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Long-term Outcomes of Bone Conduction Hearing Implants in Patients With Bilateral Microtia-atresia

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Objectives: To evaluate the long-term outcomes of three different types of bone conduction hearing implants (BCHI)—BAHA, Ponto, and Bonebridge—in Mandarin-speaking patients with bilateral microtia-atresia.

Methods: This cohort study enrolled 59 patients affected by bilateral microtia-atresia, with an upper bone conduction threshold limit of 30 dB HL at frequencies of 0.5 to 4 kHz. All subjects underwent unilateral BCHI surgery, including 26 (18 males, 8 females, of mean age 8.7 ± 1.9 yr) implanted with BAHA devices; 10 (7 males, 3 females, of mean age 11.7 ± 2.8 yr) implanted with Ponto devices; and 23 (14 males, 9 females, of mean age 9.0 ± 1.8 yr) implanted with Bonebridge devices. The main outcome measures included long-term audiological benefits, patient satisfaction, and complications. Each subject acted as his or her own control.

Results: Two years after BCHI surgery, the mean hearing thresholds in the BAHA, Ponto, and Bonebridge groups had improved to 22.6 ± 1.6 dB HL, 21.6 ± 1.2 dB HL, and 22.5 ± 1.5 dB HL, respectively. The mean percentages of subjects in these three groups recognizing speech at 65 dB SPL under quiet conditions were $97.7 \pm 4.2\%$, $96.3 \pm 1.1\%$, and $94.4 \pm 9.4\%$, respectively, whereas the mean percentages recognizing speech under noise conditions (signal:noise ratio +5) were $87.0 \pm 1.8\%$, $89.3 \pm 9.3\%$, and $85.3 \pm 4.7\%$, respectively. Questionnaires revealed patients' benefits and satisfaction with this surgery. Three (11.5%) of 26 patients in the BAHA group and 1 (10%) of 10 in the Ponto group experienced skin irritation, but all recovered after local treatment. Five (19.2%) patients in the BAHA group and two (20%) in the Ponto experienced abutment extrusion about 6 months postoperatively, with all achieving good results after revision surgery to replace the abutment. One (3.8%) patient in the BAHA group experienced local chronic inflammation and underwent surgery to replace the BAHA with a Bonebridge implant. One (4.3%) patient in the Bonebridge group developed a local infection 3 months postoperatively and underwent implant removal.

Conclusions: All three BCHIs were well tolerated after long-term follow-up, and all improved audiometric thresholds and the intelligibility of speech in the presence of both quiet and noise. These implants should be considered valid and safe options for the functional rehabilitation of patients with bilateral microtia-atresia. **Key Words:** BAHA—Bilateral microtia-atresia—Bone conduction—Bonebridge—Hearing rehabilitation—Ponto.

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Congenital microtia-atresia is characterized by abnormalities of the auricle (microtia), often associated with aplasia or hypoplasia of the external auditory canal, the middle ear, and occasionally the inner ear structures. The incidence of microtia-atresia is estimated to be one in 10,000 births and to be bilateral in approximately one-quarter of these infants (1). These patients often experience conductive hearing loss (CHL) with an air-bone gap of 50 to 60 dB, which, if not corrected in a timely manner, may delay speech development (2).

In young children, early hearing rehabilitation is of prime importance to ensure normal development of speech and language, which can be accomplished by implantation of soft-band bone conduction hearing

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devices. Traditionally, functional rehabilitation of bilateral microtia-atresia in older children requires surgical correction of the external ear canal. However, this procedure is difficult because of altered landmarks, abnormal anatomy of the facial nerve, and the limited space of the middle ear. Furthermore, reconstruction of the externa ear canal requires long-term follow-up, and complications such as canal restenosis and chronic infections are common (3). Surgical attempts at ear canal reconstruction may be considered unreasonable or risky, and these procedures should be performed only in patients who meet specific anatomic criteria (4,5).

Bone conduction hearing implantation (BCHI) is considered a reliable and predictable option for hearing rehabilitation in patients with chronic otitis media, microtia-atresia, and single-sided deafness who likely cannot benefit from the use of conventional hearing aids. The device is surgically implanted and works by transmitting sound through bone to the inner ear, thus bypassing both the external auditory canal and the middle ear (2,6,7). The discovery of implant osseointegration resulted in the introduction of the concept of direct bone conduction, which could be achieved by skin-penetrating coupling from an osseointegrated titanium implant in the mastoid bone.(8)

The bone-anchored hearing implants BAHA (Cochlear) and Ponto (Oticon) have shown advantages for patients with aural atresia or chronic ear drainage. Implantation of these devices requires no particular surgical skills, and the results of implantation do not depend on middle ear malformation or deteriorate over time. However, these percutaneous procedures have been associated with various complications, including local inflammation, skin overgrowth, and implant extrusion. Transcutaneous bone conduction implants, such as Bonebridge (MED-EL), and the Baha Attract system (Cochlear), were developed to overcome the limitations of percutaneous bone-anchored hearing implants (9).

Although BCHIs have shown good outcomes (2,10–12), few studies have assessed their long-term efficacy in speakers of Mandarin. The aim of this study was to evaluate the benefits of unilateral BCHI surgery on auditory outcomes and quality of life using Mandarin Speech Test Materials (MSTMs) and two questionnaires, in 59 Mandarin-speaking patients with bilateral microtia-atresia treated at Peking Union Medical College Hospital (PUMCH).

METHODS

Participants

This single-center prospective study included all patients who presented to PUMCH (Beijing, China) between January 2014 and January 2016 with bilateral conductive hearing loss due to congenital microtia-atresia and who were rehabilitated by unilateral BCHI. The study protocol was reviewed and approved by the Institutional Review Board of PUMCH and was in accordance with the ethical standards of PUMCH. Parents of all patients provided written informed consent.

Patients were included if they were aged >6 years, of height >1.28 m, had bone conduction hearing thresholds <30 dB HL at frequencies of 0.5 to 4 kHz, and had skull thickness ≥3 mm, as assessed by a preoperative high-resolution computed tomography (CT) scan. In our institution, all candidates for BCHI undergo high-resolution CT scans as part of their routine preoperative evaluation. All included patients underwent a complete full work-up to rule out associated anomalies, including echocardiography to rule out cardiac anomalies; ultrasound of the abdomen to rule out malformations of the urinary system; pediatric evaluation to rule out associated anomalies; an ophthalmic consultation; and MRI to rule out the possibility of cerebropontine angle tumors. Patients with unilateral microtia-atresia, malformation of the inner ear (sensorineural hearing loss), or concomitant diagnosed conditions such as cerebral palsy and intellectual disability were excluded. Parents chose the BCHI after a counseling session in which models of three devices were shown and tried, and the advantages and drawbacks of each were explained.

Fifty-nine patients with bilateral microtia-atresia (39 males, 20 females), of mean implantation age 9.31 ± 2.29 years (range, 6.5–15.5 yr), were enrolled in the study. Degrees of auricular dysplasias were evaluated according to Max's classification (13). Of these 59 subjects, 26 (18 males, 8 females, mean age 8.7 ± 1.9 yr) underwent BAHA implantation, 10 (7 males, 3 females, mean age 11.7 ± 2.8 yr) underwent Ponto implantation, and 23 (14 males, 9 females, mean age 9.0 ± 1.8 yr) underwent Bonebridge implantation. The average unaided free sound field hearing thresholds in BAHA, Ponto, and Bonebridge group were 65.2 ± 2.7 dB HL, 66.8 ± 1.6 dB HL, and 67.3 ± 2.7 dB HL, respectively. Before implantation surgery, all subjects had used a soft-band BCHI. Follow-up time from BCHI fitting ranged from 24 to 52 months with a mean of 36 months. The detailed characteristics of these patients are shown in Table 1 and Supplementary Table 1, http://links.lww.com/MAO/A826.

Device Fitting

Subjects were first fitted with the device 2 weeks after surgery. The audio processor was programmed using specific software provided by the BCHI company, via a programming cable connected to the Hi-Pro box. The target gain was evaluated by measuring bone conduction thresholds. Each fitting was adapted to each patient's behavioral responses to obtain comfortable hearing levels.

Audiometric Data

Sound field hearing thresholds and word recognition scores (WRS) for disyllabic words, both under quiet and noise (signal-to-noise ratio +5) conditions, were collected and compared at six time points: unaided, switch-on, and 3, 6, 12, and 24 months after implantation. Hearing thresholds were evaluated through loudspeakers 1 m in front of the subject at 0.25, 0.5, 1, 2, 3, 4, and 8 kHz, using the MSTM (6). Speech discrimination scores (in quiet and noise) were measured using disyllabic tests, which consisted of 10 lists each containing 50 Chinese characters or spondaic words, with speech coming from the loudspeaker in front of the subject and noise from the loudspeaker behind the subject. In quiet, intelligibility scores were evaluated, and in noise, speech stimuli were presented at 65 dB SPL, and the speech-shaped noise level was set at 60 dB SPL (signal-to-noise ratio +5 dB). The intensity required for maximum intelligibility scores in quiet was also analyzed. The average sound field hearing thresholds at each time point at 0.5, 1, 2, and 4 kHz were calculated and compared.

Questionnaires

Each patient was administered two questionnaires via face-to-face interviews 24 months after treatment. The first

TABLE 1. *Patient's characteristics and demographics*

Characteristics	BAHA Group N = 26	Ponto Group N = 10	Bonebridge Group N = 23	Total N = 59
Sex (male: female)	18:8	7:3	14:9	39:20
Age (yr); mean ± SD (range)	8.7 ± 1.9 (6.5–14.5)	11.7 ± 2.8 (7–14.5)	9.0 ± 1.8 (6.5–13.5)	9.3 ± 2.3 (6.5–14.5)
Side (left: right)	9:17	3:7	9:14	21:38
Skull thickness (mm); mean ± SD (range)	4.3 ± 0.6 (3.2–5.6)	4.8 ± 0.7 (3.6–5.6)	3.8 ± 0.6 (3.0–5.2)	4.2 ± 0.7 (3.0–5.6)
Comorbidities	Treacher Collins (2) Complex malformation (4) Goldenhar (1)	None	Treacher Collins (1) Complex malformation (2) Goldenhar (1)	Treacher Collins (3) Complex malformation (6) Goldenhar (2)
Follow-up (years); mean ± SD (range)	2.9 ± 0.4 (2.2–3.8)	2.5 ± 0.2 (2.1–2.9)	2.5 ± 0.3 (2.0–3.0)	2.7 ± 0.4 (2.0–3.8)
Skull thickness (mm)	4.3 ± 0.6	4.8 ± 0.7	3.8 ± 0.6	4.2 ± 0.7
Jahrsdoerfer score	5.9 ± 0.6	5.7 ± 0.5	6.1 ± 0.5	5.9 ± 0.6

questionnaire, on self-rated quality of life (QoL), was administered to assess the ease of use and the daily utilization period of the BCHI. QoL improvements, and overall levels of satisfaction with sound localization and aesthetics were assessed using a satisfaction rating of 1 to 10, with 1 = worst and 10 = best. This questionnaire was derived from the Nobel Biocare (Zurich, Switzerland) questionnaire, which had previously been translated into different languages and its validity and reliability confirmed (6).

Patients were also assessed using the Chinese version of the Abbreviated Profile of Hearing Aid Benefit (APHAB-CH) questionnaire (14,15), which was first utilized in 1995 to determine benefits after BCHI surgery. The APHAB-CH questionnaire includes 24 items, addressing communication difficulties in daily life. It has four subscales: Ease of Communication (EC), which assesses speech understanding under relatively favorable conditions; Reverberation (RV), which assesses communication under reverberant conditions, Background Noise (BN), which assesses communication in noisy settings, and Aversiveness of Sounds (AV), which assesses the unpleasantness of environmental sounds. Patients were asked to score each situation with and without the BCHI.

Complications

Complications, including skin safety and abutment location, were evaluated throughout follow-up. Skin condition was evaluated by the surgeon as very good, good, acceptable, or bad at switch-on of the device and at 3, 6, 12, and 24 months after surgery. Cutaneous tolerance at these time points was evaluated by the surgeon using a visual analog scale, ranging from 1 (very bad) to 10 (excellent).

Statistics

All data were analyzed using SPSS (V 21, the International Business Machines Corp) software. Continuous variables were presented as mean ± standard deviation and compared by paired *t* tests with Bonferroni corrections. Statistical significance was defined as a p value <0.05.

RESULTS

Audiometric Results

Two years after BCHI surgery, the mean hearing thresholds in the BAHA, Ponto, and Bonebridge groups had improved to 22.6 ± 1.6 dB HL, 21.6 ± 1.2 dB HL, and 22.5 ± 1.5 dB HL, respectively, thresholds significantly better than before implantation ($p < 0.05$). The mean hearing thresholds (0.5, 1.0, 2.0, 4.0 kHZ) and frequency-specific thresholds of 0.25, 0.5, 1.0, 2.0, 3.0, 4.0, 8.0 kHZ at six time points are shown in Figure 1. The mean speech recognition percentages of subjects in the BAHA, Ponto, and Bonebridge groups at 65 dB SPL under quiet conditions were 97.7 ± 4.2%, 96.3 ± 1.1%, and 94.4 ± 9.4%, respectively, whereas the mean percentages recognizing speech under noise conditions (signal-to-noise ratio +5) in these three groups were 87.0 ± 1.8%, 89.3 ± 9.3%, and 85.3 ± 4.7%, respectively (Fig. 2), with both parameters being significantly better than before implantation ($p < 0.05$). There was no significant difference between different wearing time points (3, 6, 12, 24 mo postoperatively) ($p > 0.05$).

Questionnaires

One patient who underwent implant removal was not administered questionnaires, whereas the other 58 (98.3%) responded, answering the two questionnaires with the assistance of their parents, who helped the patient to understand the questions correctly, without giving any of their own opinion about the answer (Fig. 3). Of these 58 patients, 53 (92.0%) regarded use of the BCHI as easy or very easy. Fifty-two patients (89.7%) used the BCHI an average of >8 hours per day, and the other six (10.3%) between 4 and 8 hours per day. Overall satisfaction was excellent in the BAHA, Ponto, and Bonebridge groups, with mean scores of 7.8, 7.5, and 9.0, respectively, and improvement in quality of life was 8.6, 8.3, and 9.2, respectively. The average aesthetic scores of the BAHA, Ponto, and Bonebridge were 6.2, 6.5, and 8.3, respectively, and the mean sound localization scores were 4.6, 4.7, and 4.5 respectively. All patients reported improvements in comprehension following BCHI implantation when talking with one person under silent conditions. Forty-eight (82.8%) patients also reported great satisfaction when listening to music, radio, or television, but the proportion of patients expressing great satisfaction dropped to 50% in group situations. All

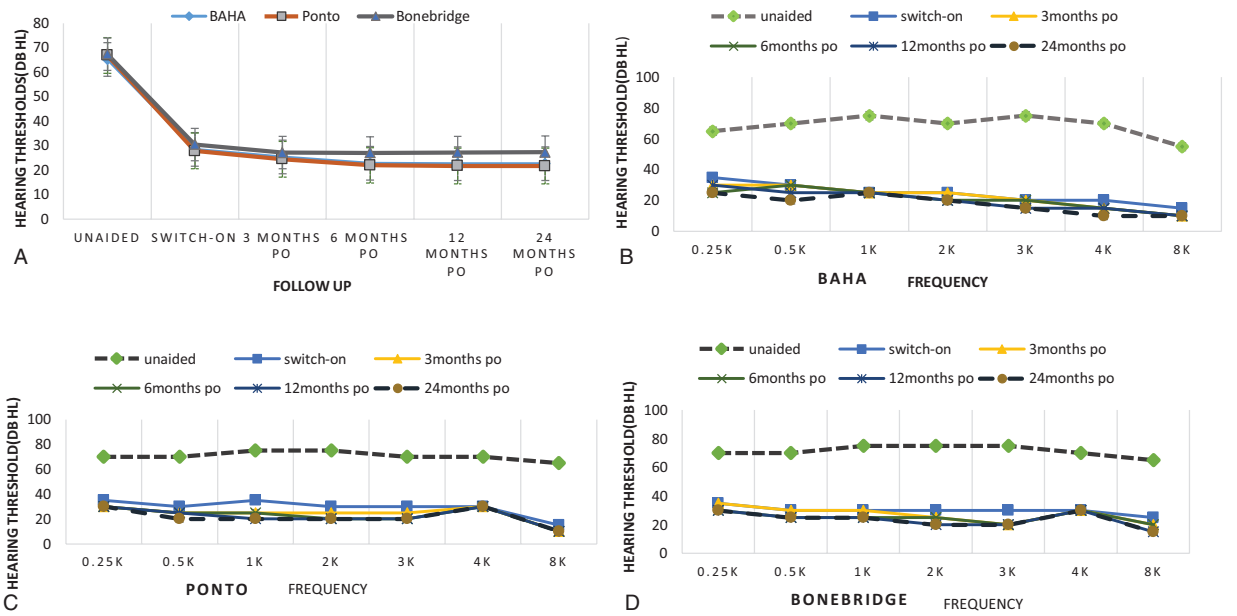

FIG. 1. The mean hearing thresholds (0.5, 1.0, 2.0, 4.0 kHZ) and frequency-specific thresholds after using BCHIs at six time points (unaided, switch-on, 3, 6, 12, 24 mo postoperatively). *A*, The mean hearing thresholds (0.5, 1.0, 2.0, 4.0 kHZ) of BAHA, Ponto, and Bonebridge at six time points. *B*, The frequency-specific (0.25, 0.5, 1.0, 2.0, 3.0, 4.0, 8.0 kHZ) thresholds after using BAHA at six time points. *C*, The frequency-specific (0.25, 0.5, 1.0, 2.0, 3.0, 4.0, 8.0 kHZ) thresholds after using Ponto at six time points. *D*, The frequency-specific (0.25, 0.5, 1.0, 2.0, 3.0, 4.0, 8.0 kHZ) thresholds after using Bonebridge at six time points. The thresholds of switch-on and postoperative time were significantly better than unaided ($p < 0.05$). There was no significant difference across different wearing time points (switch-on, 3, 6, 12, 24 mo postoperatively) ($p > 0.05$). "Po" was the abbreviation for postoperative. BCHI indicates bone conduction hearing implants.

the patients regarded BCHI as a proper option for hearing rehabilitation.

All patients completed the APHAB-CH questionnaire, with patients aged <10 years requiring help from their parents to understand the meaning of the questions. All patients reported considerable benefits from the BCHI, including no restrictions in activities. Figure 4 shows the decrease in scores (thus benefits gained) for the global score, as well as for each subscale.

Complications

Follow-up data were collected. Three (11.5%) of the 26 patients in the BAHA group and one (10%) of the 10 in the Ponto group experienced skin irritation (Holger grades 1–2), but all recovered after local treatment and did not require surgical intervention. Five (19.2%) patients in the BAHA group and two (20%) in the Ponto group experienced abutment extrusion about 6 months postoperatively, with all achieving

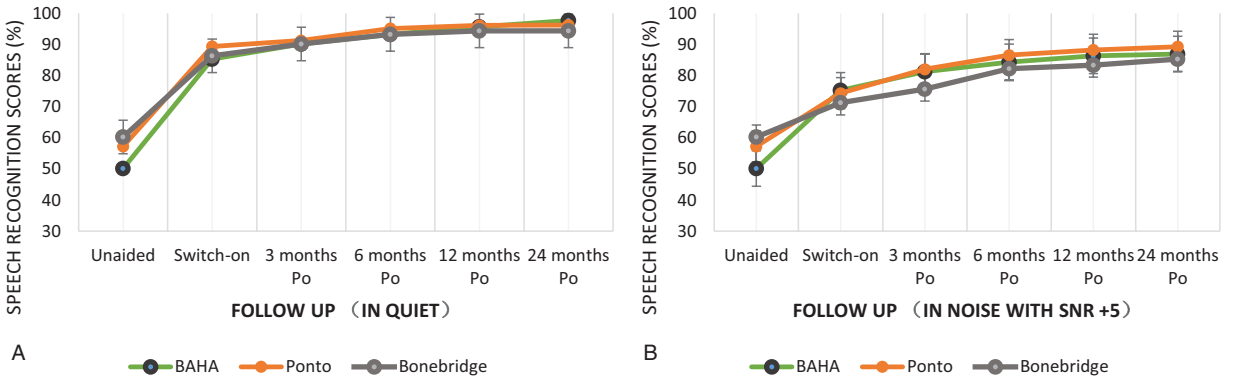

FIG. 2. The speech recognition percentage results both in quiet and in noise. *A*, The speech recognition percentage results in quiet after using BCHIs at six time points (unaided, switch-on, 3, 6, 12, 24 mo postoperatively). *B*, The speech recognition percentage results in noise (SNR +5) after using BCHIs at six time points (unaided, switch-on, 3, 6, 12, 24 mo postoperatively). The mean speech recognition percentages (both in quiet and noise) of all wearing time points (switch-on, 3, 6, 12, 24 mo postoperatively) in these three groups under quiet conditions were significantly better than unaided ($p < 0.05$). Whereas there was no significant difference across different wearing time points (switch-on, 3, 6, 12, 24 mo postoperatively) ($p > 0.05$). "Po" was the abbreviation for postoperative.

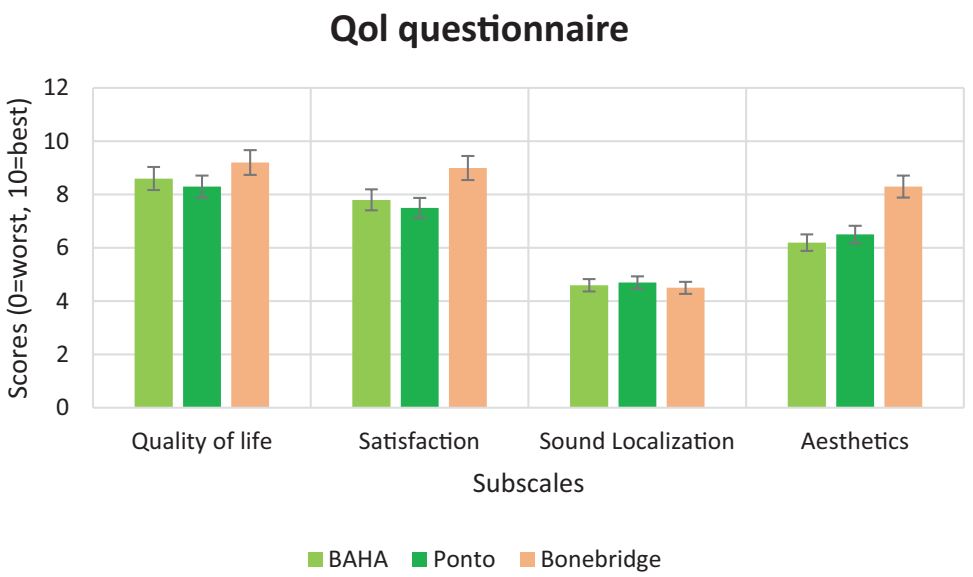

FIG. 3. Qol questionnaire results after using different BCHIs. Quality of life (average score = 8.6, 8.3, and 9.2), satisfaction (average score = 7.8, 7.5, and 9.0), aesthetics (average score = 6.2, 6.5, and 8.3), and sound localization (average score = 4.6, 4.7, and 4.5). Index average from 0 = worst to 10 = best.

good results after revision surgery to replace the abutments. One (3.8%) patient in the BAHA group experienced local chronic inflammation and skin overgrowth covering the abutment, with surgery performed to replace the BAHA implant with a Bonebridge implant. One (4.3%) patient in the Bonebridge experienced a local infection 3 months after surgery; because an abscess was present after 1 week of local treatment, the implant was removed. Skin safety was judged to be ''very good'' or ''good,'' corresponding to scores of 8 to 10 on the visual analog scale, in 45 (76.3%) of the 59 patients. Eleven (18.6%) patients had ''acceptable'' skin safety with scores of 6 to 8, and three (5.1%) had poor skin safety.

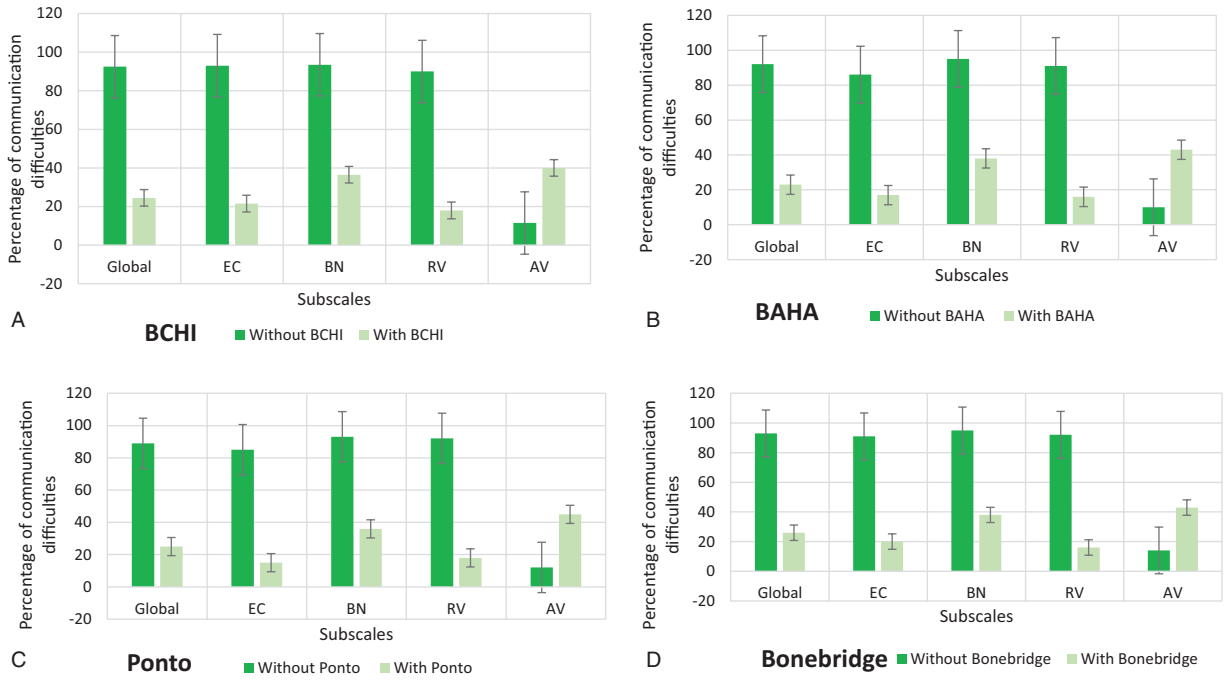

FIG. 4. APHAB scores without and with BCHIs. Global and total APHAB score for each subscale: EC, ease of communication; BN, background noise; RV, reverberation; AV, aversiveness. *A*, APHAB scores without and with BAHA. *B*, APHAB scores without and with Ponto. *C*, APHAB scores without and with Bonebridge.

DISCUSSION

BCHI Is an Optimal Option for Patients With Bilateral Microtia-Atresia Based on a 2-Year Follow-up

Reconstruction of the external ear canal is one of the most frequently performed methods of hearing rehabilitation in patients with congenital aural atresia (16). Several scoring systems have been developed to evaluate the ability of these patients to undergo surgical reconstruction. The Jahrsdoerfer grading system, based primarily on the evaluation of preoperative temporal bone CT scans and development of the external ear, is used most frequently. Hearing rehabilitation in patients with bilateral microtia-atresia is particularly difficult, because of a lack of normal landmarks. Patients with Jahrsdoerfer scores ≤ 5 are not regarded as good candidates for external ear reconstruction (17–19). Moreover, several postsurgical complications, including external auditory canal stenosis or discharge, have prevented most of the patients from using air conduction hearing aids.

In our study, three patients had undergone previous external canal reconstruction, which failed to significantly improve hearing, and experienced canal restenosis within 6 months. Moreover, two patients who had benefited from atresiaplasty surgery had problems with recurrent otitis media and none of these five patients wished to undergo revision surgery. The remaining 54 patients were not considered proper candidates for canal reconstruction according to their Jahrsdoerfer scores, because of their serious middle ear malformations. BCHIs have been used to treat patients with bilateral conductive hearing loss, with patients wearing these devices experiencing good performance and high satisfaction. Few of these previous studies, however, have evaluated long-term outcomes in patients with bilateral microtia-atresia (7,20). After 2 years of follow-up, the complication rates were similar to those reported previously for these devices (21,22).

Clinicians and families might choose one intervention over another depending on several factors, including the skull thickness, the mastoid space, the postoperative appearance, and the postoperative nursing. Before BCHI surgery, all patients in the present study underwent a temporal bone CT scan, the results of which were imported into the three-dimensional simulation software to calculate the skull thickness and mastoid space (23). Patients were graded by the Jahrsdoerfer grading scale (17). BAHA and Ponto are similar percutaneous implants with a 3/4-mm long titanium screw inserted into the mastoid (20,24). The Bonebridge implant is an active transcutaneous bone conduction implant, with a magnetic implant fully inserted into the mastoid under intact skin. Implantation of this device requires a greater mastoid space to fix the implant without damaging the dura or sigmoid sinus. This system has been reported to result in lower complication rates than percutaneous bone conduction implants and shows proven auditory benefits, because percutaneous BCHIs, such as BAHA and Ponto, need lasting careful postoperative nursing (10,11,25). For patients who have enough mastoid space, cannot ensure postoperative nursing or wish a good appearance, the Bonebridge may be an optimal option. For patients who have small mastoid space, the skull sickness is more than 3 mm and the patients themselves or their parents can give postoperative local nursing, the percutaneous BCHIs may be a proper option. In this study, BAHA devices were implanted into six patients who had a skull sickness less than 4 mm using a two-stage procedure, and into 20 patients using a one-stage procedure. One patient with a skull sickness of 3.6 mm underwent Ponto implantation using a two-stage procedure, and nine patients with a skull sickness >4 mm underwent Ponto implantation using a one-stage procedure.

Both Percutaneous and Transcutaneous BCHIs Can Significantly Improve Hearing in Patients With Bilateral Microtia-Atresia

Mean hearing gains 2 years after using the BAHA or Ponto device were similar to those results observed with the BAHA device in 40 patients (26). In this study, hearing improvement and speech recognition percentage in the Bonebridge group were seemly not as good as in the BAHA and Ponto groups, but the statistical result shows no significant differences across these three groups ($p > 0.05$). The Bonebridge is not really a transcutaneous device. While it is true that the power and signal are passed transcutaneously, the actual stimulation is not. The Bonebridge is an active bone-conduction implant which consists of two major parts, a magnetic implant and an external audio processor. The external processor provides active direct-drive transcutaneous conduction to the magnetic receiver under the skin, directly stimulating the bone via an electromagnetic transducer screwed onto the mastoid (11), avoiding skin reduction of the sound. As a result, unlike the traditional actual transcutaneous devices, such as the Baha Attract system and the soft-band BCHIs, the Bonebridge bring a statistically similar auditory result as the percutaneous devices (10).

A postoperative mean hearing threshold of ≤ 30 dB HL has been reported to be a good hearing result in patients with microtia-atresia (3,7,27). All 59 of our patients attained this threshold. In addition, the combination of a hearing threshold of ≤ 30 dB HL and a mean postoperative air-bone gap of ≤ 20 has been regarded as a standard for good results (28), with all of our patients showing these results postoperatively. Thus, implantation of all three BCHIs can provide substantial hearing improvement for patients with bilateral microtia-atresia. These devices allow the bone conducted transmission of sound directly through the cochlea, with no dependence on the degree of malformation of the external and middle ear. Moreover, the surgical procedure is simple to perform and has low morbidity rates. The hearing benefits of BCHI extend beyond the boundaries of audiological tests.

Questionnaires Used for the Subjective Evaluation of BCHI Showed Patient Satisfaction

The questionnaires administered to patients provided another perspective on the advantages of BCHIs in treating patients with bilateral atresia-microtia. In our study, the average scores in patients implanted with the BAHA, Ponto, and Bonebridge devices were consistent with previous results (6,7). The duration of daily use of the device is important in evaluating the efficacy of BCHIs. The average daily use time in 52 patients (89.7%) was longer than 8 hours, similar to previous results showing that 81% and 93% of patients used these devices for more than 8 hours per day (7,29).

All patients in the present study reported that the BCHIs improved comprehension when talking with one person under quiet conditions. Forty-eight (82.8%) patients also reported great satisfaction when listening to music, radio, or television, but the proportion of patients expressing great satisfaction dropped to 50% in group situations, similar to previous findings (7,29). This drop may have been caused by patients benefitting from rehabilitation on only one side not binaurally, which may also explain the results of sound localization. There may have be an element of bias in this study, similar to other studies in which questionnaires can be completed only with parents' assistance. Indeed, some patients may not truly respond to the questions because they were unwilling to worry their parents or did not want others to know the problems they encountered.

The APHAB questionnaire showed that device implantation significantly reduced hearing difficulties under different listening conditions. BCHIs markedly improved the ability of patients to communicate, both in quiet and noisy environments, with a mean score of 90%. AV was greater when wearing BCHIs, because although unaided patients may not have recognized loud sounds as annoying, those using devices heard sounds they had not heard for a long period of time, which may be helpful in hearing restoration. Thus, an increase in AV may be a positive sign of hearing recovery (12,25). The APHAB questionnaire includes quite complicated questions and does not seem to be well understood by young patients, even with their parents' help. Future studies should utilize other means of assessment to evaluate improvements in patient communications.

CONCLUSION

The three bone conduction hearing implants assessed in this study, BAHA, Ponto, and Bonebridge are all reliable methods of hearing rehabilitation for Mandarin-speaking patients with bilateral microtia-atresia. These BCHIs yielded predictable, reliable, and long-term hearing results, with a high rate of patient satisfaction and a significant improvement in patient quality of life.

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