Bone Conduction Implants: The When and Why
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Bone Anchored Hearing Aids (BAHA) have been in routine clinical use since 1977. BAHAs are useful for either those patients with middle ear dysfunction who have not responded to medical or surgical intervention, or for those with congenital atresias. The BAHA also can be used for those patients with mixed hearing losses, where the average bone conduction thresholds (at 500 Hz, 1000 Hz and 2000 Hz) does not exceed 45 dB (for the head worn, or 65 dB for the body worn version). This means that a patient can use a BAHA who has an unresolveable permanent conductive hearing loss, and a significant presbycusic or noise-induced sensorineural component. As long as the bone conduction average does not exceed the above figures, these patients are candidates regardless of the air conduction thresholds. For more information on the design and clinical results, the reader is referred to Hakinsson et al.1 and Chasin.2,3

When confronted with a patient that is considering a BAHA, it must first be established whether any other non-surgical alternative is available. This may include air conduction hearing aids with sufficient venting or even a CROS fitting if the problem is unilateral. In the case of congenital atresias, alternative conventional bone conduction fitting approaches can be attempted (including, two sided carpet tape and alternative head-band arrangements).

Once established that the patient is a candidate for a BAHA (see Table 1), the question naturally arises for the patient: “Will I hear better with a BAHA than with my current bone conduction hearing aid?” There have been a number of studies directly comparing the clinical differences between conventional bone conduction hearing aids and the BAHA, and these are based mostly on word recognition and signal-to-noise ratio (SNR) improvement. For example, Cremers, Snik & Beynon4 show that the SNR improvement with the BAHA is anywhere from 1.4 dB to 8 dB.

The following is an attempt to explain these differences in terms of the results of the coupling options between a conventional bone conduction hearing aid and the BAHA.

IMPLANT ADVANTAGES

The BAHA is shown in Fig. 1 (along with a conventional bone conduction hearing aid). It is comprised of a titanium screw that is surgically implanted in the temporal bone behind the ear. Through an abutment connected to the implanted screw, an external hearing aid (called the BAHA) can be attached. Sound is then transduced from the external hearing aid to the implanted screw. By bone conduction, the sound is transmitted directly to the cochlea in a similar fashion to a conventional bone conduction hearing aid. The main difference is that a conventional bone conduction hearing aid uses a bone oscillator (like the one used in bone conduction testing) that has a layer of skin between it and the temporal bone, whereas the BAHA uses a small “point source” vibrator that is coupled more directly to the temporal bone (i.e., no layer of skin).

Fig. 2, which is adapted from Stenfelt5, shows the main performance difference. The conventional approach necessitates a layer of skin between the external bone oscillator and the temporal bone, and a rather large area (surface area of the bone conduction oscillator) is set in vibration. In contrast, the BAHA uses a smaller area “point source” to transmit the sound energy, and there is no layer of skin between the external environment and the temporal bone.

This layer of skin (and, secondarily, the smaller surface area) creates a significant loss of sound energy. Fig. 3 (from Carlsson6) shows the difference between a transducer going across a layer of skin (like a conventional bone conduction hearing aid) and the same transducer that is coupled more directly to the temporal bone (like a BAHA). Note that there is about 15 dB more gain (and output) with the more direct BAHA coupling than with conventional bone conductor transduction.

With conventional bone conduction coupling, the frequency response is highly variable; the peak of the frequency response can change dramatically depending on the thickness of the layer of skin. Because there is no layer of skin involved, this is not the case with a BAHA. Indeed, middle ear implant researchers have acknowledged that a more direct “BAHA-like” coupling would improve gain and output by up to 20 dB—an approximate 40-50% increase in efficiency.2,5 Therefore, the device would provide 15 dB greater gain (and output) compared with a conventional bone conduction hearing aid.

What about the shape of the frequency response? As can be seen in Fig. 2 and Fig. 3, there is relatively more mid- and high-frequency gain and output with the BAHA as compared with conventional bone conduction amplification. The exact difference can also depend on which type of conventional bone conductor that is used, along with the surface area. The data from Fig. 2 uses a type that is more routinely used with bone conduction hearing aid fittings, while the data from Fig. 3 is based on data from an audiometric bone conductor that would be used during routine testing.

Other than word recognition score improvement, or an improvement in the signal-to-noise ratio, a useful “one number” clinical measure is the articulation index (AI). Table 2 shows the increase in AI (a measure of the proportion of audible speech sounds) in three conditions. Clearly, more of the speech sounds are audible with the BAHA than with conventional amplification. The articulation index (AI), when expressed as a percentage, is a measure of the proportion of speech cues that is audible. Such increases shown in Table 2 are maximum increases, given a flat aided threshold of 50 dB HL across the frequency range. In such a condition, the “unaided” AI would be 33%. This would also be the AI for a conventional bone conduction hearing aid fitting. Increasing the threshold by a flat 15 dB across the frequency range (in essence, bringing it up to 35 dB HL) would elevate the AI to 83%—a 50% increase. Adding in the high-frequency boost that is characteristic of the BAHA type of coupling yields a further 20% increase. Looking at the improvement in terms of AI for just the high-frequency boost, the 20% increase would improve the AI from 33% to 53%. Taking the high-frequency boost together with the greater 15 dB improvement in amplification, the AI is 94%. If different starting aided values were chosen (other than the sensitivity equivalent to a flat “loss” of 50 dB HL), the AI results would differ.

For those with chronic middle ear dysfunction who have not responded to medical or surgical means, the increased gain, output and improved articulation index, as compared with conventional bone conduction amplification, means improved communication ability in a wide range of life situations.

The case for those with congenital atreasias have been even more dramatic. Many of these patients are young children (Treacher-Collins and Goldenhar's Syndromes make up the majority) who have been fit with bulky conventional bone conduction hearing aids where the bone oscillator presses into their mastoid area(s). The BAHA is designed not to cause irritation due to pressure sores, is more compact, and most importantly, allows the child to derive significantly more gain and output, realizing significantly improved speech discrimination ability (better articulation index) as compared to conventional bone conduction hearing aids.

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