
Wi SERIES: CUSTOMIZING THE WIRELESS EXPERIENCE

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Enhancements to technology have led to more efficient hearing aid fittings and enriched listening experiences for patients with hearing impairment. Starkey's Wi Series™ custom hearing aids are the industry's first custom hearing aids that integrate a long-distance wireless antenna completely within the shell of the hearing aid. Wi Series offers all of the advantages of wireless communication and advanced signal processing in both custom and receiver-in-canal (RIC) products. Wi Series custom products include completely-in-canal (CIC), in-the-canal (ITC) and in-the-ear (ITE) styles.

With Wi Series custom products, Starkey introduces new hardware designs and several new advanced features. The new hardware design integrates Starkey's wireless antenna into the custom shell along with advanced moisture and wax protection for the receiver. Among the new features available are Voice iQ², iQ Boost, Self Learning and Spectral iQ. The integration of IRIS™ Technology in custom hearing aids provides ear-to-ear processing, media streaming and wireless programming without the need for a relay device.

The hardware and features of Wi Series custom hearing aids were evaluated in an eight-week clinical trial at Starkey. Twenty patients evaluated the functionality and performance of both the wireless custom products and accessories. Mean hearing loss among patients ranged from mild to severe. Both subjective and objective data were collected throughout the study and will be summarized in part throughout this paper.

Hardware Design

Fitting all the necessary components of a hearing aid into the small space of a custom product presents certain challenges. One of the most important hardware components in Wi Series custom hearing aids is the wireless antenna that allows for communication between the hearing aids and the wireless accessories and programmer. This antenna must be capable of transmitting and receiving information while situated deeply in the patient's ear canal. Operating within the 900 MHz band of the Industrial and Scientific Medical Spectrum, Wi Series products are capable of wireless communication in both near and far fields without the use of a relay device. In order to implement and achieve wireless functionality, Wi Series custom hearing aids incorporate a unique hardware design. Figure 1 is an illustration of an assembled Wi Series CIC, in which the copper wireless antenna encircles the hardware and processing components of the hearing aid, including the battery, microphone and integrated circuit. Figure 2 shows the same CIC with the components disassembled: from left to right, the faceplate, hardware components, copper wireless antenna and shell.

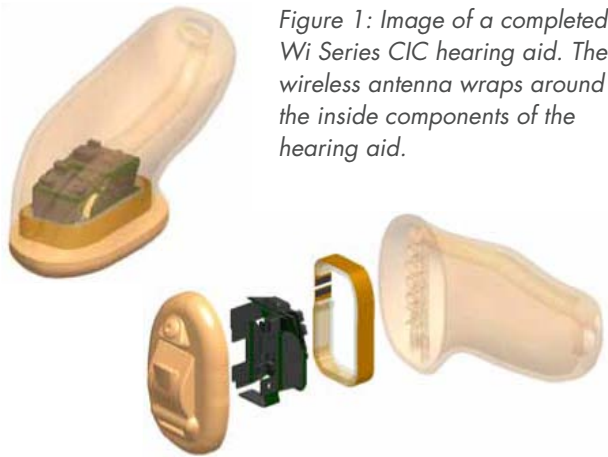


Figure 1: Image of a completed Wi Series CIC hearing aid. The wireless antenna wraps around the inside components of the hearing aid.

Figure 2: Expanded side view of a Wi Series CIC hearing aid. Visible on the faceplate is the microphone port and battery door. Components fit within the wireless antenna, which slides into the shell of the hearing aid.



Figure 3: Photograph of a drop of olive oil on an untreated surface.

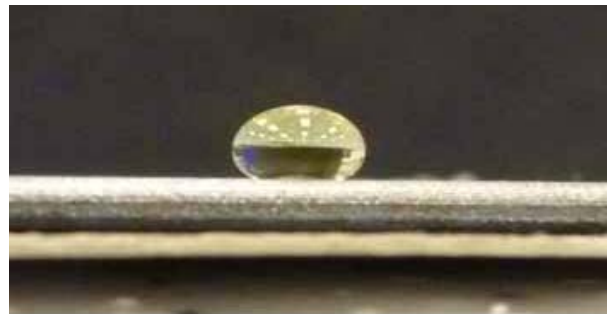


Figure 4: Photograph of a drop of olive oil on a surface coated with HydraShield².

HydraShield^{®2}

HydraShield² is designed to protect hearing aids from many of the substances they are exposed to during typical use. HydraShield², used on the Hear Clear[™] wax guard, is an oleophobic and hydrophobic nano-coating that repels oils and liquids such as wax and perspiration. Figure 3 is a photograph of a drop of olive oil that has been placed on a surface that has not been treated with HydraShield². Note that the surface absorbs the oil. Figure 4 is a photograph of a drop of olive oil that has been placed on a surface that has been treated with HydraShield². Note that in this photograph the oil is not absorbed; rather, the oil sits like a bead on top of the surface. The Hear Clear, treated with HydraShield², prevents such substances from accumulating in the receiver tubing of the hearing aid, improving the durability and reliability of the hearing aid and making it easier for patients to maintain their hearing aids.

Wireless Accessories

Starkey's SurfLink[™] Programmer is one of the first wireless programming options that allows for truly cordless programming sessions. Automatic detection of the hearing aids via Inspire[®] fitting software makes engaging a patient's hearing aids in a programming session quick and easy. In addition, the patient has the freedom to experience different listening environments within a range of approximately 20 feet while the clinician programs the hearing aids.

SurfLink Media, which can be used with all Wi Series hearing aids including the custom options, streams audio from a media device directly to patients' hearing aids. This allows patients to connect to their television, MP3 player, computer and more. Multiple Wi Series users can connect to one media streamer, facilitating use in households with more than one Wi Series user. Because the audio is sent directly to the hearing aids, there is no perceptible delay for the listener, maintaining good sound quality. A subset of patients in this clinical

trial with moderate-to-severe hearing loss evaluated SurfLink Media with custom hearing aids. Four of five patients with moderate-to-severe hearing loss reported good or very good speech understanding when using SurfLink Media while watching television.

The SurfLink Remote allows the patient to adjust various settings in the hearing aids with the simple press of a button. Three convenient remote control designs are available to accommodate any patient's needs. During the clinical trial, patients rated the value and convenience of the remote control very highly, as shown in Figure 5. Patients who did not express satisfaction with the controls reported no need to adjust the hearing aids. With a battery life of up to five years, the SurfLink Remote provides patients with a convenient solution for adjusting their hearing aids.

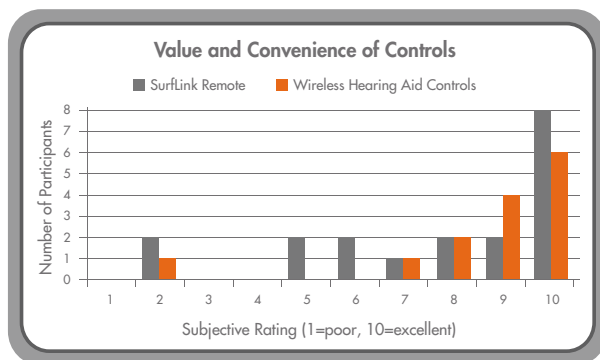


Figure 5: Patients' ratings of the value and convenience of the SurfLink Remote and of the wireless hearing aid controls.

Ear-to-Ear Processing

In addition to the far-field communication capability used for streaming and programming, Wi Series custom hearing aids also offer near-field processing capability. Near-field communication is necessary to allow for communication between the left and right hearing aids. Because the hearing aids are capable of communicating with each other, the user is able to make adjustments to both hearing aids by using the control on only one device. Patients using

wireless hearing aid controls were asked to rate their value and convenience during the clinical trial. Results are displayed in Figure 5. Patients responded favorably, noting that it was very easy to make changes to volume and memory.

An additional benefit of ear-to-ear processing is Binaural Spatial Mapping. Binaural Spatial Mapping uses data collected from each hearing aid to arrive at optimal algorithm settings in a variety of environments, with the goal of improving patients' speech understanding and listening comfort, particularly in the presence of background noise.

Voice iQ²

Voice iQ² offers greater reduction of noise —when compared to the original Voice iQ design — while still preserving speech understanding. Previous studies investigating Voice iQ have reported satisfaction in background noise and no degradation of speech understanding in noise (Pisa, Burk, & Galster, 2010). Clinical data from the current study, with Wi Series custom products featuring Voice iQ², indicate that Voice iQ² preserves patients' ability to understand speech in noise (Figure 6). Speech understanding in noise was evaluated using the Hearing in Noise Test (Nilsson, Soli, & Sullivan, 1994) across multiple conditions with Voice iQ² off and with Voice iQ² on. No significant difference in performance was observed, indicating that Voice iQ² preserves patients' ability to understand speech when a background noise is present.

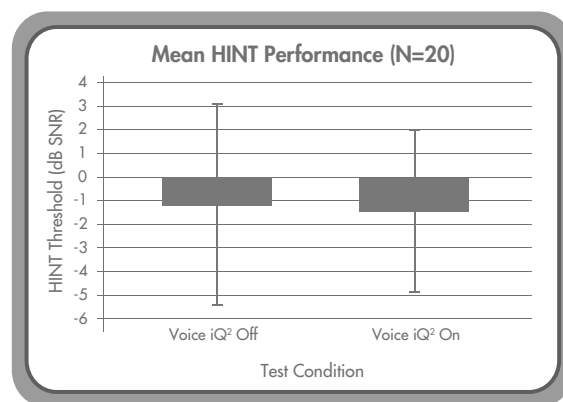


Figure 6: Mean HINT performance with Voice iQ² off and with Voice iQ² on. Note that lower scores indicate better performance.

iQ Boost

Designed for use in extremely noisy environments, iQ Boost allows patients to activate directionality and more aggressive noise reduction settings. iQ Boost features specialized Voice iQ² settings and up to 20dB of noise reduction. This is intended to improve patient comfort in extremely noisy environments. Accessed using the "Favorite" button on the SurfLink Remote, iQ Boost is designed to improve comfort in noise with the click of a button.

Self Learning

Self Learning automatically adjusts the gain settings in the hearing aids in response to volume control changes made by the patient. If a patient makes consecutive, consistent adjustments to the volume of their hearing aids, the devices will slowly start to "learn" this behavior and adjust the gain to better meet the needs of the patient. Self Learning will learn preferred volume settings for different memories, allowing memory-specific learning and optimization of the hearing aid response.

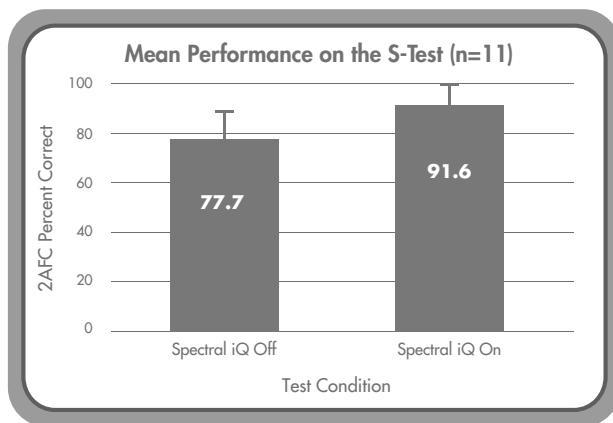


Figure 7: Mean two-alternative forced choice (2AFC) percent correct scores for the S-Test. The two test conditions displayed in the figure show scores with Spectral iQ off and Spectral iQ on. Patients performed significantly better with Spectral iQ on ($p < 0.001$).

Spectral iQ

Spectral iQ is designed to improve audibility for high-frequency speech sounds like /s/, /ʃ/, and /z/ for patients with steeply sloping high-frequency hearing loss. The algorithm identifies high-frequency speech sounds and translates them to a lower frequency region where hearing thresholds are better, while also maintaining the original speech signal. This dynamic process preserves harmonic relationships, which are critical to speech understanding and sound quality, resulting in audible speech cues while maintaining excellent sound quality. Eleven of the twenty clinical trial patients met the candidacy criteria for Spectral iQ and evaluated this feature throughout the clinical trial. To evaluate patient performance with Spectral iQ, the S-Test (Robinson, Baer, & Moore, 2007) was used to evaluate a listener's ability to detect word final /s/ or /z/ sounds. S-Test results were converted from d-prime scores to percent correct according to the procedures described by Hartmann (1997, p. 543). Figure 7 displays mean patient performance on the S-Test. Significant benefit from Spectral iQ was observed when comparing results with Spectral iQ on versus results with Spectral iQ off ($p < 0.001$).

Overall Impressions

Upon completion of the clinical trial, patients completed the Device-Oriented Subjective Outcome Scale (DOSO) (Cox, Alexander, & Xu, 2009) to rate Wi Series custom hearing aids. These ratings were compared to ratings of the patients' own hearing aids which were completed at the onset of the study. The DOSO is designed to evaluate and compare the performance of the hearing aids (Cox, Alexander, & Xu, 2009). Patients rated the Wi Series custom hearing aids significantly better than their own hearing aids on all of the subscales of the DOSO: speech cues ($p < 0.001$), listening effort ($p < 0.001$), pleasantness ($p < 0.01$), quietness ($p < 0.001$), and convenience ($p < 0.005$) (see Figure 8).

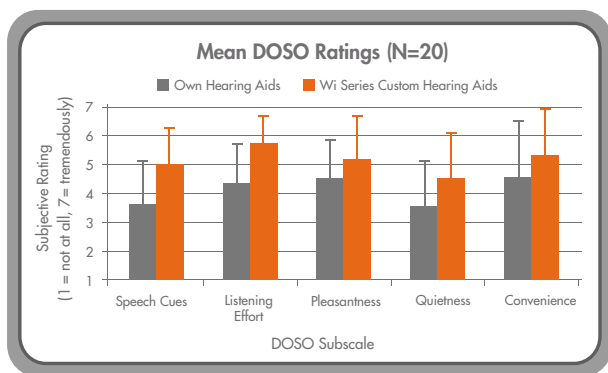


Figure 8: Patients' responses to the DOSO scale with their own hearing aids at the start of the study compared to the Wi Series custom hearing aids at the end of the study. For all subscales, the Wi Series custom hearing aids were rated significantly better than the patients own devices on each of the DOSO subscales: speech cues ($p < 0.001$), listening effort ($p < 0.001$), pleasantness ($p < 0.01$), quietness ($p < 0.001$), and convenience ($p < 0.005$).

Conclusion

Starkey's Wi Series custom hearing aids are among the first hearing aids to offer near- and far-field wireless technology in combination with advanced signal processing within the case of a custom hearing aid. The use of IRIS Technology and our new features like Voice iQ², iQ Boost, Self Learning and Spectral iQ enhance the patient experience. Starkey's Wi Series custom products integrate exceptional sound quality, speech understanding and all the benefits of wireless communication into a smaller package than ever before.



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