Minimally Invasive Surgery for Osseointegrated Auditory Implants: A Comparison of Linear versus Punch Techniques

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

Abstract

Objectives. (1) To describe the benefits of the minimally invasive punch technique without soft tissue reduction (PT) for the placement of percutaneous osseointegrated auditory implants. (2) To compare and contrast techniques and outcomes from PT with the linear technique with soft tissue reduction (LT).

Study Design. Case series with chart review

Setting. Performed at a tertiary otology practice at an academic medical center.

Subjects and Methods. LT was used until 2012 when a switch was made for all patients to PT. Preoperative variables recorded included age, sex, BMI, smoking status, indication, device selected, and abutment length. Outcomes measures included surgical time, skin reaction grading by Holgers score at 1 week and at most recent follow-up, and any other complications. Two-sample t test and χ² was used to compare.

Results. A total of 51 patients (34 LT, 17 PT) were identified. Surgical time was found to be significantly shorter for the PT group (LT, 49.2 min; PT, 13.4 min; \( P < .001 \)). There were no statistically significant differences between LT and PT for mean Holgers at first (LT, 0.24; PT, 0.47; \( P = .87 \)) or final follow-up (LT, 0.62; PT, 0.41; \( P = .22 \)).

Conclusions. The punch technique offers several potential surgical and cosmetic advantages over the linear technique without compromising skin-reactivity outcomes. This study supports a growing trend toward minimally invasive percutaneous auditory implant surgery.

Keywords

Baha, minimally invasive surgery, punch technique, osseointegrated auditory implant

Introduction

The advent of osseointegrated auditory implants has provided an effective and popular method of aural rehabilitation for patients with conductive, mixed, or unilateral sensorineural hearing loss. By transmitting sound from the processor through an osseointegrated titanium abutment embedded in the temporal bone, users are able to enjoy an improvement in auditory gain of 10 to 25 dB when compared to traditional bone conduction hearing aids.¹ These implants have been met with widespread acceptance, satisfaction, and improved quality of life.²⁴

Since its introduction in 1977, the standard technique used for decades required pedicled skin grafts with wide local thinning of subcutaneous tissue down to the periosteum.⁵ Although largely successful, this technique was not without its shortcomings. The most frequently reported complications have centered around adverse skin reactions and include skin flap necrosis with healing by second intention, flap infection, skin growth over the abutment, failure of osseointegration, and extrusion of the implant.⁶⁻¹⁰ More recently, attempts have been made to mitigate these difficulties by introducing alternative, minimally invasive techniques. Most popular among these is the single linear incision methods, first described developed at the Radboud University Nijmegen Medical Centre in the early 1990s. This technique resulted in minimizing graft failures; however, tissue thinning was still required.¹¹ Recently, the introduction of longer abutments has allowed for implant placement without any soft tissue reduction. This study aims to describe and compare outcomes for 2 methods of osseointegrated implant placement—the linear incision technique with subcutaneous thinning and the skin punch technique without subcutaneous thinning.

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This article was presented at the 2014 AAO-HNSF Annual Meeting & OTO EXPO; September 21-24, 2014; Orlando, Florida.

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Table 1. Holgers Classification System for Skin Reactions at Bone-Anchored Hearing Aid Implant Site.  

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Reaction free skin around the abutment</td>
</tr>
<tr>
<td>1</td>
<td>Redness with slight swelling around the abutment</td>
</tr>
<tr>
<td>2</td>
<td>Redness, moistness, and moderate swelling</td>
</tr>
<tr>
<td>3</td>
<td>Redness, moistness, and moderate swelling with tissue granulation around the abutment</td>
</tr>
<tr>
<td>4</td>
<td>Overt signs of infection resulting in removal of the implant</td>
</tr>
</tbody>
</table>

Methods

Once approved by the Institutional Review Board at Virginia Commonwealth University, a retrospective chart review was conducted of all patients who received a single-stage percutaneous bone anchored auditory implant from 2009 to 2013 at a tertiary academic otology practice by a single surgeon (D.H.C.). Linear incision technique (LT) was used until January 2012 when a switch was made for all patients to the punch technique (PT). The demographic variables recorded for this study were age, sex, BMI, smoking status, surgical indication, and system implanted (Baha [Cochlear Corp, Australia] or Ponto [Oticon Medical, Denmark]). Outcomes measures included surgical time, follow-up interval, skin reaction grading by Holgers score (Table 1) at the first postoperative visit (1 week) and at last follow-up, and any other complications including implant loss. Statistical analysis was performed using a 2-tailed t test and \( \chi^2 \) analysis. Skin and subcutaneous thickness was not assessed preoperatively.

Surgical Techniques

All surgeries were performed in a single stage by a single surgeon. Adults underwent local anesthesia with or without light sedation and children underwent general anesthesia.

Linear Technique. The technique used is as described at the Nijmegen Medical Centre and expanded by Hulcrantz et al. The appropriate area is shaved, prepped, and draped. 0.25% bupivacaine with 1:100,000 epinephrine is injected into the surgical bed. After waiting for adequate vasoconstriction to take place, a 6 mm skin-biopsy punch is used to excise skin, subcutaneous tissue, and periosteum in 1 step. The implant with abutment is then placed in the standard fashion under copious irrigation. All patients received a 4 mm implant with a 9 mm abutment. An Allevyn dressing with a hole for the abutment is placed over the surgical site and a healing cap placed on.

Punch Technique. After the appropriate area is shaved, prepped, and draped, 0.25% bupivacaine with 1:100,000 epinephrine is injected at the periphery roughly 10 mm to 20 mm around the intended implant site so as not to further thicken the subcutaneous tissues. After waiting for adequate vasoconstriction to take place, a 6 mm skin-biopsy punch is used to excise skin, subcutaneous tissue, and periosteum in 1 step. The implant with abutment is then placed in the standard fashion under copious irrigation. All patients received a 4 mm implant with a 9 mm abutment. An Allevyn dressing with a hole for the abutment is placed over the surgical site and a healing cap placed on.

Results

A total of 51 patients underwent osseointegrated auditory implant surgery during the study period. Thirty-four patients underwent the linear technique and 17 the punch technique (PT). There was no statistically significant difference in age, sex, BMI, indication, system implanted, or smoking status between groups (Table 2). Longer abutments were implemented in the PT group, as there was concomitant change from 6 mm to 9 mm abutments when techniques were switched in 2012. The PT group had a statistically significant shorter mean surgical time when compared to LT (mean, 13.4 min vs 49.2 min; median, 11 min [7-34] vs 47 min [35-84]; \( P < .0001 \)). Table 3 demonstrates postoperative skin reactions seen according to the Holgers criteria. There were no statistically significant differences between LT and PT for mean Holgers at initial 1-week (LT, 0.24; PT, 0.47; \( P = .87 \)) or last follow-up (LT, 0.62; PT, 0.41; \( P = .22 \)). Additionally, on subgroup analysis there was no statistical significance in mean Holgers score between PT (n = 10) and LT (n = 30) for those patients with at least 6 months of follow-up (LT, 0.27; PT, 0.00; \( P = .10 \)).

One pediatric patient from the LT group who developed Holgers 3 elected to have the abutment removed 21 months after implantation. One adult PT patient experienced implant extrusion before the first postoperative visit (Holgers zero) and was subsequently successfully re-implanted. One adult from the PT group had his abutment changed to 10 mm in the early postoperative period.

As a result of the timing of the study and the recent change in technique in early 2012, there was an unsurprising statistically significant difference in mean follow-up time between groups (LT, 22 months; PT, 10 months; \( P < .001 \)). There was a similar statistically significant difference in median follow-up time (LT, 23 months [range, 1-47 months]; PT, 10 months [range, 1 week-25 months] \( P < .03 \)).

Discussion

Since its introduction, the implementation of osseointegrated implant systems has improved auditory performance for (Smith & Nephew, Memphis, Tennessee) with a hole for the abutment is placed over the surgical site and a healing cap placed on.
Table 2. Comparison of Patients Undergoing Osseointegrated Auditory Implant Surgery Using Linear versus Punch Technique.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Linear (n = 34)</th>
<th>Punch (n = 17)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age</td>
<td>49.1</td>
<td>52.2</td>
<td>NS</td>
</tr>
<tr>
<td>Location (% right-sided)</td>
<td>41.2</td>
<td>70.6</td>
<td>.048</td>
</tr>
<tr>
<td>Gender (% male)</td>
<td>47.1</td>
<td>41.2</td>
<td>NS</td>
</tr>
<tr>
<td>Smoking status (% yes)</td>
<td>11.8</td>
<td>5.9</td>
<td>NS</td>
</tr>
<tr>
<td>Indications (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSD</td>
<td>70.6</td>
<td>52.9</td>
<td>NS</td>
</tr>
<tr>
<td>CHL</td>
<td>23.5</td>
<td>23.5</td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>5.9</td>
<td>25.5</td>
<td></td>
</tr>
<tr>
<td>BMI (mean)</td>
<td>27.1</td>
<td>29.1</td>
<td>NS</td>
</tr>
<tr>
<td>Device (% Cochlear/Oticon Medical)</td>
<td>44.1/55.9</td>
<td>0/100.0</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Surgical time (min)</td>
<td>49.2</td>
<td>13.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Implant extrusion (%)</td>
<td>0</td>
<td>5.8</td>
<td>NS</td>
</tr>
<tr>
<td>Most recent follow-up (mo)</td>
<td>22.3</td>
<td>10.3</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index; CHL, conductive hearing loss; NS, nonsignificant; SSD, single sided deafness.

Table 3. Soft Tissue Complications at First and Final Visits by Technique Implemented.

<table>
<thead>
<tr>
<th>Holgers Classification</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>First visit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear technique</td>
<td>28</td>
<td>5</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>34</td>
</tr>
<tr>
<td>Punch technique</td>
<td>12</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>Final visit</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear technique</td>
<td>19</td>
<td>12</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>34</td>
</tr>
<tr>
<td>Punch technique</td>
<td>13</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>17</td>
</tr>
</tbody>
</table>

many patients who would otherwise be unsuitable for traditional hearing devices. Many reports have shown improvement in auditory gain as well as excellent quality of life scores in patients using this technology. However, non-audiologic outcomes have been incredibly varied, reflecting the multitude of techniques utilized over the same time period. Skin overgrowth and irritation continue as the most common complication seen, though hair loss, numbness, and suboptimal cosmetic appearance remain important markers for patient satisfaction.

The rate of soft tissue complications varies across the literature. For instance, while the theoretical benefits of the skin graft technique include removal of all sebaceous glands and hair follicles decreasing the probability of infection and inflammation, those advantages were not reproduced in practice. Lustig et al\textsuperscript{16} reported that this technique was associated with a 7.5% rate of significant skin reactions. Similarly, Shirazi et al\textsuperscript{2} found a 10% incidence of partial or complete loss of the skin graft. Van Rompaey et al\textsuperscript{17} saw the highest incidence of skin reactions in their experience with significant postoperative complications requiring revision surgery occurring 37 times in 30 patients and adverse skin healing identified in 36.6% of patients. Ultimately, the techniques utilizing a skin graft have been found to be associated with partial or total graft loss of up to 10% while continuing to experience high rates of adverse skin reactions.\textsuperscript{2,6} Badran et al\textsuperscript{2} found that fewer than 60% of patients report that their percutaneous implant was a cosmetic improvement over traditional hearing devices.

In response to dissatisfaction with skin reactions and cosmesis, newer, less “invasive” techniques were developed. First described by Tjellstrom et al,\textsuperscript{18} and expanded upon by Mylanus and Cremers,\textsuperscript{19} Van der Pauw et al,\textsuperscript{20} and de Wolf et al,\textsuperscript{21} linear incisional technique without skin graft was associated with improvements in adverse skin complications. Van der Berg and colleagues\textsuperscript{22} analyzed the complication rates of 4 different surgical techniques and found that the use of the linear incision technique was associated with significantly fewer major complications compared with skin grafting techniques. Additionally, the linear technique was found to have a significantly higher proportion of implants that remained free of major complications during first 2 years of follow-up (P = .036).\textsuperscript{22} However, skin overgrowth remained a problem. Maarten et al\textsuperscript{23} discussed their experience with the linear incision technique and reported a 16.9% rate of severe skin reactions (Holgers grade 2 or greater). Nonetheless, the linear incision technique with soft tissue reduction remains a recommended technique by the manufacturers.

One potential solution involved the development and placement of longer abutments at primary surgery (rather than subsequently in the event of skin overgrowth). Beginning in 2009-2010, longer abutments became available in the United States, and since then both Cochlear Baha and the Oticon Medical Ponto systems currently offer a wide portfolio of abutment lengths, including lengths even longer than what was available during this study period. Pelosi and Chandresekhar\textsuperscript{24} found that an 8.5 mm abutment remedied cases of soft tissue overgrowth over the shorter 5.5 mm abutment. Similarly, D’Eredita et al\textsuperscript{25} indicated that longer abutment lengths are not associated with any greater vulnerability to extrusion. The data from the current study support these findings.

Historically, stable longer abutments theoretically set the stage for the elimination of subcutaneous soft tissue reduction. Hultcrantz\textsuperscript{12} and Hultcrantz and Lanis\textsuperscript{26} found that lack of soft tissue thinning did not compromise implant stability or affect the rate of soft tissue reactions following auditory implant. This was bolstered by a recent 5-year follow-up study by Hultcrantz and Lanis\textsuperscript{26} demonstrating success using the 8.5 mm abutment and non–skin thinning technique when they found “preservation of tissue with decreased skin reactions and no adverse events.” These findings were further validated by the histologic findings of Larsson et al,\textsuperscript{27} who determined limited signs of inflammation in the soft tissue surrounding the abutment when no soft tissue reduction was performed during auditory implantation in sheep.
Further attempts at minimalization led to the development of the punch Technique. First utilized by Michael Novak in 2009 (personal communication), our group independently developed (and subsequently refined) the technique in 2011. In a pilot study of 15 patients, Goldman and colleagues found that although there was a mild degree of erythema during the immediate healing period, there were no cases of infection or significant skin reaction (Holgers grade 2 or higher) in the postoperative period or in follow-up. Likewise, Wilson et al similarly found shorter operative times with no difference in skin reaction rates in 29 patients when compared to dermatome with subcutaneous tissue reduction techniques. One limitation of this technique is lack of visualization and difficulty in assessing skin thickness, the former likely contributing to the 1 case of early implant loss and the latter likely contributing to an underestimation of abutment length necessitating early postoperative replacement. Various methods to measure skin thickness at the time of surgery have been described. Perhaps the simplest involves the placement of a needle through and perpendicular to the skin before injection of local anesthetic. The needle is grasped with a forceps, and the length of the needle is measured and correlated to the appropriate length abutment.

This report is the first to compare the more commonly employed linear technique with soft tissue reduction to the punch technique. There were no statistical differences in the studied outcome variables between the 2 techniques, with the exception of a decreased operative time. This has the potential to have a substantial impact, as decreased operative time is associated with considerably reduced costs. Given that most patients can be implanted under straight local anesthesia, office-based implantation may become a real and effective option for limiting cost. Of particular interest, there were no statistically significant differences in late follow-up Holgers score between the 2 techniques. Therefore, the data would suggest PT is, at a minimum, comparable to the LT with respect to skin reactions. As this was a retrospective study, additional advantages (or disadvantages) may be borne out with a larger cohort or with longer follow-up times. Holgers score for PT patients remained generally stable over the course of this study, and it is unlikely that longer follow-up will yield substantially different findings.

Patient assessment of numbness, hair loss, and cosmetic satisfaction were not evaluated. However, the punch technique theoretically offers improvement in these areas based on its minimally invasive nature and lack of soft tissue thinning, follicle removal, or skin grafting. In our experience, patients have substantially less postoperative discomfort following PT.

Due to the nature of this study, there are some limitations that must ultimately be addressed. The decrease in operative time seen could be a function of improved surgical proficiency over time. However, this is unlikely as the change in technique was made during a 5-day interval and was met with a sharp and immediate decrease of 27 minutes in operative time. In addition, the shortest LT case was longer than the longest PT case.

Although both methods of implantation provide benefit to patients, the punch Technique appears to offer several benefits when compared to the linear Technique. This includes shorter surgical time and associated costs without a difference in skin reaction in both short and long terms. Additional potential benefits of decreased postoperative pain and improved long-term cosmesis make the punch Technique an attractive next step in the evolution of minimally invasive bone anchored auditory implant surgery.

Author Contributions

Steven A. Gordon, data gathering, data analysis, interpretation of data, drafting of manuscript; Daniel H. Coelho, design of work, interpretation of data, drafting of manuscript.

Disclosures

Competing interests: Daniel H. Coelho, travel grant from Oticon Medical in March 2013.

Sponsorships: None.

Funding source: None.

Reference