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Auditory Gain, Quality of Life, and Audiological Benefits in Bone-Anchored Hearing Device Users in Fundación Santafé De Bogotá, Colombia

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Abstract

The objective of this study is to determine the auditory gain, quality of life, audiological benefits, in bone-anchored hearing device users (BAHA). It is a retrospective and concurrent evaluation of thirty patients fitted unilaterally and seven fitted bilaterally for at least six months. Patients were assessed with audiometric testing and application of Glasgow Benefit Inventory (GBI) and Abbreviated Profile of Hearing Aid Benefit (APHAB). Regarding sound-field pure audiometry results, we found a statistically significant gain in all frequencies using the bone-anchored device. APHAB scores showed statistically significant subjective audiological gains in all subscales except for the aversiveness subscale. GBI mean scores for all items in both groups were all above 3, suggesting quality of life improvement in conductive and mixed hearing loss patients. BP100 users showed a greater clinical gain in the APHAB global score and subscales compared with Divino users. In conclusion the BAHA provides significant auditory gain, subjective audiological benefits and improves quality of life in all BAHA users. This study shows a significant clinical and statistical benefit of BAHA measured by audiometric testing and by the APHAB and GBI questionnaires.

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Keywords

BAHA, Quality of Life, Audiological Benefits, Auditory Gain

1. Introduction

The Bone Anchored Hearing Aid, (BAHA) based on the concept of osseointegration coined by Branemark *et al.* [1], consists in stimulating the cochlea by bone-conducted transmission. Von Bekesy's [2] experiments showed that direct stimulation of the cranium induced the same cochlear transduction mechanism than air-conduction. In 1977 Tjellstrom [3] presents the first three patients with conductive hearing loss implanted with a hearing aid transducer coupled directly to a percutaneous titanium implant, thus establishing the beginning of osseointegration in otology [3]-[5].

Conductive hearing loss can be treated, according to the etiology, clinically, surgically or with traditional hearing aids. However, there are a number of patients who, for multiple reasons, don't respond to these treatments. In fact, in the surgery for congenital hearing defects, even in very experienced hands, the outcomes are difficult to predict and high complications rates still remain [6]-[8]. In these groups of patients, BAHAS are a solution.

BAHA indications include conductive and mixed hearing loss, unilateral or bilateral, and more recently severe and profound unilateral sensorineural hearing loss [9]-[11]. In order to assess patient's satisfaction and quality of life with hearing aids, several questionnaires have been used in adults (12;13) [12] [13] and children [14]-[16] with different hearing profiles, unilateral or bilateral hearing losses, whether congenital or acquired [13] [16], and Down síndrome [17] [18]. These questionnaires evaluate the effects of hearing loss on the daily lives of the patients and the benefits experienced by the patients when using the hearing aids. The questionnaire must also precisely measure the contribution of the implant to the quality of life of the patient and assess his opinion about his general state health [12] [15] [16]. In many studies, the Abbreviated Profile of Hearing Aid Benefit (APHAB) questionnaire has been used to assess subjective benefit in hearing aid users [19]-[22], and the Glasgow Benefit Inventory has been appropriate to assess the quality of life after the surgical procedure [23]-[25].

The main purpose of this study was to evaluate auditory gain, quality of life, audiological benefits, and to relate types of hearing loss to the quality of life and patient satisfaction in patients fitted with BAHA in the FundaciónSantafé, Bogotá, Colombia.

2. Materials and Methods

2.1. Patients

This is a retrospective and concurrent study conducted in an otologic referral center (Otolaryngology Department, Hospital Universitario, Fundación Santafé, (FSFB), Bogotá, Colombia). 37 patients were evaluated with the APHAB and GBI questionnaires, and 32 patients with audiometric testing, which includes 25 patients fitted with unilateral BAHA and 7 fitted with bilateral BAHA (39 ears), between 2003 and 2011. All patients with osseointegrated BAHA were invited to participate in this study. The study was approved by the ethics committee of Fundación Santafé de Bogotá.

2.2. Methods

Audiometric measurement included sound-field pure-tone audiometry and sound-field speech audiometry. They were taken at clinical consultation with and without the semi-implantable bone-conduction sound processor fitted in place. Air-conduction thresholds in sound-field pure-tone audiometry at frequencies 0.25, 0.5, 1, 2, 3 and 4 kHz were recorded using calibrated warble tones [26]. Hearing improvement was calculated by subtracting the aided thresholds at different frequencies from air-conduction thresholds without the device.

Speech audiometry was performed using a list of bisyllabic spondees Spanish words to calculate the speech reception threshold and maximum speech discrimination (% and dB). Sound stimuli were delivered from 2 loudspeakers placed at horizontal azimuth of 0 degrees [26] [27]. All the measurements were conducted in sound-treated double-walled booths by 1 experienced audiologist [19].

Two questionnaires were used in this study: the Glasgow Benefit Inventory (GBI) and Abbreviated Profile of Hearing Aid Benefit (APHAB) and the subjects completed both questionnaires in a follow up consult and were supervised by an audiologist and a medical student who explained the different questions when needed. Children always responded to the questionnaires in company of their parents.

The GBI is a retrospective generic quality-of-life questionnaire developed by Robinson *et al*. [28] to measure outcomes after otorhinolaryngologic procedures. It is sensitive to changes in health status that result from an intervention, and it enables comparisons between different interventions. 18 items cover three domains, 12 related to general improvement, 3 to social improvement, and 3 to physical improvement. Responses can be given on a 5-point Likert scale. Scores range from −100 (maximum lack of benefit), to 0 (no benefit), to + 100 (maximum benefit) [29]. We used the Spanish translation given by the Institute of Hearing research web site [29].

The APHAB is a hearing disability specific questionnaire that assesses auditory functioning with 24 items scored in four 6-item subscales [30]. It produces scores for unaided and aided conditions, and benefit is calculated by comparing the patient's reported difficulty in the unaided condition with their difficulty with amplification. Three of these subscales address speech understanding in various everyday environments: ease of communication (EC, under relatively favorable conditions), listening under reverberant conditions (RV, communication in reverberant rooms), and listening in background noise (BN, in settings with high background noise levels). The aversiveness (AV) of sounds subscale measures the negative reactions to environmental sounds. The APHAB has a scoring scale from 1 to 99; the higher the score, the greater the hearing disability. An overall difference in the scores of more than 10 points for a given subscale (EC, RV, BN, and AV) was considered statistically significant [19] [30]. We used the Spanish version of the APHAB provided by the University of Memphis website [31].

2.3. Statistical Analysis

The audiometries, GBI and APHAB questionnaires variables were explored using medians and interquartile ranges. For each audiological test, d_i is defined as the difference between the results of the test between the i ear with and without BAHA. We intended to prove the null hypothesis (H0): No difference exists between the results with and without the bone-anchored hearing device, as opposed to the alternative hypothesis (HA): The bone-anchored hearing aid results in audiological and audiometric benefits. In order to prove/reject these hypotheses, we used the Wilcoxon signed rank test for paired samples due to the lack of normal distribution of data. The same methodology was used to evaluate the differences in the APHAB for the different subscales and for the global scores. Results for the GBI questionnaire between mixed and conductive hearing loss were assessed using the U Mann-Whitney test. This test was used due to the presence of independent samples and ordinal variables. In addition, the U Mann-Whitney test was also used to determine if the difference between unaided and aided results were determined by the type of hearing loss in the implanted ear or by the type of the processor. Moreover, we used a regression model that adjusted baseline hearing levels in order to determine basal differences between groups, where gains were analyzed as the dependent variable, patient groups as the factor variable and the basal level scores as covariates. A level of significance of $\alpha = 0.05$ was chosen, and a p value lower than α rejected the null hypothesis. The statistical analysis was performed using the statistical software, SPSS.

3. Results

Our results showed a male/female relation of 1.3:1 and subject's age ranged from 9 to 67 years old. One patient wasn't audiometrically assessed due to non-use of the technology, and 4 patients with sudden sensorineural hearing loss weren't audiometrically assessed because the contralateral ear would always be evaluated, but were evaluated with the APHAB and GBI questionnaires. Concerning hearing loss in the implanted ear, 49% (n = 18) of patients experienced mixed hearing loss, 41% (n = 15) presented with conductive hearing loss, and 10% (n = 4) presented with sensorineural hearing loss. In unilateral patients, hearing level in the contralateral ear was 48% (n = 14) with mixed hearing loss, 21% (n = 6) with normal hearing, 17% (n = 5) with sensorineural hearing loss, and 14% (n = 4) presented with conductive hearing loss.

The etiologies of the hearing loss in the implanted ear are summarized in **Table 1**. Of note, one patient had both chronic otitis media and mastoidectomy. Also noteworthy, 21 patients had External Auditory Canal Agenesia.

Table 1. Baseline characteristics of patients.

Variable	Category	Patients n (%)
Age of Activation Median		32 (9 - 63)
Gender	Male	21 (57%)
	Female	16 (43%)
Amplification	Unilateral	30 (81%)
	Bilateral	7 (19%)
Etiology	Bilateral Microtia	11 (29%)
	Unilateral Microtia	10 (26%)
	Bilateral Mastoidectomy	5 (13%)
	SensorineuralHearingLoss	4 (10%)
	Chronic Otitis Media	2 (5%)
	Teacher Collins syndrome	2 (5%)
	Pfiffersyndrome	2 (5%)
	Unilateral Mastoidectomy	2 (5%)
Hearing Loss in the ear with the Device	Mixed	18 (49%)
	Conductive	15 (41%)
	Sensorineural	4 (10%)
Unilateral patients. Hearing in contralateral ear.	Mixed	14 (48%)
	Normal	6 (21%)
	Sensorineural	5 (17%)
	Conductive	4 (14%)
Processor	Bp100	22 (61%)
	Divino	12 (33%)
	Ponto	2 (6%)

3.1. Comparison of Audiometric Gain Results

Regarding sound-field pure tone audiometry results, we found a statistically significant gain in all frequencies using the bone-anchored device ($p < 0.001$) (**Table 2**, **Figure 1**). Moreover, sound-field speech audiometry results showed a significant increase in maximum speech discrimination at 60 dB ($p < 0.001$) (**Figure 1**).

3.2. Audiological Benefits. APHAB Results.

The global APHAB score significantly decreased 28 points (from 55% to 27%, $p < 0.001$). Mean scores for all the subscales (EC, RV, BN and AV) were all above the difference of 10-point level. Scores in all subscales significantly decreased, except for the aversiveness subscale, which significantly increased 49 points from 6.83 to 56 ($p < 0.001$) (**Table 2**).

3.3. Quality of Life. GBI Results.

We found statistically significant gain on the GBI overall scale, and general and physical benefit subscales (**Table 3**) on mixed hearing loss patients compared to conductive hearing loss patients; except for the social support

Table 2. Comparison of audiometric and APHAB results with and without the bone-conduction device.

	Without	With	p
Sound-field pure tone audiometry			
Air-conduction threshold at 250 Hz	60 (55 - 65)	25 (15 - 30)	<0.001
Air-conduction threshold at 500 Hz	65 (60 - 70)	25 (15 - 30)	<0.001
Air-conduction threshold at 1000 Hz	60 (55 - 70)	20 (15 - 30)	<0.001
Air-conduction threshold at 2000 Hz	55 (50 - 65)	20 (15 - 30)	<0.001
Air-conduction threshold at 3000 Hz	60 (55 - 65)	25 (15 - 35)	<0.001
Air-conduction threshold at 4000 Hz	60 (55 - 75)	25 (20 - 35)	<0.001
Air-conductionthreshold PTA	62 (55 - 67)	25 (17 - 32)	<0.001
Sound-fieldspeechaudiometry			
Percent of maximum speech discrimination at 60 dB	0 (0 - 15)	100 (90 - 100)	<0.001
APHAB scales			
Ease of communication	57 (39 - 83)	7 (2 - 17)	<0.001
Backgroundnoise	71 (50 - 89)	19 (10 - 33)	<0.001
Reverberation	5 (42 - 83)	19 (12 - 26)	<0.001
Aversiveness	**7 (1 - 22)**	**56 (37 - 79)**	**<0.001**
APHAB global score	55 (36 - 63)	28 (19 - 34)	<0.001

Median values and interquartile ranges and Wilcoxon p values.

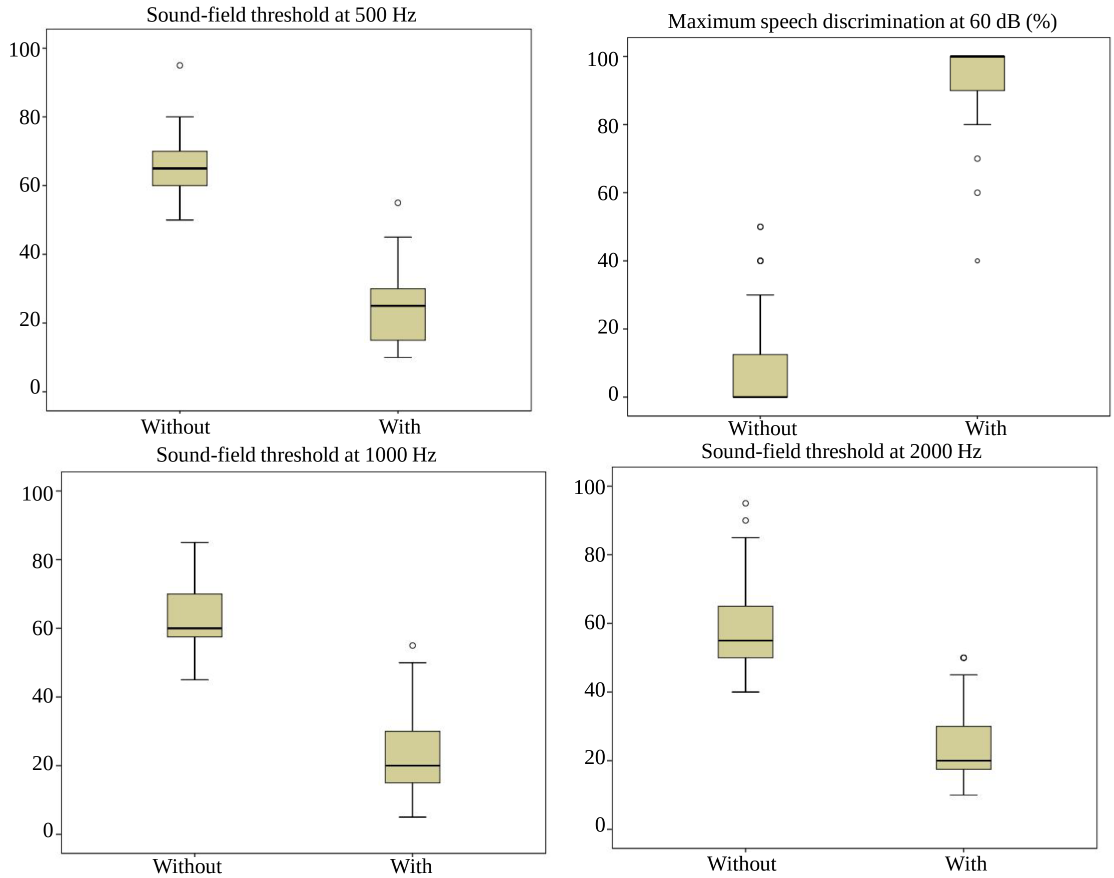

Figure 1. Sound-field pure tone audiometry and maximum speech discrimination at 60 dB with and without the bone-anchored hearing device.

Table 3. Comparison in GBI results between conductive and mixed hearing loss patients.

	Conductivehearingloss	Mixedhearingloss	p
General benefit	38 (25 - 58)	54.17 (45 - 71)	0.042
Physicalbenefit	0 (0 - 33)	25 (17 - 50)	0.019
Social supportbenefit	**17 (0 - 67)**	**50 (33 - 71)**	**0.154**
Overallbenefit	50 (36 - 64)	69 (54 - 75)	0.006

Median and interquartile ranges and wilcoxon p values.

scale, where no statistically significant results were found. The mean scores for all items in both groups were all above 3, suggesting quality of life improvement in conductive and mixed hearing loss patients [24]. Sensorineural hearing loss was not analyzed due to the small number of patients with this type of hearing loss.

3.3. Audiological and APHAB Results According to Type of Hearing Loss

Table 4 summarizes the audiological and APHAB results without the device and comparisons between audiological and APHAB gains depending on the type of hearing loss in the implanted ear. Without the device, statistically significant audiometric differences were found in the two groups of patients: conductive hearing loss in comparison with mixed hearing for air-conduction thresholds of 500 Hz, 3 KHz and 4 KHz ($p < 0.001$).

With the device, audiometric results show a gain in the group of patients with conductive hearing loss for sound-field pure tone audiometry at the 1 KHz frequency. Moreover, adjusted results for the unaided condition (without) only revealed statistically significant results for the air conduction threshold PTA and for frequencies at 1 KHz and 2 KHz.

In terms of APHAB results for the unaided condition (without the device) and for the aided condition (with the device), no statistically significant differences were found between the two groups of patients with conductive and mixed hearing loss (**Table 4**).

3.4. Results According on Type of Processor

No statistically significant differences between BP100 and Divino users were found for audiological or APHAB results (**Table 5**). Adjusted results for unaided condition (without) didn't show statistically significant differences both audiometrically and for the APHAB results. However, the BP100 did show greater overall gains in all subscales.

4. Discussion

The present study aimed to evaluate objective and subjective benefits, as well as improvement of quality of life after the BAHA surgery in our cohort, using 3 different instruments for the results evaluation.

Many studies have assessed objective audiometric benefits, subjective benefits using the Glasgow Benefit Inventory Questionnaire, or quality of life benefits using the Abbreviated Profile of Hearing Aid Benefit Questionnaire [19]-[25] [28] [30]. However, few published studies have addressed these three instruments simultaneously, and only one study has adjusted for the unaided conditions [19]. Our study seeks to address if these three instruments used to measure benefits in BAHA patients result in positive outcomes.

4.1. Objective Audiometric and Speech Discrimination Gain

First, our results correlate with those published by other authors, [11] [19] [32]-[34] who found statistically significant improvements in nearly all audiometric results (sound-field pure-tone audiometry and sound-field speech audiometry) and subjective satisfaction measures. Our study validates their findings in our cohort, as we also found an increase gain in all frequencies in pure-tone audiometry using the device. Unadjusted results for the unaided condition (without) revealed no statistically significant differences for sound-field pure tone audiometry between conductive hearing loss and mixed hearing loss patients. However, adjusted results for the unaided condition (without) did reveal statistically significant gains for conductive hearing loss patients compared with mixed hearing loss in air-conduction thresholds 1 kHz, 2 kHz and PTA, which correlates with results found in other surveys [19].

Table 4. Audiometric and APHAB results without the device and gains depending on type of hearing loss in the implanted ear.

	Without			Gain			
	Mixed[a]	Conductive[a]	***U***[b]	Mixed[a]	Conductive[a]	***U***[b]	*p*[c]
Sound-field pure tone audiometry							
Air-conduction threshold at 250 Hz	60 (55 - 65)	58 (55 - 64)	0.34	38 (29 - 45)	40 (26 - 45)	0.81	0.339
Air-conduction threshold at 500 Hz	68 (65 - 70)	63 (60 - 65)	**0.03**	43 (35 - 45)	40 (35 - 50)	0.76	0.263
Air-conduction threshold at 1000 Hz	60 (59 - 70)	60 (50 - 70)	0.5	38 (25 - 45)	40 (35 - 50)	0.04	**0.01**
Air-conduction threshold at 2000 Hz	60 (50 - 70)	55 (50 - 60)	0.27	35 (24 - 41)	38 (30 - 40)	0.3	**0**
Air-conduction threshold at 3000 Hz	65 (55 - 68)	58 (48 - 60)	**0.01**	38 (30 - 45)	33 (30 - 40)	0.34	0.291
Air-conduction threshold at 4000 Hz	70 (55 - 85)	55 (51 - 60)	**0.02**	38 (25 - 41)	33 (26 - 39)	0.54	0.226
Air-conductionthreshold PTA	63 (57 - 70)	62 (51 - 66)	0.15	38 (31 - 43)	39 (33 - 46)	0.14	0.013
Sound-fieldspeechaudiometry							
Percent of maximum speech discrimination at 60 dB	0 (0 - 11.25)	0 (0 - 25)	0.78	90 (68 - 100)	100 (73 - 100)	0.17	0.074
APHAB scales							
Ease of communication	66 (49 - 92)	52 (31 - 79)	0.347	57 (27 - 82)	37 (11 - 78)	0.32	0.284
Backgroundnoise	83(66 - 97)	52 (30 - 71)	0.015	72 (23 - 79)	38 (-2 - 61)	0.16	0.385
Reverberation	83 (73 - 88)	58 (36 - 79)	0.03	64 (49 - 71)	33 (-5 - 66)	0.08	0.431
Aversiveness	6 (1 - 13)	5 (1 - 26)	0.522	−46 (−60 - −29)	−51 (−68 - −18)	0.6	0.595
APHAB global score	60(50 - 68)	49 (28 - 61)	0.104	34 (15 - 47)	23 (−8.25 - 39)	0.17	0.488

[a]Median values and interquartile ranges; [b]U Mann-Whitney test, p values; [c]Regression model p values for gain adjusted for hearing.

Table 5. Audiometric and APHAB results without the device and gains depending on type of implant.

	Without			Gain			
	Divino[a]	BP100[a]	***U***[b]	Divino[a]	BP100[a]	***U***[b]	*p*[c]
Sound-field pure tone audiometry							
Air-conduction threshold at 250 Hz	65 (55 - 70)	60 (55 - 64)	0.17	40 (35 - 45)	38 (25 - 45)	0.3	0.605
Air-conduction threshold at 500 Hz	70 (60 - 75)	65 (60 - 70)	0.1	45 (40 - 50)	40 (35 - 45)	0.08	0.326
Air-conduction threshold at 1000 Hz	60 (50 - 80)	60 (56 - 69)	0.49	40 (35 - 45)	40 (26 - 45)	0.35	0.672
Air-conduction threshold at 2000 Hz	55 (45 - 80)	55 (50 - 69)	0.9	35 (25 - 40)	38 (30 - 44)	0.4	0.438
Air-conduction threshold at 3000 Hz	60 (45 - 85)	60 (55 - 64)	0.74	40 (30 - 45)	35 (30 - 40)	0.36	0.456
Air-conduction threshold at 4000 Hz	55 (50 - 85)	58 (55 - 68)	0.74	35 (30 - 40)	32.5 (25 - 40)	0.39	0.817
Air-conductionthreshold PTA	60 (55 - 75)	62 (55 - 67)	0.59	38 (35 - 45)	38 (32 - 45)	0.41	0.701
Sound-fieldspeechaudiometry							
Percent of maximum speech discrimination at 60 dB	0 (0 - 10)	0 (0 - 25)	0.5	90 (80 - 100)	95 (60 - 100)	0.83	0.624
APHAB scales							
Ease of communication	50 (25 - 95)	71 (47 - 90)	0.215	24 (0 - 82)	65 (35 - 78)	0.1	0.064
Backgroundnoise	83 (44 - 97)	72 (60 - 94)	0.756	55 (−2 - 78)	57 (28 - 77)	0.59	0.149
Reverberation	69 (36 - 87)	80 (60 - 84)	0.331	49 (−4.5 - 75)	62 (37 - 69)	0.5	0.758
Aversiveness	5 (1 - 14.5)	6 (1 - 24)	0.617	−61(−68 - −29)	−49 (−57 - −19)	0.26	0.446
APHAB global score	54 (30 - 68)	58 (49 - 66)	0.342	27 (−25 - 38)	33 (21 - 43)	0.25	0.215

[a]Median values and interquartile ranges; [b]U Mann-Whitney test, p values; [c]Regression model p values for gain adjusted for hearing.

4.2. Subjective Audiological Benefits (APHAB)

Again, our results correlate with published reports indicating global subjective audiological benefits, but still lack of benefit of the aversiveness subscale [19] [34] [35]. Our report further highlights the need for improvement in auditory aversive situations. Similarly to the results published by Boleas-Aguirre [19], we didn't find statistically significant differences between conductive and mixed hearing loss without and with the processor.

4.3. Quality of Life Benefits

Regarding the Glasgow Benefit Inventory results, most of the subscales revealed statistically significant differences between conductive hearing loss and mixed hearing loss patients. Studies have compared GBI results between bilateral and unilateral patients [11] [24] revealing more subjective and objective benefit for bilateral patients; however, statistically significant differences between conductive and mixed hearing loss patients for GBI results have yet to be proved. We argue that due to the small number of patients in studies comparing conductive and mixed hearing loss patients, it is still difficult to thoroughly compare quality of life between these two groups. The precision of the different results are very low due to the small number of the patients.

4.4. Type of Processor

Our findings didn't show any statistically significant audiometric differences in gain between Divino and BP100 users. However, BP100 users showed more clinically significant gains in the APHAB global score and Ease of communication subscale. Likewise, one study by Boleas-Aguirre *et al*. compared audiometric and APHAB results between the Compact, Divino and Intenso processors and didn't find any difference between these three processors [19]. Another study by Wazen *et al*. stated that the Intenso processor resulted in better subjective hearing satisfaction than the Divino [36]. Specifically, a recent study by Pfiffner *et al*. showed that speech understanding in noise is significantly better with the Baha BP100 than with the Baha Divino [37]. Moreover, in patients with single-sided deafness, significantly better results for the Background Noise and Reverberant Conditions subscales, and better average results for the Ease of Communication scale, have also been found when comparing the BP100 processor with the other model [38]. Therefore, our study further highlights the audiological subjective benefits provided by the BP100 in comparison with the Divino model in our specific studied group.

5. Conclusion

In our group of patients, the BAHA provides significant auditory gain, subjective audiological benefits and improves quality of life in all BAHA users examined. When adjusted for the unaided conditions, statistical significance is achieved in some variables; thus, we recommend using the adjusted models in order to obtain better precision of the results.

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