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Feasibility of Minimal Inverted-J Incision for Bone-Anchored Hearing Aid Attract Implantation

Guhan Kumarasamy[1,2] and In Seok Moon[2]

[1]Department of Otorhinolaryngology, Hospital Raja Permaisuri Bainun, Ipoh, Perak, Malaysia
[2]Department of Otorhinolaryngology, Yonsei University College of Medicine, Seoul, Korea

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Address for correspondence
In Seok Moon, MD, PhD
Department of Otorhinolaryngology,
Yonsei University
College of Medicine,
50-1 Yonsei-ro, Seodaemun-gu,
Seoul 03722, Korea
Tel +82-2-2228-3626
Fax +82-2-393-0580
E-mail ismoonmd@yuhs.ac

Background and Objectives: This study aimed to evaluate the feasibility of a minimal inverted-J incision for bone-anchored hearing aid (BAHA) Attract implantation. Classical large incisions often result in prolonged surgical time and wound-related complications. A linear incision can lead to an incision scar overlapping the implanted magnet, resulting in wound complications, magnet instability, and problems with external device attachment. Our novel incision method overcomes the limitations of both incision methods. **Subjects and Methods**: We assessed the outcomes of patients who underwent BAHA Attract implantation using a minimal inverted-J incision, which was designed to provide adequate exposure while avoiding excessive incision. The total surgery duration, wound healing, and implant stability were evaluated based on hearing outcomes and compared with those of patients who underwent a classical incision. **Results**: The minimal inverted-J incision and classical incision groups demonstrated no significant differences in surgical time (32.7±6.3 min vs. 36.9±5.4 min, p=0.056), postoperative major wound complications (6.3% vs. 20%, p=0.176), and hearing outcomes (51.8±31.1 dB vs. 49.3±27.8 dB, p=0.585); however, the trends consistently showed that the minimal inverted-J incision group was either superior or comparable to the other groups. **Conclusions**: Our novel incision technique for BAHA Attract implantation addresses the limitations associated with both the classical and minimal linear incision approaches.

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Keywords: Bone conduction hearing; Hearing aid; Sensorineural hearing loss; Conductive hearing loss; Minimally invasive surgical procedure.

Introduction

Since their first introduction by Tjellström and Granström almost five decades ago, bone conduction implants (BCI) have been implanted in more than 150,000 cases worldwide and have evolved into various types [1,2]. Percutaneous BCIs are the most common to date, which involve direct coupling to the skull, placing an osseointegrated implant, placing an abutment via a skin opening, and transmitting the vibration through the processor. This enables the entire transmitted sound energy to be passed onto the skull, which is considered the gold standard treatment for conductive hearing loss and single-sided deafness.

Because percutaneous BCI involves skin penetration, it is associated with many complications, such as peri-abutment skin inflammation, loosening of the implant, and wound dehiscence in up to 59% of cases. Of these, 10%–12.1% required revision surgeries [3]. In 2013, with the advent of bone-anchored hearing aid (BAHA) Attract (Cochlear Bone Anchored Solutions AB), it was possible to avoid most of the skin complications as it allowed the skin to remain intact in the transcutaneous BCI. BAHA Attract comprises two magnets: one attached to an implant that is osseointegrated and the other, a soft-padded external magnet, attached to a vibrating transducer. The coupling effects of the two magnets are optimized to reduce skin complications and improve sound conduction [4].

The surgical guidelines from Cochlear Ltd. recommend a large C-shaped incision of 150° and flap elevation for this procedure, which can lead to complications such as seroma, hematoma, and numbness [2,5]. To overcome these challenges, various small linear incisions for implanting the BAHA Attract have been introduced over the years. However, they also carry disadvantages that can lead to incision overlap with the implanted magnet, causing wound problems. To avoid this overlap, a modified linear incision placed anteriorly may limit surgical exposure and lead to oblique drilling angles during screw placement, thereby compromising implant stability.

Therefore, with the aim of addressing this gap, we introduced a novel incision technique that avoids large flaps but retains the advantages of exposure and access, avoids local complications, and reduces surgery time.

Subjects and Methods

Study design, outcome measures, and statistical analysis

A retrospective review of the records of patients who underwent BAHA Attract implantation via a small inverted-J incision between 2020 and 2023 in a tertiary hospital in South Korea was performed. All surgeries were performed by a single senior otologist (ISM) under local anesthesia. Preoperative hearing tests and temporal bone computed tomography were performed. Patients with mixed hearing loss were excluded from the study. We categorized the patients into two groups: the minimal inverted-J incision group and the classical incision group. Surgical time, complications, and audiological outcomes were analyzed and compared between the groups. The hearing outcome measured was functional gain, which is the difference between aided and unaided hearing threshold. Complications were adapted from Cooper, et al. [5]. Complications that hindered the use of the device and necessitated active medical or surgical intervention included major seroma/hematoma, dehiscence, explantation, and full-thickness ulcers. Statistical analysis was performed using R statistical software version 4.4.2 (R Foundation for Statistical Computing). Surgical time and hearing outcomes were analyzed using the paired t-test, and Fisher's exact test was used to analyze the complication rates.

Surgical technique

After analyzing the temporal bone using computed tomography, the central part of the implant magnet template was placed and marked 30–40 mm posterior to the superior tip of the pinna and superiorly by 0–10 mm. This point corresponds to the flat area above the temporalis line. The magnetic implant dummy was then placed, and the outline was marked using a surgical marker. A curvilinear incision was then made. The linear component of the incision was 2–3 mm anterior to the tangent, parallel to the hairline touching the margin of the implant magnet. The curved part extended posterosuperiorly from the linear incision, forming a fishhook or an inverted J-shape. The vertical and curved segments were 20 mm and 10 mm, respectively. With precise placement marking with the implant magnet dummy and choosing an optimal site for drilling, we could avoid the incision overlap with the magnet.

Local anesthesia with adrenaline (1:100,000) was administered along the incision line and implant magnet outline. An incision was then made until the periosteum and area above the implant magnet were exposed. A circular area of the periosteum 10 mm in diameter was removed from the point where the implant was to be placed. The area was marked, and the implant was screwed in place. Polishing or drilling of the temporal bone was not required because the chosen area was inherently flat with no bony projections. The implant magnet was then placed, and hemostasis was secured with bipolar cautery. The skin was closed in two layers using a suture and a topical skin adhesive (Figs. 1 and 2).

Ethics statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Yonsei University Health System (protocol code 4-2024-1608 and approved at 2025.02.12). This study was exempted from the requirement for prior informed consent as the data were anonymized and collected retrospectively.

Results

A total of 42 patients were included in this study: 32 in the minimal inverted-J group and 10 in the classical incision group. All the patients had single-sided deafness or asymmetric hearing loss. Fifteen patients had hearing loss following skull base surgery, and the remaining 27 patients suffered sudden hearing loss. Age, sex, side of surgery, cause of hearing loss, and preoperative hearing threshold were not significantly different (Table 1).

Surgical time for the minimal inverted-J group was not different from that of the classic incision group (32.8±6.3 vs. 36.9±5.4 min, p=0.056). The minimal inverted-J group showed a 6.3% major complication rate, while the classical group showed a 20% major complication rate (20%) (p=0.176). In the minimal inverted-J group, one patient had seroma at surgical site in the immediate postoperative period which had to be aspirated and compressed. The second patient developed wound infection and had to be admitted for intravenous antibiotics.

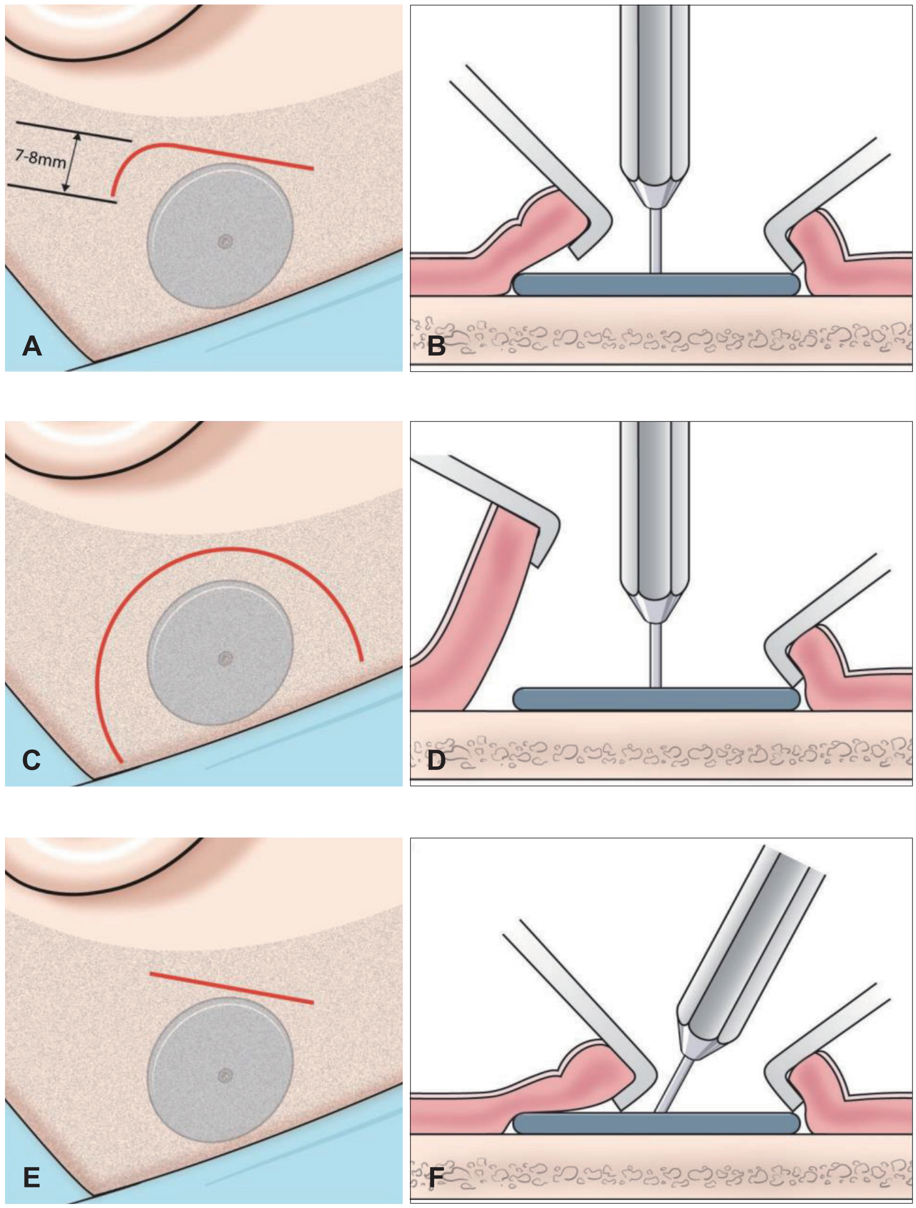

Fig. 1. Comparison of incisions and angles of drilling between minimal-J, curvilinear, and linear incisions. A: In minimal inverted-J incision, skin is marked anterior to the magnet and curved 7–8 mm postero-superiorly. B: The cross-section of the minimal inverted-J incision shows adequate exposure and the possibility of perpendicular drilling of the implant. C: Classical incision for BAHA Attract implant. D: In classical incision, a wide exposure is achieved at the expense of a large flap. E: A modified linear incision is made anterior to the magnet. F: In the modified linear incision, excessive retraction of skin is required, and perpendicular drilling of the implant is difficult.

In the classical group, one patient had recurrent wound infection after 1 month at BAHA site, which needed explantation after 6 months. Another patient had wound breakdown, which was treated with wound debridement and intravenous antibiotics. The minimal inverted-J group showed a slightly higher hearing gain compared to the classical incision group; however, the difference was not statistically significant (51.8±31.1 vs. 49.3±27.8 dB gain, $p=0.585$).

Discussion

The BAHA Attract is a well-established treatment option for patients suffering from asymmetric or unilateral hearing loss. The prerequisite conditions for optimal BAHA Attract placement are a bone depth of at least 3 mm, a flat surface of the implant site, and adequate exposure to the implant site [6,7]. The implant must be placed on the flat surface of the skull. To achieve this placement, a large and wide incision (classical) is advantageous; however, such an incision in-

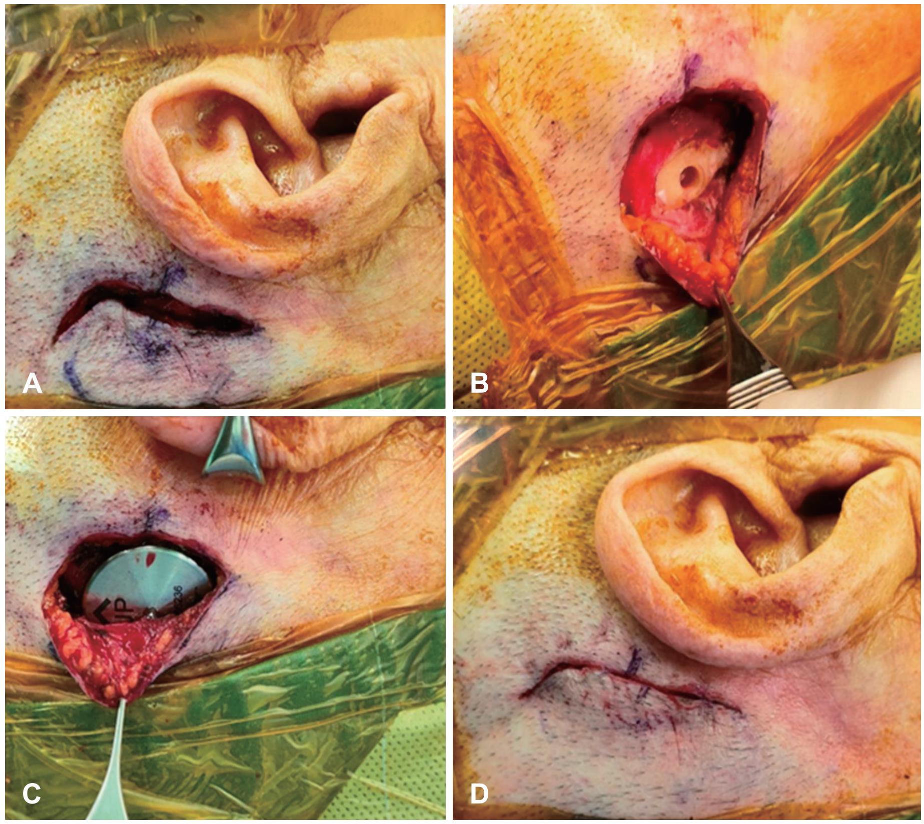

Fig. 2. Surgical steps of minimal inverted-J incision. A: Minimal inverted-J incision made. B: With gentle retraction, the area denuded of the periosteum and implant well is clearly visualized. C: The implant magnet is screwed in. D: Incision is closed in two layers.

Table 1. Patient characteristics and postoperative results

	Minimal inverted-J group (n=32)	Classical group (n=10)	*p*-value
Age (yr), mean (range)	63.8 (42–80)	64.1 (45–82)	0.940
Sex (female:male)	18:14	6:4	>0.999
Side (right:left)	13:19	6:4	0.895
Preoperative PTA threshold (dB)*	59.0±40.6	54.5±28.0	0.747
Cause (skull base surgery:sudden HL)	10:22	5:5	0.302
Postoperative hearing gain (dB)	51.8±31.1	49.3±27.8	0.585
Surgery duration (min)	32.7±6.3	36.9±5.4	0.056
Major wound complication (%)	6.3	20	0.176

*pure tone average (PTA) of 500, 1,000, 2,000, and 3,000 Hz. Values are presented as mean±standard deviation unless otherwise indicated. HL, hearing loss.

creases the surgery duration and risk of wound complications. However, a modified linear incision aimed at overcoming these issues can reduce the surgical field and visibility, thereby increasing the risk of oblique implant insertion. Therefore, we employed a novel technique called the "minimal inverted-J incision."

In our study, the complication rate was lower in the minimal inverted-J incision group than in the classical incision group (6.3% vs. 20%). The smaller number of patients in the study could have been attributed to the lack of a statistical difference; the classical incision group showed a higher rate of wound dehiscence. This healing impairment could be due to the large 7.5 cm curved line that transects major vessels on the scalp, leading to deprivation of the blood supply to the flap and venous congestion [8]. A previous report also described that classic incisions have a high complication rate of up to 33.3% [2]. This complication rate may also indirectly reflect the magnet stability.

Assessing implant stability is crucial for ensuring the success of hearing implants. While direct assessment methods are limited, several indirect techniques are employed to evaluate implant stability. We hypothesized that an unstably implanted screw and magnet can result in an unstable attachment of the external device and may hamper sound transmission. Therefore, we analyzed the hearing gain as an indirect measure of implant stability. The minimal inverted-J incision group did benefit from higher hearing gain compared to the classical group, even though statistically not significant. The number of patients was higher, which may have been statistically significant. Several studies have experimented with mini-incisions for the BAHA Attract, where the incisions are placed linearly over the implant magnet or anterior to it in a straight line [6,9-11]. In cases where a linear incision is placed directly above the magnet, almost no retraction is required, and the implant can be easily screwed. However, if an infection ensues and the wound undergoes dehiscence, the implant magnet is directly exposed. Scar tissue or keloid formation may impede the magnetic coupling. To mitigate this risk, a modified linear incision is made and placed anteriorly to the rim of the implant magnet. This modified linear incision requires excessive traction, and perpendicular drilling under direct vision is challenging. The implants must be screwed into the skull perpendicular to the surface. This may cause the implant magnet to become unstable or the magnet to come into direct contact with the skull. If the implant magnet comes in direct contact with the bony projection or skull, much of the vibration is lost [6]. This would be reflected in the postoperative hearing test results.

To overcome these limitations, we devised a new technique that avoids a large classical incision but retains its exposure and implant site visibility. Although longer than linear incisions, we feel that the minimal inverted-J incision opening may help avoid excessive traction on the skin, which may traumatize the skin and lead to postoperative seroma formation or pain. In addition, the implant area was exposed for quick and accurate drilling under direct visualization (Fig. 1). This enabled us to monitor the drilling depth and ensure that the implant was stably fixed. Anatomical variation between patients occasionally necessitates some bone polishing or larger exposure. With our versatile technique, this can be rectified by extending the pre-existing curved incision to provide a larger exposure to facilitate drilling and moving the implant.

The surgery duration in the minimal inverted-J incision group was not significantly different from that in the classical incision cohort in our study. However, when analyzing the surgical time of classical incisions in the published literature, we found that our operative time was significantly shorter [4,12-14]. We believe that the lack of statistically significant difference could be due to surgeon's skill, who performed both incisions equally quickly.

This study has several limitations. First, its retrospective design introduces potential selection bias and limits the ability to control for unmeasured confounding factors. Second, the relatively small sample size, particularly in the classical incision group, may have reduced the statistical power to detect significant differences between techniques. Additionally, the study's short follow-up period may not fully capture long-term outcomes and implant stability. Future prospective studies with larger cohorts and extended follow-up are warranted to validate these preliminary findings. The statistical shortcomings of this study could be rectified by recruiting a larger sample size.

In conclusion, this novel incision technique for BAHA Attract implantation overcomes the disadvantages associated with classical and linear incisions while minimizing skin complications, enabling faster recovery, and maintaining cosmesis at the operating site. Unlike the traditional large incisions that are associated with increased wound complications and prolonged surgical times, and the minimal linear incisions that may compromise implant stability due to restricted exposure, this approach offers an optimal balance. It minimizes skin complications, facilitates a faster recovery by reducing operative trauma, and maintains superior cosmesis at the operating site. Ultimately, this technique has the potential to enhance patient satisfaction and clinical outcomes, warranting further investigation through larger prospective studies to confirm its long-term benefits and broader applicability in otologic surgery.

Conflicts of Interest

The authors have no financial conflicts of interest.

Author Contributions

Conceptualization: In Seok Moon. Data curation: Guhan Kumarasamy. Formal analysis: Guhan Kumarasamy. Funding acquisition: In Seok Moon. Investigation: In Seok Moon. Methodology: Guhan Kumarasamy, In Seok Moon. Project administration: In Seok Moon. Resources: Guhan Kumarasamy, In Seok Moon. Software: Guhan Kumarasamy, In Seok Moon. Supervision: In Seok Moon. Validation: In Seok Moon. Writing—original draft: Guhan Kumarasamy. Writing—review & editing: Guhan Kumarasamy, In Seok Moon. Approval of final manuscript: Guhan Kumarasamy, In Seok Moon.

ORCID iDs

Guhan Kumarasamy https://orcid.org/0000-0002-4613-3496
In Seok Moon https://orcid.org/0000-0002-3951-5074

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