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The Birmingham bone anchored hearing aid programme: referrals, selection, rehabilitation, philosophy and adult results

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Abstract
The Birmingham bone anchored hearing aid team is part of the Birmingham osseointegrated programme. In the first seven years of its existence it has received 309 referrals. Twenty-six per cent had suffered a congenital conductive hearing loss and 74 per cent had an acquired conductive hearing loss; the majority secondary to chronic suppurative otitis media.

This report is of 68 out of 106 adults wearing bone anchored hearing aids (BAHAs). Ninety-eight per cent showed audiological improvement with the congenital group demonstrating marginally the best free-field thresholds and speech discrimination. Questionnaire data as to the patient experience confirms the benefits especially hearing in noise, and comfort, and the vast majority were more satisfied with the bone anchored hearing aid than their previous aid.

Key words: Hearing aids, bone anchored; Audiology; Outcome and process assessment (health care)

Introduction

Bone anchored hearing aids (BAHA) are used in the rehabilitation of patients with bilateral conductive hearing loss. The main groups that benefit from this type of treatment are those patients with either chronic middle ear disease, or congenital conductive hearing loss and in some cases otosclerosis. There are existing surgical and hearing aid rehabilitation options for these patients, but the BAHA offers a new dimension of treatment.

A multi-disciplinary osseointegrated team was instigated at the Queen Elizabeth Hospital, Birmingham in mid-1988 to provide the BAHA and facial prostheses secured by titanium implants. A team is composed of otolaryngologists, audiologists, maxillofacial surgeons and maxillofacial prosthetists and later a specialist speech therapist for the hearing-impaired. Osseointegration was pioneered by Branemark *et al.* (1969) in the mid-1960s and has been used in Gothenburg, Sweden to secure BAHAs since 1977 (Hakansson *et al.*, 1985, 1990).

This paper will decribe the first seven years experience using the Nobel Biocare auditory system HC200/300 (ear level) and HC220 (transducer in conjunction with Philips S 1694 body-worn aids) on adult patients seen at The Queen Elizabeth Hospital, Birmingham.

Referrals

To date, the programme has received 309 referrals for the BAHA from around the United Kingdom. Many of these referrals have been for patients not only seeking the BAHA but also facial prostheses. Of the referrals received, 26 per cent were patients with congenital conductive hearing loss, for example, Treacher Collins Syndrome, hemi-facial microsomia, Goldenhaar's syndrome, bilateral or unilateral atresia, and 74 per cent were patients with an acquired conductive hearing loss. Most of these were due to chronic suppurative otitis media but some were otosclerotic, one was trauma (gun shot) and one had carcinoma of the external ear.

A breakdown of these referrals shows the outcomes of assessment (Table I). The results of the adult group only will be reported (Table II).

Selection

All patients selected to receive a BAHA must have met audiological criteria. The assessment includes a pure tone audiogram with air and bone conduction, a speech audiogram using Boothroyd word lists, loudness discomfort levels, a free-field warble tone audiogram and a free-field speech audiogram. The free-field tests are performed unaided with the patient's existing hearing aid, and if the old hearing aid is an air conductive device, these tests are carried out with a conventional bone

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TABLE I
BREAKDOWN OF REFERRALS (AS AT 13/9/95)

	Adults	Children	Total
BAHA users	104	21	125
BAHA fitted, non-users	2	0	2
Found suitable, decided against BAHA	25	1	26
Unsuitable	71	3	74
Fitted elsewhere	0	1	1
Under assessment	59	6	76
Did not attend for assessment	3	2	5
Totals	264	34	309

conduction hearing aid and/or a BAHA attached to a bite bar.

If the existing aid is old or inadequate for the patient's hearing loss, a new appropriate aid(s) will be fitted before testing so that all patients will be tested against their previous optimal aiding. Finally there follows a questionnaire about the use of the present hearing aid and their feelings about it.

The audiological criteria for a BAHA are:

(1) Average bone conduction thresholds (0.5–4 kHz) <40 dBHL (ear level) <60 dBHL (bodyworn).
(2) Speech discrimination score greater than 60 per cent.
(3) Realistic expectations.
(4) Reasonable social support.

TABLE II
ADULT REFERRALS

Congenital cases Total = 48		
General 19	Unsuitable = 12; Suitable = 7	Wearing BAHA = 5; Awaiting op/aid = 2
Treacher Collins syndrome 21	Unsuitable = 4; Suitable = 17	Wearing BAHA = 16; Awaiting op/aid = 1
Thalidomide 2	Suitable = 2	Wearing BAHA = 2
Ushers syndrome 1	Unsuitable = 1	
Noonans syndrome 1	Unsuitable = 1	
Goldenhaar's syndrome 3	Suitable = 3	Awaiting op/aid = 3
Klippel-Feil syndrome 1	Suitable = 1	Wearing BAHA = 1
Acquired cases Total = 216		
CSOM 180	Unsuitable = 62; Suitable = 106; For tests/decision = 12	Wearing BAHA = 71; Waiting for op/aid = 35
Otosclerosis 33	Unsuitable = 13; Suitable = 20	Wearing BAHA = 12; Waiting op/aid = 8
Trauma 2	Unsuitable = 2	
Cancer 1	Unsuitable = 1	

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BAHA candidates are given the opportunity to discuss the surgical procedure and the advantages and disadvantages of the BAHA including other available options. The patients' expectations need to be realistic if disappointment when the BAHA is first fitted is to be avoided. During assessment each new patient must meet another patient who has been fitted with a BAHA on the programme so that all questions may be asked without the presence of involved professionals. The final decision as to whether the patient will receive a BAHA is made by the multi-disciplinary team, in conjunction with the patient. Most importantly, patients that are found to be unsuitable for the programme are not abandoned. They are offered whatever rehabilitation is needed to improve quality of life whether that be a change of hearing aid (including a cochlear implant), support from other professionals or referral to other appropriate agencies. The BAHA programme is structured so that every patient whether suitable, or unsuitable, receives equal and appropriate care sufficient to meet their needs.

Rehabilitation

Once selected for a BAHA a treatment plan is formulated and it is at this point that a decision is made as to whether input from speech therapy is indicated. The specialist speech therapist provides not only appropriate speech therapy as required but also a counselling and support role for any BAHA patients requiring this help, as well as analytical auditory training if appropriate. Patients are expected, especially in the first year, to attend the clinic regularly so that an assessment of the benefit they are gaining can be made, and to provide continuous support (see paper by Thomas, J. S., in this supplement).

Results

Audiological and questionnaire data are gathered on all BAHA patients both pre-operatively and at one month, six months and 12 months post-fitting of the BAHA and annually thereafter.

For the purposes of data analysis, pure tone averages are calculated from the thresholds at 500, 1000, 2000, 3000 and 4000 Hz. For analysis of the free-field speech results, the parameter used is the percentage discrimination at 63 dB(A). This figure is obtained in three conditions, namely without any aid, with the existing conventional aid and with the BAHA. The average free-field warble tone threshold (at the same frequencies as described above) is also obtained in the same three conditions.

The questionnaires used are designed to show the usage and satisfaction with both the old (conventional) aid and the BAHA. Both a semantic differential method and a closed set multiple choice method are used to obtain patients' subjective impression. Satisfaction ratings in marks out of ten are also obtained both for the old aid and the BAHA.

The results described relate to the adult group of patients, minimum age 17 years. Of the 106 patients wearing their BAHAs, 68 were successfully followed-up. All the data for analysis were taken from the pre-operative assessment and six months post-BAHA fitting assessment. The six-month data set was chosen because patients had achieved the main benefits with the BAHA by this stage. The aetiology of conductive hearing loss varies amongst the patient group but falls into two main categories, chronic suppurative otitis media (CSOM) and congenital (CON). For the purposes of this analysis the patients are divided into four groups based upon their aetiology and their previous hearing aid use as follows:

(1) CSOM, previous air conduction aid. (CSOM/AC) – 24 patients;
(2) CSOM, previous bone conduction aid. (CSOM/BC) – 19 patients;
(3) Congenital, previous air conduction aid. (CON/AC) – nine patients;
(4) Congenital previous bone conduction aid. (CON/BC) – 16 patients.

It is hypothesised that both the aetiology of conductive hearing loss and the type of hearing aids used before the BAHA will have significant effects upon the results obtained with the BAHA.

A statistical comparison, based on the Students unpaired *t*-test, was made between the CSOM groups and the CON groups for age and pure tone average thresholds. Statistical analysis of the free-field warble tone thresholds and free-field speech discrimination scores (at 63 dB) was based on the Students paired *t*-test. For each group, results observed with the BAHA were compared with those with the patient's old aid.

Statistical analysis of the questionnaire results was made using the sign test for paired samples. Each group was considered separately and due to low numbers the better +1 and better >1 scores were combined.

Figure 1 shows the mean ages for each of the groups. The congenital group are significantly younger than the CSOM group ($p<0.01$) and their mean age is approximately half that of the CSOM group.

The youngest case with CSOM was aged 30 years and this finding is not surprising because conventional methods of treatment of chronic middle ear disease are still being applied to that younger group.

Figures 2, 3 and 4 show the pure tone average thresholds (AC and BC) and air bone gap for each of the groups. There is no significant difference between the CSOM and congenital groups for the air conduction thresholds ($p>0.05$). For bone conduction, pure tone averages are significantly better in the congenital group than in the CSOM group ($p<0.01$). Indeed, the bone conduction thresholds for the congenital group are on average just inside the normal range (overall group mean 17.2 dBHL), whilst the group means for the CSOM patients are both outside the normal range. It would appear from this that the congenital group have more purely

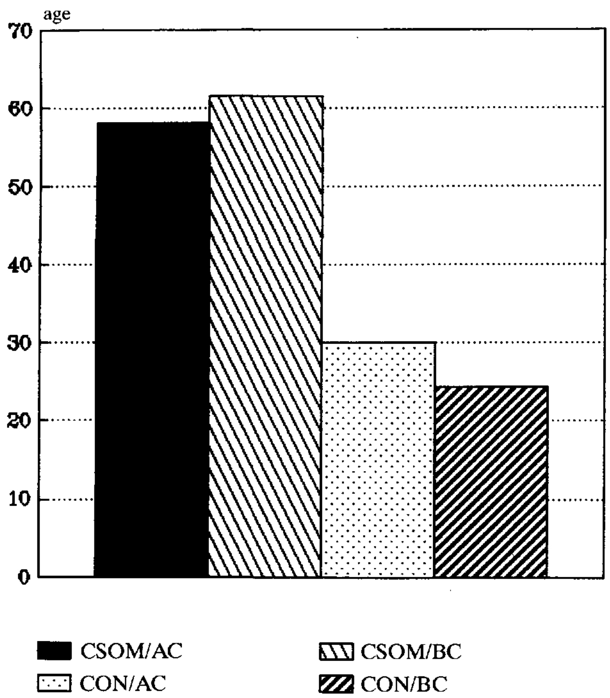

FIG. 1

Mean age of each group of adult patients (see text for explanation of each group title).

conductive hearing losses whilst the CSOM patients have an additional sensorineural element most likely from their chronic middle ear disease and greater age. As expected the mean air bone gaps are greatest for the congenital group and thus this group can be expected to obtain the greatest gain from their BAHA.

Figure 5 shows the mean free-field warble tone thresholds for each group. The results with no aid, the old (conventional aid) and with the BAHA are compared. In all cases the aided thresholds are significantly better with the BAHA than with the previous aid ($p<0.01$, all groups). The average improvement in free-field thresholds is very similar for the CSOM and congenital groups at approximately 10 dB. Figure 6 shows the number of cases in each group that gave worse, same or better (by more than 5 dB) warble tone thresholds in each group.

In Figures 7 and 8, the aided and unaided free-field speech discrimination scores at 63 dB are

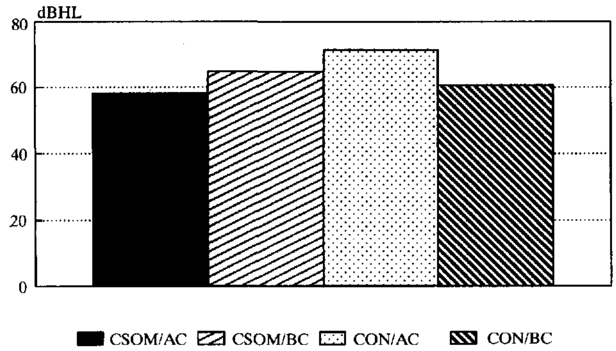

FIG. 2

Mean pure-tone hearing thresholds (air conduction, 500–4000 Hz) for each patient group.

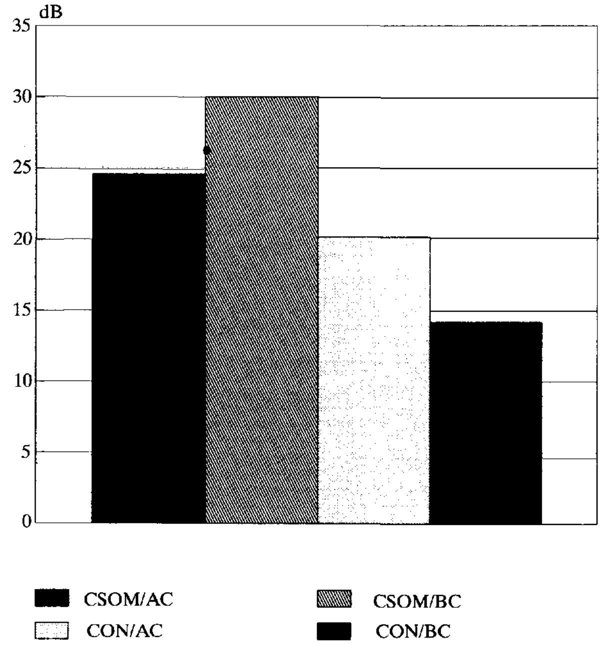

FIG. 3

Mean pure-tone hearing thresholds (bone conduction, 500–4000 Hz) for patient group.

shown. For the CSOM/AC and BC and CON/BC groups, the differences between the speech discrimination scores obtained with previous aid and with the BAHA were not significant ($p>0.05$). However, the CON/AC patients showed a significant improvement with the BAHA ($p<0.05$). The CSOM/AC group contained the largest proportion of cases with worse speech discrimination with the BAHA.

The questionnaire consisted of 15 questions of which the first 11 will be considered here. (Questions 12–15 related to hardware usage and views on the service provided.)

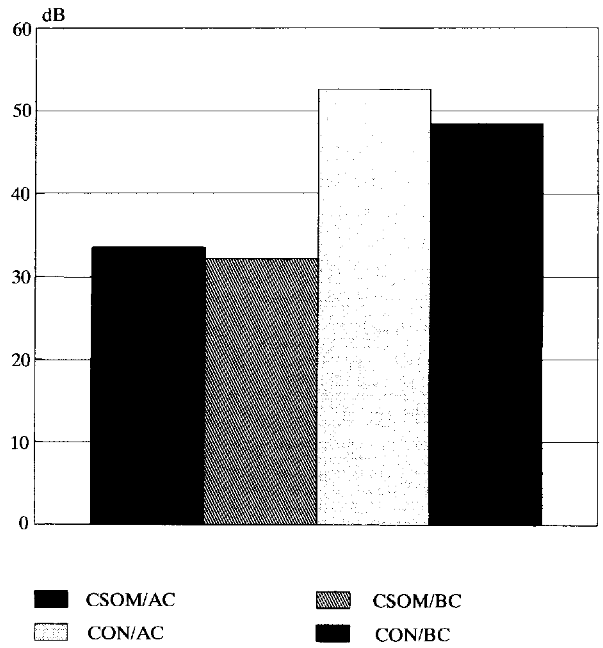

FIG. 4

Mean air-bone gap for each patient group (500–4000 Hz)

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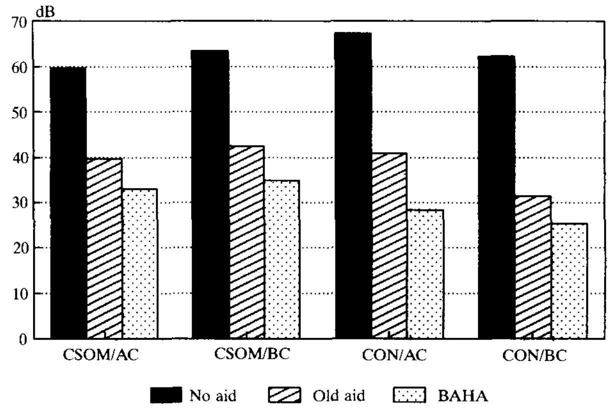

FIG. 5

Mean free-field warble tone thresholds (dBA, 500–4000 Hz) for each patient group; unaided, with previous aid, and with BAHA.

All patients reported that they often had someone in their immediate vicinity. Of the 95.5 per cent of patients who used their BAHA for more than eight hours each day, the vast majority (89.7 per cent) found that the hearing aid amplified the sound sufficiently.

Responses to question 7 'How would you rate your BAHA in the following situations?' were scored in the following way:

Very satisfactory	=	1
Quite satisfactory	=	2
Passable	=	3
Not very satisfactory	=	4
Very unsatisfactory	=	5

By this method a numerical score was obtained pre-operatively (with 'old' hearing aid), then subsequently with the BAHA. The results for each patient group were then analysed in terms of the number of cases that showed a worse score, the number improved by one point, and the number improved by more than one point. Three questions out of the seven were picked out for the analysis namely:

(a) Listening to radio or television news (TV);
(b) being with family or friends at home (quiet);
(c) being with a group of people in noisy surroundings (noise).

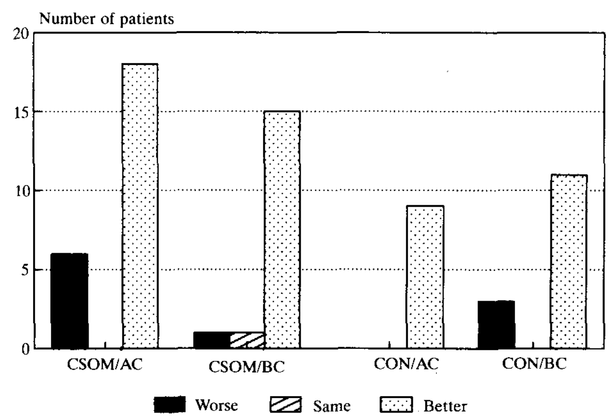

FIG. 6

Histogram showing numbers of patients in each group whose mean free-field warble tone thresholds were worse, the same, or better with their BAHA as compared to their previous aid.

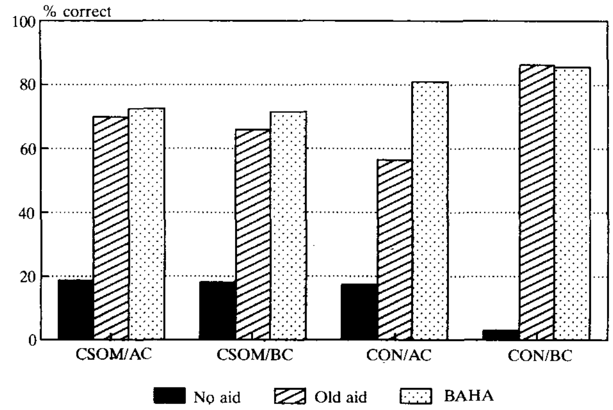

FIG. 7

Mean free-field speech discrimination scores (measured at 63 dB) for each patient group; unaided, with the previous aid, and with the BAHA.

These three areas were identified by the patients as being the most important when using their BAHA.

The results for hearing in quiet surroundings are shown in Figure 9. The use of the BAHA resulted in a significant improvement in the CON/BC group of patients ($p<0.05$) and also in the CSOM/BC group ($p<0.01$). For hearing in noise (Figure 10), the CSOM groups AC and BC showed a significant improvement with the BAHA ($p<0.01$). For hearing the television or radio, significant improvement with the BAHA was observed in the following groups – CSOM/BC ($p<0.01$) and CON/AC and BC ($p<0.05$ and $p<0.01$) with the largest number of cases reporting an improvement over their old aid amongst the CSOM/BC group (Figure 11).

The CSOM/BC group derived the greatest overall benefit in the three hearing situations when using the BAHA.

The results for question 9 were scored by allocating a positive point to any positive comments made and a negative point for any of the negative ones. From this, an overall score was obtained again both for the old aid (from the pre-operative questionnaire) and with the BAHA. Again, the performance of the BAHA was compared with the

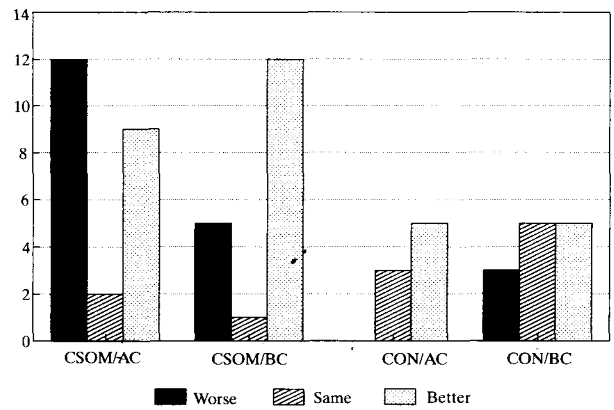

FIG. 8

Histogram showing numbers of patients in each group whose speech discrimination scores at 63 dB were worse, the same or better with their BAHA as compared to their previous aid.

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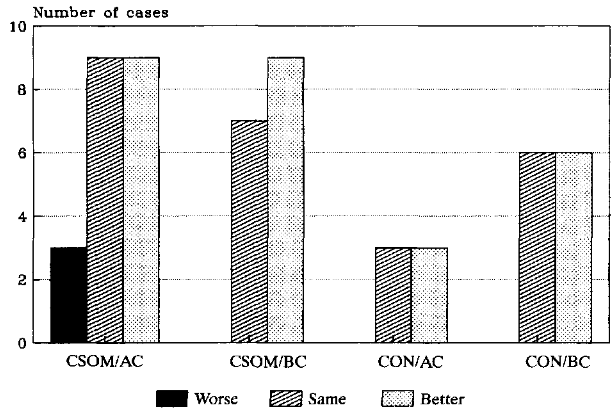

FIG. 9

Histogram showing numbers of patients in each group who reported hearing in quiet worse, the same or better with their BAHA as compared to their previous aid.

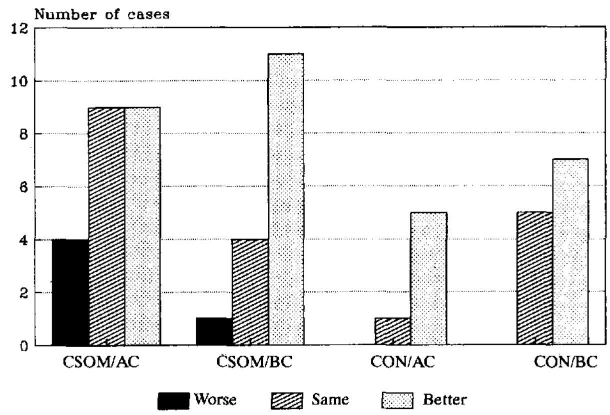

FIG. 11

Histogram showing numbers of patients in each group who reported hearing TV worse, the same or better with their BAHA as compared with their previous aid.

old aid by counting the number in each group that showed worse, same or better score on this question (Figure 12). All groups showed a significantly improved score with the BAHA compared with their old aid ($p<0.01$) except CON/BC where $p<0.05$. Only six patients gave a worse score to the BAHA than their old aid: three CSOM/AC, one CSOM/BC and two CON/BC.

Question 10 examined the patients' feelings regarding the quality of sound experienced with their old hearing aid and with the BAHA. Twelve descriptions of sound were presented to the patient and they were asked to tick those which best described their experience. Descriptions 1 and 3 were positive sound quality attributes while the remainder were negative quality attributes.

Referring to their old aid, 44 per cent of patients ticked one or both of the positive points while 63 per cent ticked one or more of the negative points. With the BAHA there was an increase in the number of patients who ticked positive attributes 1 and 3 (67 per cent) and a decrease in the number who selected the negative attributes (50 per cent).

On the overall satisfaction score (Figure 13), significantly more patients were more satisfied with the BAHA than with their old aid in the following groups: CSOM/BC and CON/BC ($p<0.01$) and CON/AC ($p<0.05$). Only seven patients gave the BAHA a worse score, five of these were from the CSOM/AC group which failed to show a significant difference.

Discussion

A number of trends emerge from the results. Perhaps the most important point is that all the patients fitted with the BAHA use their aids and obtain clear benefit. However, our hypothesis that both the aetiology of hearing loss and type of hearing aids previously used would have an effect upon the results obtained with the BAHA has been supported.

In theory, the congenital group whose bone conduction thresholds were generally essentially normal and who, on average, had larger air bone gaps than the acquired group could be considered most suitable for the BAHA and our results support this. Improvements in free-field thresholds did not reveal any difference between the congenital and CSOM group. However, patients did show improvements in their audiological results with the BAHA as

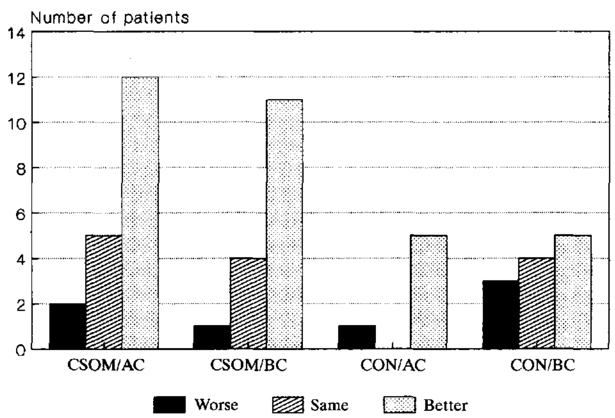

FIG. 10

Histogram showing numbers of patients in each group who reported hearing in noise worse, the same or better with their BAHA as compared with their previous aid.

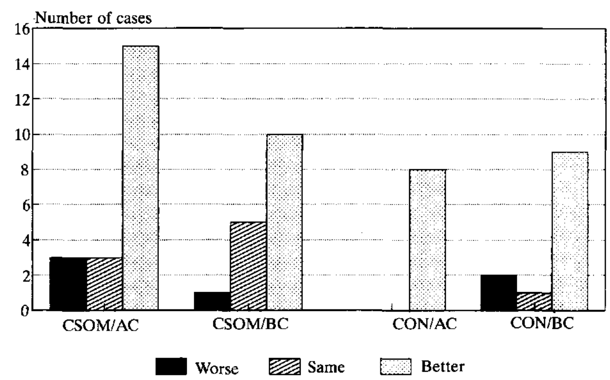

FIG. 12

Histogram showing numbers of patients in each group who reported their feelings about the BAHA (as compared to their previous aid) worse, the same, or better.

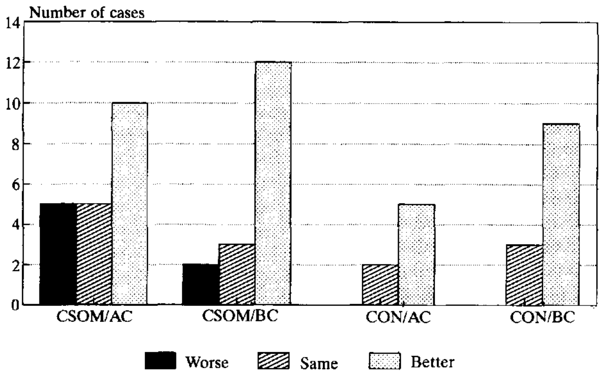

FIG. 13

Histogram showing reported overall satisfaction with the BAHA, as compared with the previous aid, for each patient group

compared with their old aids. Overall the congenital group obtained marginally the best free-field thresholds and speech discrimination with the BAHA as might have been expected. This agrees with the data from Gothenburg and Nijmegen (Tjëllström *et al.*, 1983; Cremers *et al.*, 1992; Mylanus *et al.*, 1994a,b, 1995).

Our results also demonstrated the value of the questionnaires in providing additional information not obtained from the purely audiological results. As with any aid, it is necessary to ask the patient their feelings about the performance of the aid in real life situations which often reveal positive and negative points which would have been missed by conventional audiological testing.

One might expect the CSOM patients to be poorer users of their conventional bone conduction aids than the congenital patients who would be likely to have a longer period of experience using bone conduction. All except one of the congenital AC patients rated their BAHA significantly better than their previous aid in listening in noise. When listening to television, the only patients reporting that the BAHA was worse than their previous aids were from the CSOM group (Tjëllström *et al.*, 1992; Mylanus *et al.*, 1995).

When patients were asked to rate their feelings about their aid, only six patients gave their BAHA a more negative score than their previous aid. All of the congenital air conduction patients rated the BAHA better. The important fact here is that the vast majority of patients gave the BAHA better ratings than their previous aid. The same was largely true on the question about overall satisfaction except for the CSOM air conduction group who gave a mixture of responses. The CSOM/AC group were the most non-committal in their endorsement of the BAHA and have emerged as obtaining less clear benefit from the BAHA than the congenital group. It has been our experience with this group that they require more rehabilitation input and are perhaps less straightforward cases than the congenital patients. However, the results do show that they obtain useful benefit from the BAHA.

In summary, clear trends did emerge from our results and the difference found between different patient groups will be useful when assessing new patients suitability and also planning their rehabilitation needs. As expected, the congenital patients obtained clear benefits and, along with the patients with chronic otitis media, are clear candidates for the BAHA. They also obtain major benefits from the multi-disciplinary approach which has been set up in Birmingham, where maxillofacial technology and reconstructive facial surgery can also be applied with great success where appropriate (Stevenson *et al.*, 1993).

Conclusion

The results of the patient series described in this paper confirm the effectiveness of the BHA as a treatment for acquired or congenital conductive hearing loss. It also demonstrates the level of success that can be achieved with an appropriate and experienced multi-disciplinary team dedicated to helping this group of patients.

Our results confirmed that both the congenital and acquired hearing-loss group of patients can obtain significant improvements in their hearing status and are in the vast majority of cases more satisfied with the results than with their previous aids.

In summary, our findings confirm the BAHA, when applied by the sort of multi-disciplinary team described, is a successful new development in audiological rehabilitation which will undoubtedly continue to be given widespread application.

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