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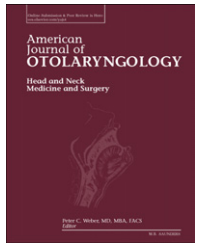

Tinnitus management with percutaneous osseointegrated auditory implants for unilateral sensorineural hearing loss☆

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ABSTRACT

Objective: To determine the effects, if any, of percutaneous osseointegrated auditory implants (OAI) on tinnitus in patients with unilateral SNHL.
Study design: Prospective cohort series.
Setting: Tertiary academic referral center, single surgeon.
Patients: Adult OAI recipients with unilateral severe to profound sensorineural hearing loss (SNHL) in the implanted ear.
Intervention: Percutaneous OAI.
Main outcome measure(s): The Tinnitus Reaction Questionnaire (TRQ) and the Tinnitus Handicap Inventory (THI) were recorded pre-implantation, and at 6 and 12 months following device activation.
Results: Ten eligible patients were enrolled. The mean pre-operative TRQ and THI scores for all subjects were 32.80 ± 23.41 and 37.00 ± 22.75, respectively. Both scores decreased 6 months after device activation, with TRQ mean of 19.67 ± 21.73 ($p = 0.0012$) and THI mean of 27.11 ± 23.41 (NS). After 12 months, the downward trend continued with TRQ mean of 17.30 ± 20.67 ($p = 0.0008$) and THI mean of 21.70 ± 23.02 ($p = 0.0116$). Subgroup analysis comparing patients with severe SNHL to those with profound SNHL demonstrated a decrease in TRQ and THI scores at 12 months for both groups, but it was only statistically significant for the severe SNHL group ($n = 7$).
Conclusions: OAI use in SSD is associated with a statistically significant decrease in tinnitus as measured by the TRQ and THI. The reasons for this are likely multifactorial, though possibly due to stimulation of residual cochlear function in the SSD ear. Further study of a larger cohort is ongoing.

1. Introduction

Tinnitus is a frequently bothersome symptom defined as the perception of sound without an external source, varying in loudness, pitch, and quality in each affected individual. Up to 85% of patients suffering from tinnitus have associated hearing loss [1]. Currently, most treatments for tinnitus in patients with hearing loss involve addressing the auditory

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deprivation through the use of hearing aids or masking devices in combination with cognitive behavioral therapy. It is thought that amplification of external sounds may reverse or reduce the factors responsible for pathological changes in the central auditory system associated with hearing loss, such as increased gain or auditory cortex reorganization, possibly by strengthening lateral inhibitory connections. Another theory is that increased neuronal activity resulting from amplified sounds may reduce the contrast between tinnitus activity and background activity, thus reducing audibility and awareness of the tinnitus [2]. In their review of 17 studies evaluating the effect of hearing aids on tinnitus, Shekhawat et al. concluded that hearing aids were beneficial in reducing tinnitus [3]. However, for patients with severe to profound single sided hearing loss and tinnitus such conventional therapies may be limited by the magnitude of the hearing loss.

In recent years, numerous reports have established the effectiveness of osseointegrated auditory implants in treatment of single sided deafness [4,5]. However there are no reports to date of a prospective study analyzing the effect of OAIs on tinnitus severity. In the present study, we investigated the degree of tinnitus in patients with SSD prior to surgery and evaluated the changes in tinnitus with OAI use.

2. Materials and methods

The study was approved by the Virginia Commonwealth University Institutional Review Board (HM 13638) and written informed consent was obtained from all participants. Patients were included if they suffered from stable unilateral severe to profound hearing loss and ipsilateral tinnitus for greater than 12 months. Pediatric patients (<18 years old) or any patient with any contralateral hearing loss were excluded. All patients were initially fit with contralateral routing of signal (CROS) hearing aids, and those that were dissatisfied were offered a trial of the osseointegrated device on a headband. Those patients satisfied with the osseointegrated device subsequently proceeded with implantation of a percutaneous OAI.

Preoperative hearing assessment including pure tone audiometry, and hearing loss was described by means of a 3-tone pure tone average (PTA), the average of the hearing thresholds at 0.5, 1, and 2 kHz. Speech discrimination scores were also obtained and recorded. Subjects were asked to complete the Tinnitus Reaction Questionnaire (TRQ) and the Tinnitus Handicap Inventory (THI) pre-operatively, 6 months post-fitting, and 12 months post-fitting. Results from each questionnaire were recorded and analyzed using linear mixed mode, with time as fixed effect for longitudinal data with repeated measures. The difference of least square means among the three time points for each of the two measures (TRQ and THI) was tested, where $P \leq 0.05$ was considered significant.

Subgroup analysis was carried out by dividing the patients into two groups according to the degree of hearing loss. Group A was considered the profound SNHL group, and contained 3 patients (S1, S9, S10) with PTA of 70 or greater. Group B was considered the severe SNHL group, and contained 7 patients (S2–S8) with PTA less than 70 and poor discrimination.

3. Results

Ten subjects (2 males, 8 females) met these criteria and were enrolled in this study. Their mean age was 54.9 years (SD ± 14.79 years), and duration of deafness ranged in duration from 1 year to greater than 15 years. All subjects had unilateral hearing loss characterized by a mean PTA of 67.4 ± 26.42 dB and a speech discrimination score of 16.80 (SD 26.52) in the ear to be implanted. The contralateral ear exhibited normal hearing (mean PTA 16.47 ± 8.83 dB) with a mean speech discrimination score of 99.6 (SD 1.26).

The mean pre-operative TRQ and THI scores for all subjects were 32.80 ± 23.41 and 37.00 ± 22.75, respectively (Fig. 1A, B). Both scores decreased 6 months after device activation, with TRQ mean of 19.67 ± 21.73 ($p = 0.0012$) and THI mean of 27.11 ± 23.41 (NS). After 12 months, the downward trend continued with TRQ mean of 17.30 ± 20.67 ($p = 0.0008$) and THI mean of 21.70 ± 23.02 ($p = 0.01$). One patient was unable to return for follow-up at 6 months, thus his 6 month post-op data are lacking He did return for a 12 month follow-up.

The mean pre-operative TRQ and THI scores for group A were 42 ± 36.59, and 52.67 ± 31.64, respectively. For group B, the corresponding scores were 28.86 ± 17.76, and 30.29 ± 16.35. At 6 months, Group A did not exhibit statistically significant reduction in TRQ (mean 31.33 ± 32.33; $p = 0.11$) or THI (mean 44.67 ± 29.69; $p = 0.11$). Group B demonstrated significant reduction in TRQ (mean 13.83 ± 14.65; $p = 0.04$), but not THI (mean 18.33 ± 15.72; $p = 0.30$). After 12 months, no significant reduction was noted in TRQ (30.00 ± 31.22 [$p = 0.19$]) or THI scores (43.33 ± 32.33 [$p = 0.42$]) of Group A patients. In Group B, both TRQ and THI scores decreased significantly, with mean TRQ of 11.86 ± 14.17 ($p = 0.01$), and mean THI of 12.43 ± 10.58 ($p = 0.05$). Fig. 2 compares the Tinnitus Questionnaire scores between the two subgroups as a function of time, while Fig. 3 highlights the Tinnitus Handicap Inventory.

4. Discussion

Persistent tinnitus occurs in approximately 15%–20% of the adult population, making it one of the most common otological complaints [6,7]. Of those affected, 20% report severe enough symptoms as to negatively impact the quality of life, and 6% of these individuals describe the condition as “incapacitating” [7,8]. Sleep deprivation, psychiatric and emotional disturbances, and impaired cognitive function are all associated with tinnitus. Multiple mechanisms for the etiology of tinnitus have been proposed, linking it to abnormal changes at multiple levels along the auditory pathway, although the exact pathophysiology remains unknown. Likewise, the mechanism of tinnitus suppression is incompletely understood. Seeing that 85% of patients with tinnitus also have hearing loss and auditory deprivation is the likely initiating factor of tinnitus, it seems logical that restoration of auditory input would lead to its mitigation. In practice, nearly all successful treatments entail some method of sound enrichment (ideally in combination with cognitive behavioral therapy).

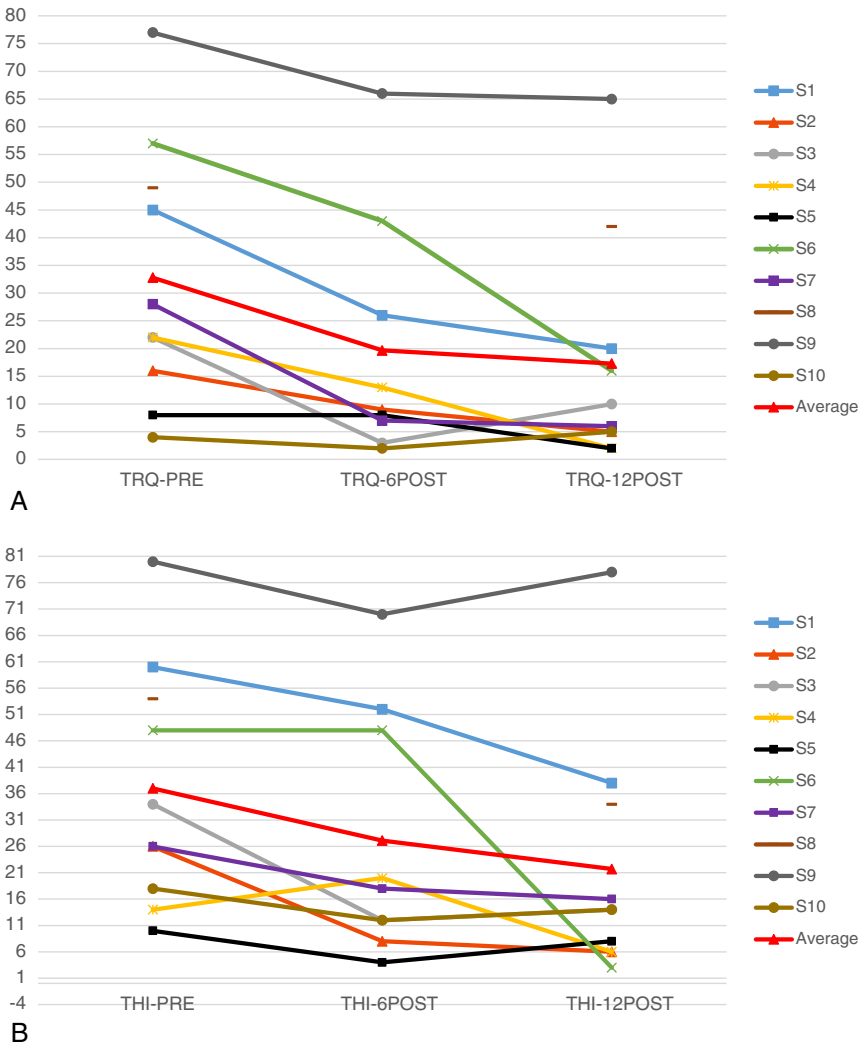

Fig. 1 – (A) TRQ for all subjects according to time following implant activation.(B) THI for all subjects according to time following implant activation.

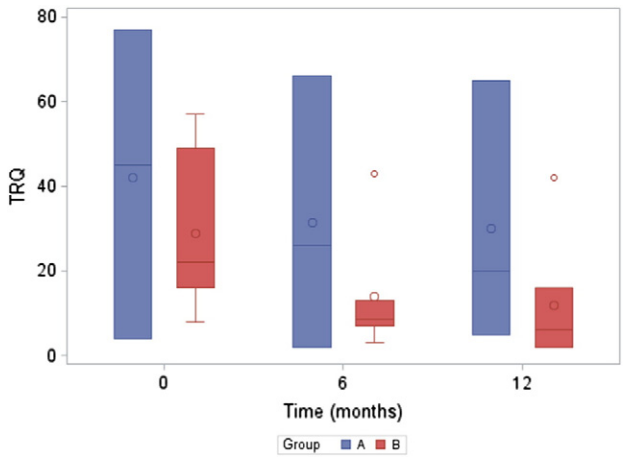

Fig. 2 – Change in Tinnitus Reaction Questionnaire scores as a function of time (months) in Group A (profound SNHL) and Group B (severe SNHL) subjects.

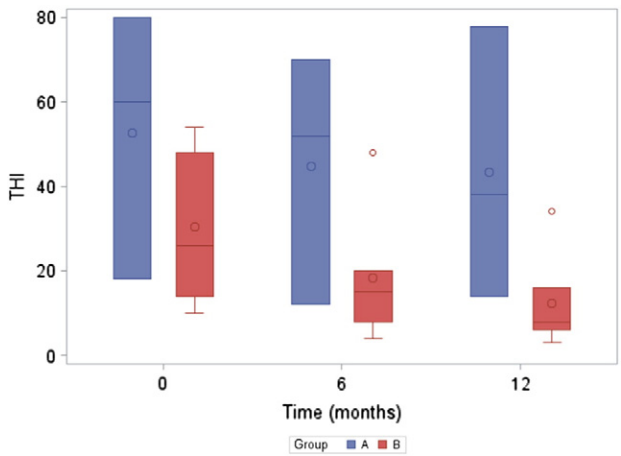

Fig. 3 – Change in Tinnitus Handicap Inventory scores as a function of time (months) in Group A (profound SNHL) and Group B (severe SNHL) subjects.

More recently, insight may be gleaned from the role of cochlear implantation in tinnitus suppression in single sided deafness. In their review of 9 research articles on the effect of cochlear implants as a treatment for ipsilateral tinnitus in single sided deafness, Arts et al. theorized that increasing afferent input in the auditory nerve reverses the possible neuronal changes that occur with auditory deprivation, thereby reducing tinnitus [1]. Likewise, Ito et al. hypothesized that the electrical stimulation from a cochlear implant device is transmitted to the cochlear nucleus and superior olivary nucleus, which elicit a direct inhibition of the hair cells via the cochlear efferent nerves. The activation of this efferent system likely decreases the sensitivity of the cochlea and suppresses the aberrant activity of the hair cells that produce tinnitus [9]. Yet despite their widespread use for SSD, the role of osseointegrated implants in tinnitus remains relatively unexamined. In one of the only studies to specifically look at tinnitus in OAI users, Holgers and Hakansson demonstrated retrospectively effectiveness of bone conduction for sound stimulation in achieving reduction in tinnitus (though this was in patients with bilateral tinnitus and varying degrees of conductive hearing loss) [10].

The data presented above demonstrate a reduction in tinnitus in patients with unilateral SNHL, but more so in patients with severe loss than in patients with profound SNHL. This would support the idea that greater residual ipsilateral cochlear function allows for enhanced activation of the tinnitus-suppression mechanism — i.e. those with any cochlear reserve to stimulate more were expectedly more likely to have improvements in their tinnitus. However, some patients with profound SNHL (and presumably no cochlear function) still had reduction in their tinnitus. The reasons for this are unclear. Certainly a placebo effect cannot be ruled out, though strong anecdotal evidence would suggest that tinnitus suppression in a totally deaf ear by OAI is a very real phenomenon. Stimulation of the contralateral auditory track may play an important role in tinnitus suppression, and has been seen in hearing aid users.

One limitation of our study is the small sample size. Further studies must be conducted with larger sample sizes for a thorough evaluation and reliable conclusion with statistical power. In addition, the longest follow-up interval was limited at 12 months. However, this is not likely to influence the results, given that the study excluded patients with less than 1 year duration of tinnitus with high likelihood of spontaneous improvement.

5. Conclusion

Unilateral sensorineural hearing loss is frequently associated with bothersome tinnitus that is disruptive to daily life. A multitude of sound-restoring modalities have been employed in an attempt to achieve tinnitus relief, including CROS hearing aids, osseointegrated devices, and cochlear implantation. The results of the current study suggest that unilateral tinnitus resulting from unilateral sensorineural hearing loss can be effectively mitigated with osseointegrated auditory implants in most patients. Individuals with some cochlear reserve may report more abatement of their tinnitus compared to those with profound hearing loss. However, patients with profound hearing loss also benefit from OAIs, suggesting a much more complex mechanism of tinnitus suppression involving both the peripheral and central auditory systems. This may have important implications for future candidate selection criteria. Studies of larger cohorts are ongoing.

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