532/632



Note: Proportions have been exaggerated to more clearly show differences

Impedance Differences

In comparing the impedance values of the Slim Modiolar electrode (CI532) to the Slim Straight electrode (CI422/522)[4] the average impedance value for the Slim Modiolar electrode (**6,787 ohms**) was significantly lower than the Slim Straight electrode (**8,021 ohms**), p<0.001. Differences across the electrode type are shown in figures 4 and 5.

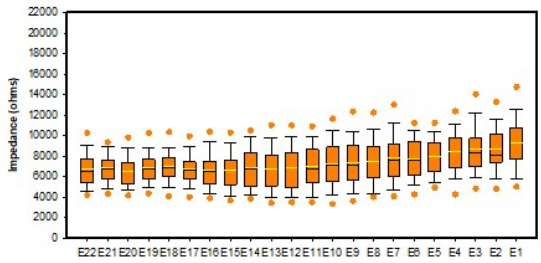


Figure 4: CI532 electrode impedance values

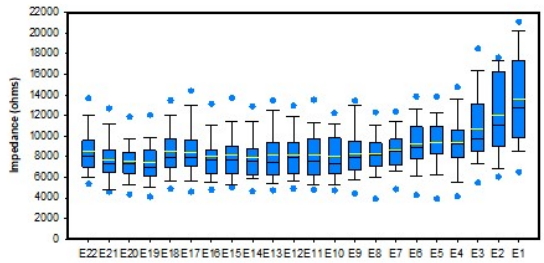


Figure 5: CI422/522 electrode impedance values

Managing Out-of-Compliance

- Increasing pulse width allows the same electrical charge and loudness percept to be achieved at lower current level
- The lower current level keeps the stimulation below the compliance limit

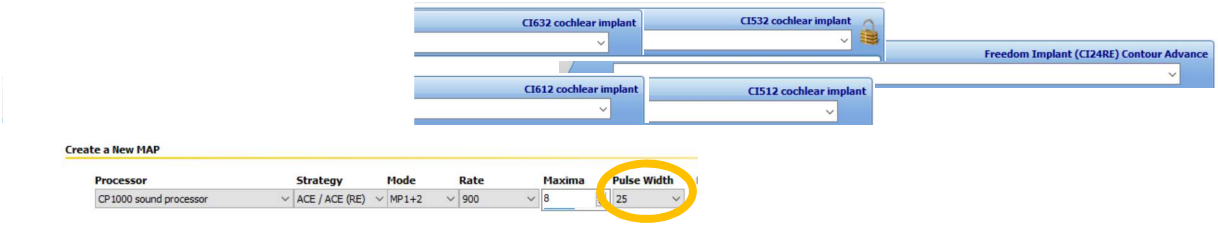
25 µsec/ph

37 µsec/ph

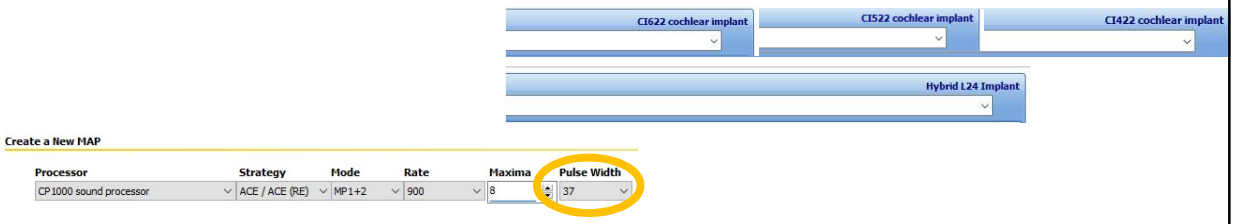
Pulse Width from a different perspective

Both houses are 2700 Square Feet…

Perimodiolar Arrays have a default 25 µs pulse width



Lateral Wall Arrays have a default 37 µs pulse width



Threshold and Comfort Levels with Slim Modiolar

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Threshold (T) and Comfort (C) Levels

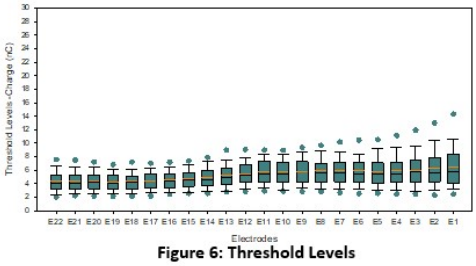


Figure 6: Threshold Levels

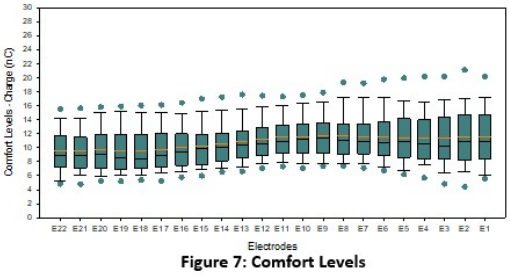
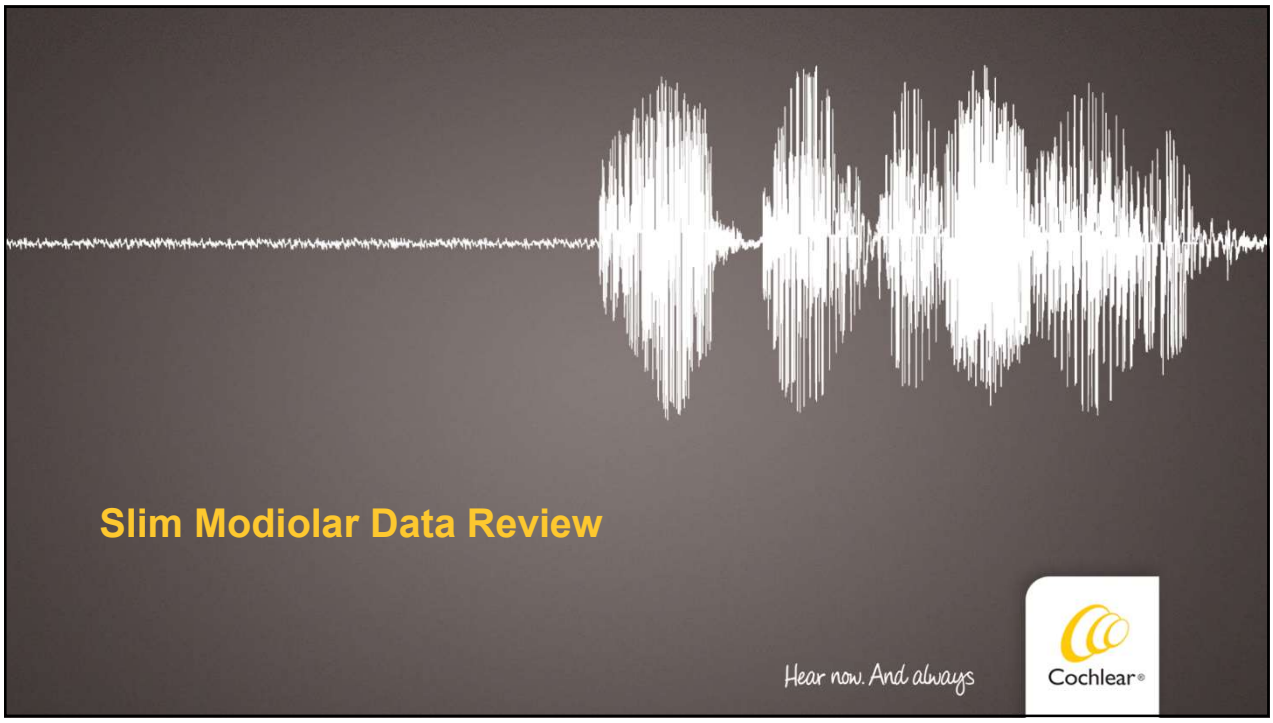


Figure 7: Comfort Levels

Multiple studies have shown significantly lower threshold and comfort levels with perimodiolar arrays.[11,20]



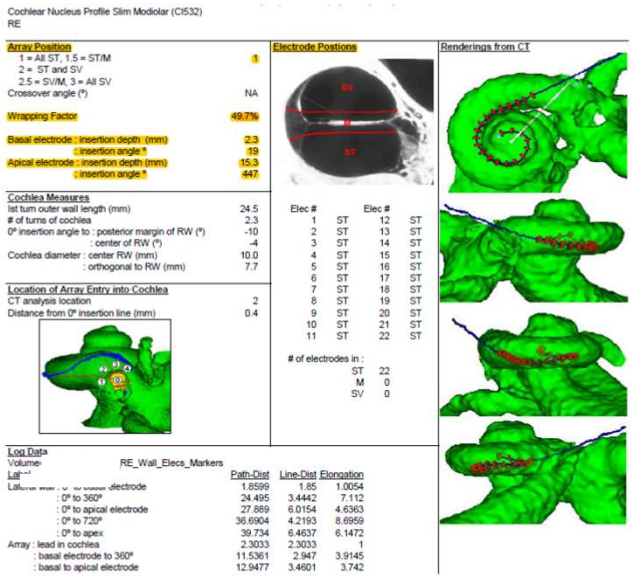
US Multicenter Study

- Washington University, St. Louis, MO
- Center for Hearing and Balance, St. Louis, MO
- Dallas Ear Institute, Dallas, TX
- Ear Medical Group, San Antonio, TX
- Hearts for Hearing, Oklahoma City, OK
- Midwest Ear Institute, Kansas City, KS
- New York University, New York, NY
- Ohio State University, Columbia, OH
- Rocky Mountain Ear Center, Denver, CO
- Spokane ENT, Spokane, WA
- University of California San Francisco, CA
- University of Iowa, Iowa City, IA
- University of Michigan, Ann Arbor, MI

US Multicenter Subject Demographics (N=96)[11]

Characteristic	Mean (S.D.)	
Age at Implantation	67.39 years (±15 yrs) *Range: 23 – 91 years*	
Gender	62 males (65%) 34 females (35%)	
	Ipsilateral Ear	**Contra Ear**
	Mean (SD)	**Mean (SD)**
Duration of Hearing Loss	27.1 years (±14 yrs)	26.7 years (±14 yrs)
Pre CI CNC Word Score	15% (±12%)	24% (±15%)
Pre CI AzBio +10 Score	15% (±17%)	25% (±21%)
Pre CI PTA (500, 1 & 2 KHz)	85 dB (±15 dB)	78 dB (±13 dB)

Understanding the 3D Reconstructions



Cochlear Nucleus Profile Slim Modiolar (CI532)
RE

Array Position

1 = All ST, 1.5 = ST/M	1
2 = ST and SV	
2.5 = SV/M, 3 = All SV	
Crossover angle (°)	NA
Wrapping Factor	49.7%
Basal electrode : insertion depth (mm)	2.3
: insertion angle °	19
Apical electrode : insertion depth (mm)	15.3
: insertion angle °	447

Cochlea Measures

1st turn outer wall length (mm)	24.5
# of turns of cochlea	2.3
0° insertion angle to : posterior margin of RW (°)	-10
: center of RW (°)	-4
Cochlea diameter : center RW (mm)	10.0
: orthogonal to RW (mm)	7.7

Location of Array Entry into Cochlea

CT analysis location	2
Distance from 0° insertion line (mm)	0.4

Electrode Postions

Elec #		Elec #	
1	ST	12	ST
2	ST	13	ST
3	ST	14	ST
4	ST	15	ST
5	ST	16	ST
6	ST	17	ST
7	ST	18	ST
8	ST	19	ST
9	ST	20	ST
10	ST	21	ST
11	ST	22	ST

# of electrodes in :
ST 22
M 0
SV 0

Log Data
Volume: RE_Wall_Elecs_Markers

	Path-Dist	Line-Dist	Elongation
Lateral wall : 0° to basal electrode	1.8599	1.85	1.0054
: 0° to 360°	24.495	3.4442	7.112
: 0° to apical electrode	27.889	6.0154	4.6363
: 0° to 720°	36.6904	4.2193	8.6959
: 0° to apex	39.734	6.4637	6.1472
Array : lead in cochlea	2.3033	2.3033	1
: basal electrode to 360°	11.5361	2.947	3.9145
: basal to apical electrode	12.9477	3.4601	3.742

Key Metrics

1. Electrode Position
   - Wrapping Factor
   - Basal electrode : insertion depth (mm
     insertion angle °
   - Apical electrode : insertion depth (mm)
     insertion angle °
2. Electrode Location
   - Scala tympani vs. scala vestibuli

Consistent Scala Tympani Placement

89% (82/92) Scala tympani placement

- **3%**(3/92) Scala Vestibuli placement
- **8%** (7/92) translocated

89%
remained
within
scala tympani

Multiple studies show that the translocation rate of CI512 varies between 27% and 53% [5, 13,14]

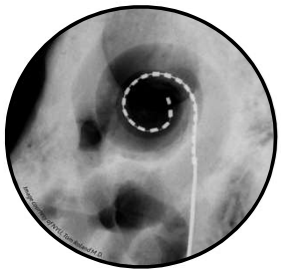
Electrode Proximity to the Modiolus

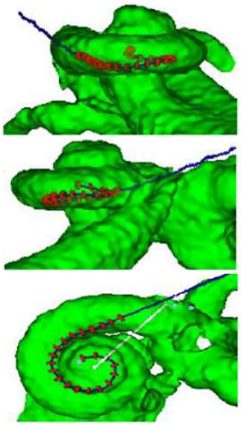
Consistent Wrapping Factor [11]: Mean: 59.6% (SD± 5%)

Previous studies reported lateral wall electrodes to have wrapping factor closer to 100% and well placed individual arrays that led to increased performance were found to be <60%. [2]

59.6%

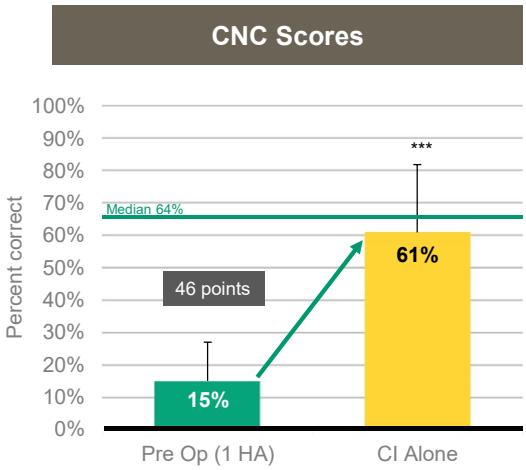
average wrapping factor [11]





CT image renderings from CI532 case examples.

US Multicenter Study: Speech Understanding in Quiet at 6 Months (N=96)

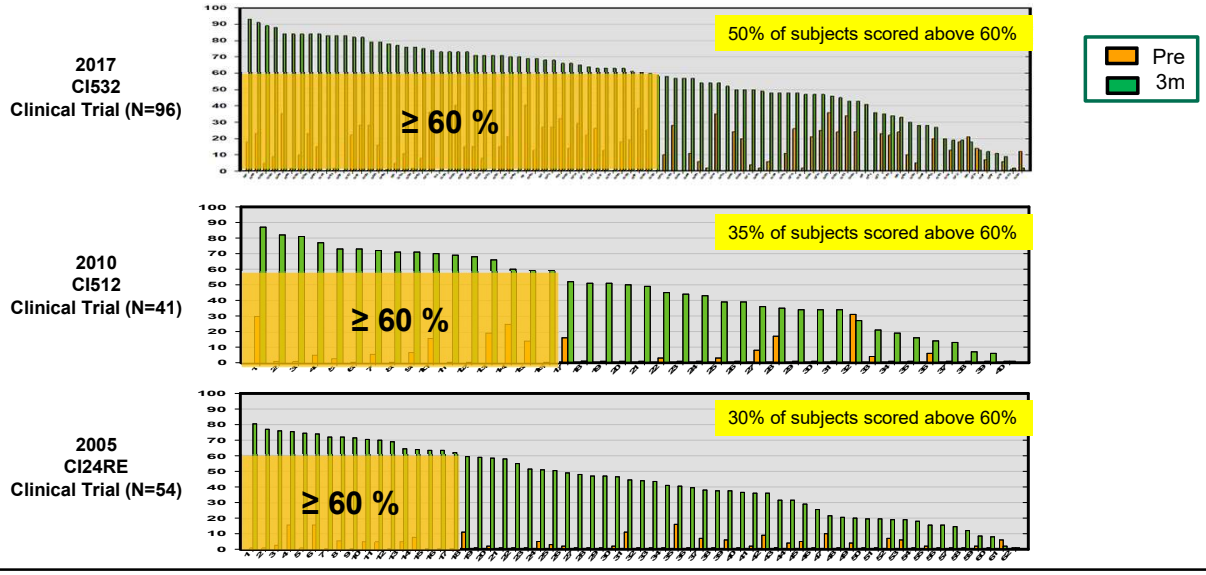


***p = < 0.001

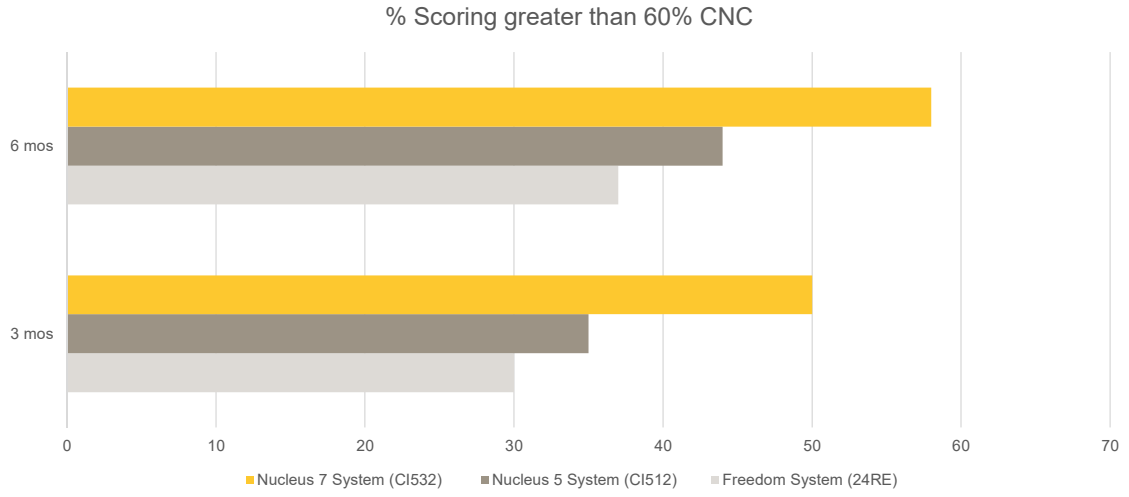
4X

speech understanding with CNC word scores in quiet compared to aided pre-operative scores[11]

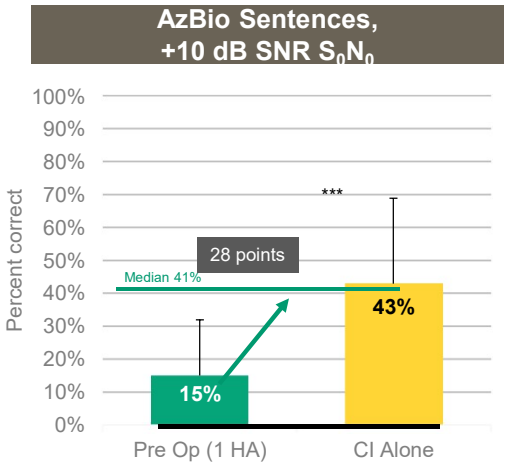
More People Hearing Better Faster[11]



A New Benchmark with N7 System[11]



US Multicenter Study: Speech Understanding in Noise at 6 Months (N=96)



***p = < 0.001

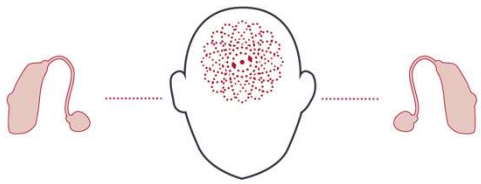
MORE THAN DOUBLED

Secondary study endpoint met – CI more than doubled mean score than with a hearing aid[11]

Study Conditions and Technology

Bilateral Hearing Aids
fit to NAL-Targets

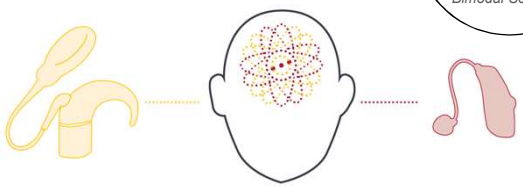
- Preop condition
- HA Experience on average 20 yrs. (1-54 yrs.)



Smart Bimodal System

- Nucleus Slim Modiolar Implant + N7 Sound Processor
- ReSound Hearing Aid

The Cochlear & ReSound partnership offers the industry's most comprehensive portfolio of Smart Bimodal Solutions



A comprehensive audiological, quality of life, and hearing satisfaction/disability test battery was designed for use in the study.[11]

Outcomes with Bilateral Hearing Aids[11]

Cochlear

1 Hearing Aid History

Fit to NAL-Targets

- Hearing aid experience on average **20 years** ***(Range 0 -54 years)*** for the ear implanted
- Average number of hearing aids purchased is **6** (±4)

2 Speech Perception

Bilateral Hearing Aids

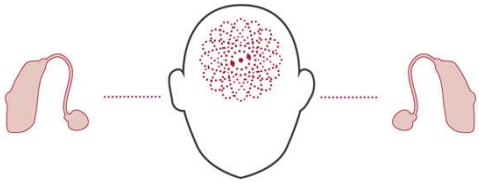
- **29%** Word Recognition in Quiet
- **32%** Sentence Recognition in Noise

One Hearing Aid
(Ear Implanted)

- **15%** Word Recognition in Quiet
- **15%** Sentence Recognition in Noise

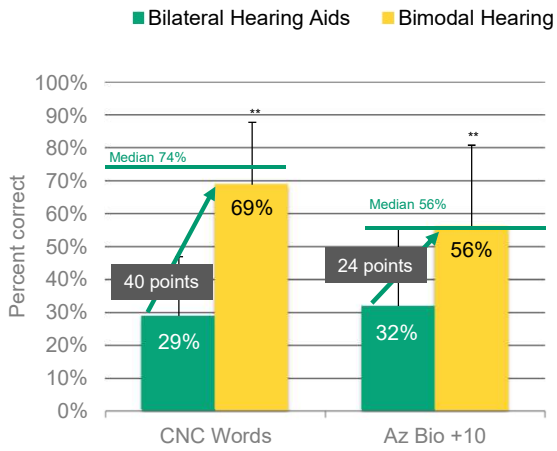
3 Patient Reported Outcomes

- **91%** were **very dissatisfied/ dissatisfied** with bilateral hearing aid performance



Speech Understanding with a CI+HA (N=94)*

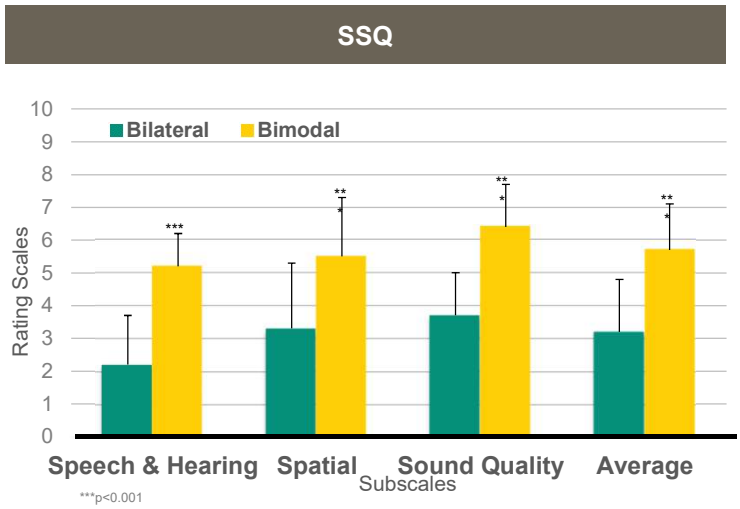
Cochlear



Speech perception **SIGNIFICANTLY IMPROVED** in both quiet and noise[11]

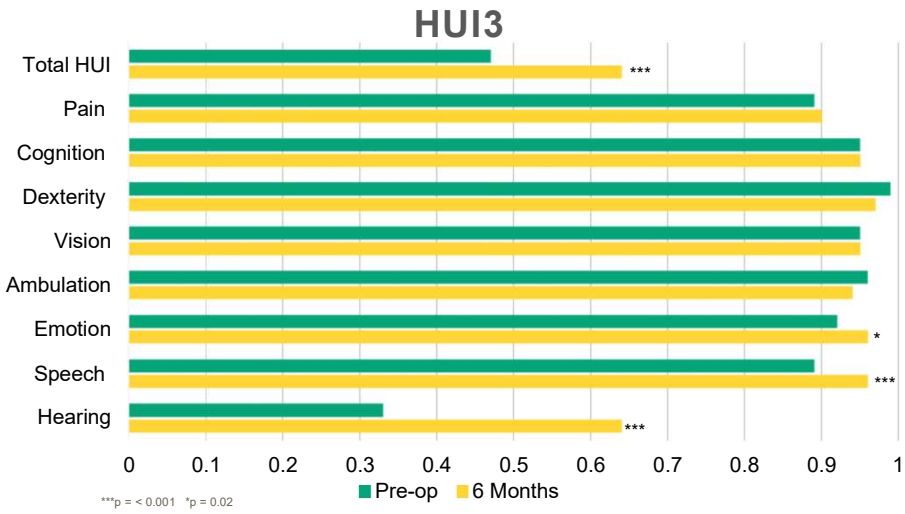
**p = < 0.001 * two subjects not bimodal

Patient Reported Hearing Disability *(N=95)*



SIGNIFICANT BENEFIT ACROSS ALL SUBSCALES[11]

Secondary Endpoint: PRQoL (N=94)



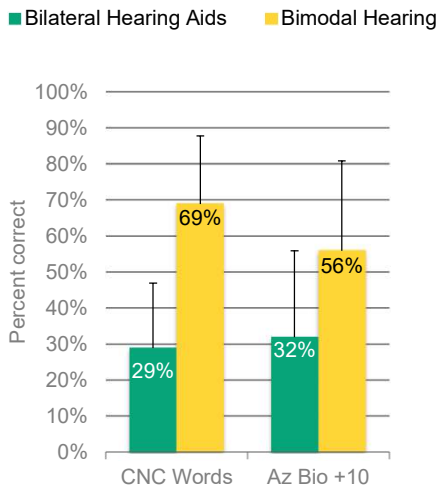
Study Endpoint met – Average HUI score significantly better by 0.19[11] (p <0001)

Comparison to Results from Other Studies

Reference	Device	Baseline	Post Score	Improvement
Feeny & Eng (2004) [15] *N=86; Mean Age = 69 yrs*	Hip Replacement	0.53	0.72	0.19
Groessl et al (2013) [16] *N= 235; >35 yrs old*	Cataracts	0.66	1 mo & 6 mo =0.72	1 mo = 0.048 6 mo = 0.011
Arnoldner,et al (2014) [17] *N=81; Mean Age = 62 yrs*	Cochlear Implant	0.46	0.61	0.146
CI532 Study[11] *N=96; Mean Age = 67 yrs*	Cochlear Implant	0.45	0.64	0.19

1. Feeny,D. & Eng,K. (2004). Comparing Utility Scores Derived From the Short-Form 36, Standard Gamble, and Health Utilities Index. Legal Deposit 2000, National Library Canada
2. Groessl, E.J., Liu, L., Sklar, M., Tally, S.R., Kaplan, R.M., Ganiats, T.G. (2013) Measuring the Impact of Cataract Surgery on Generic and Vision-Specific Quality of Life. *Qual Life Res*, August; 22(6): 1405-1414.
3. Arnoldner, C., et al., (2014). Quality of Life in Cochlear Implantees: Comparing Utility Values Obtained Through the Medical Outcomes Study Short-Form Survey-6D and the Health Utility Index Mark 3. *Laryngoscope*: 124

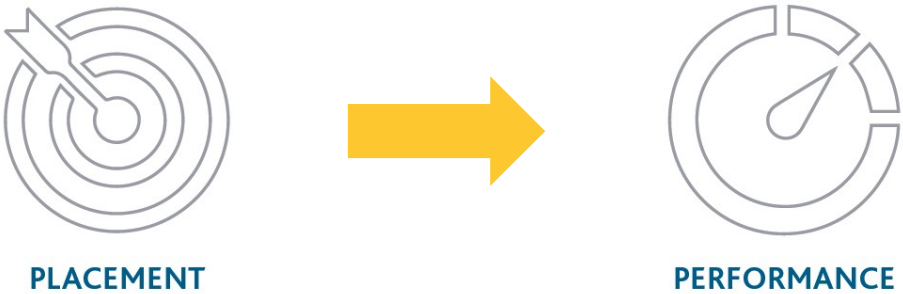
Changing the Conversation[11]



Satisfaction

HEARING PERFORMANCE *Satisfied or Very Satisfied*	**95%**
Ability to understand what is said on TV	**76%**
Ability to understand conversations in a small group	**79%**
Hearing performance in background noise	**58%**
Ability to listen to and appreciate music	**68%**
Ability to understand people on the phone	**71%**

Placement impacts performance[9,11]



References

1. Nucleus® ANSI/AAMI CI86 Reliability Report, Volume 1, Data as of June 2019
2. Holden, L. K., Finley, C. C., Firszt, J. B., Holden, T. A., Brenner, C., Potts, L. G., … Skinner, M. W. (2013). Factors Affecting Open-Set Word Recognition in Adults With Cochlear Implants. *Ear and Hearing*, *34*(3), 342–360. doi: 10.1097/aud.0b013e3182741aa7
3. Blamey, P., Artieres, F., Baskent, D., Bergeron, F., Beynon, A., Burke, E., … Lazard, D. S. (2013). Factors Affecting Auditory Performance of Postlinguistically Deaf Adults Using Cochlear Implants: An Update with 2251 Patients. *Audiology and Neurotology*, *18*(1), 36–47. doi: 10.1159/000343189
4. Lazard, D. S., Vincent, C., Venail, F., Heyning, P. V. D., Truy, E., Sterkers, O., … Blamey, P. J. (2012). Pre-, Per- and Postoperative Factors Affecting Performance of Postlinguistically Deaf Adults Using Cochlear Implants: A New Conceptual Model over Time. *PLoS ONE*, *7*(11). doi: 10.1371/journal.pone.0048739
5. Oconnell, B. P., Hunter, J. B., & Wanna, G. B. (2016). The importance of electrode location in cochlear implantation. *Laryngoscope Investigative Otolaryngology*, *1*(6), 169–174. doi: 10.1002/lio2.42
6. Shaul, C., Dragovic, A. S., Stringer, A. K., Oleary, S. J., & Briggs, R. J. (2018). Scalar localisation of peri-modiolar electrodes and speech perception outcomes. *The Journal of Laryngology & Otology*, *132*(11), 1000–1006. doi: 10.1017/s0022215118001871
7. Polonenko, M. J., Cushing, S. L., Gordon, K. A., Allemang, B., Jewell, S., & Papsin, B. C. (2016). Stimulation parameters differ between current anti-modiolar and peri-modiolar electrode arrays implanted within the same child. *The Journal of Laryngology & Otology*, *130*(11), 1007–1021. doi: 10.1017/s0022215116009026
8. Hughes, M. L., & Abbas, P. J. (2006). Electrophysiologic channel interaction, electrode pitch ranking, and behavioral threshold in straight versus perimodiolar cochlear implant electrode arrays. *The Journal of the Acoustical Society of America*, *119*(3), 1538–1547. doi: 10.1121/1.2164969
9. Chakravorti, S., Noble, J. H., Gifford, R. H., Dawant, B. M., O'Connell, B. P., Wang, J., & Labadie, R. F. (2019). Further Evidence of the Relationship Between Cochlear Implant Electrode Positioning and Hearing Outcomes. *Otology & Neurotology*, *40*(5), 617–624. doi: 10.1097/mao.0000000000002204
10. Cochlear Usability Studies. Data on File (Document 588021 & 415680)
11. Clinical Evaluation of the Cochlear Nucleus CI532 Cochlear Implants in Adults Investigator Meeting. 2019 Apr.
12. Pijl, S., Clark, M., Menapace, C., & Hazard, L. (2006) North American Freedom Clinical Trial : Preliminary results in Adults. Cochlear Limited White Paper
13. Boyer, E., Karkas, A., Attye, A., Lefournier, V., Escude, B., & Schmerber, S. (2015). Scalar Localization by Cone-Beam Computed Tomography of Cochlear Implant Carriers. *Otology & Neurotology*, *36*(3), 422–429. doi: 10.1097/mao.0000000000000705
14. Wanna, G. B., Noble, J. H., Carlson, M. L., Gifford, R. H., Dietrich, M. S., Haynes, D. S., … Labadie, R. F. (2014). Impact of electrode design and surgical approach on scalar location and cochlear implant outcomes. *The Laryngoscope*, *124*(S6). doi: 10.1002/lary.24728
15. Feeny,D. & Eng,K. (2004). Comparing Utility Scores Derived From the Short-Form 36, Standard Gamble, and Health Utilities Index. Legal Deposit 2000, National Library Canada
16. Groessl, E.J., Liu, L., Sklar, M., Tally, S.R., Kaplan, R.M., Ganiats, T.G. (2013) Measuring the Impact of Cataract Surgery on Generic and Vision-Specific Quality of Life. *Qual Life Res*, August; 22(6): 1405-1414.
17. Arnoldner, C., Lin, V. Y., Bresler, R., Kaider, A., Kuthubutheen, J., Shipp, D., & Chen, J. M. (2014). Quality of life in cochlear implantees: Comparing utility values obtained through the Medical Outcome Study Short-Form Survey-6D and the Health Utility Index Mark 3. *The Laryngoscope*, *124*(11), 2586–2590. doi: 10.1002/lary.24648
18. Cohen, L. T., Saunders, E., & Richardson, L. M. (2004). Spatial spread of neural excitation: comparison of compound action potential and forward-masking data in cochlear implant recipients. *International Journal of Audiology*, *43*(6), 346–355. doi: 10.1080/14992020400050044
19. Holder, J. T., Yawn, R. J., Nassiri, A. M., Dwyer, R. T., Rivas, A., Labadie, R. F., & Gifford, R. H. (2019). Matched Cohort Comparison Indicates Superiority of Precurved Electrode Arrays. *Otology & Neurotology*, *40*(9), 1160–1166. doi: 10.1097/mao.0000000000002366
20. Saunders, E., Cohen, L., Aschendorff, A., Shapiro, W., Knight, M., Stecker, M., … Cowan, R. (2002). Threshold, Comfortable Level and Impedance Changes as a Function of Electrode-Modiolar Distance. *Ear and Hearing*, *23*(Supplement). doi: 10.1097/00003446-200202001-00004

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