Custom Mastoid-Fitting Templates to Improve Cochlear Implant Electrode Insertion Trajectory

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Abstract

Hypothesis: Intracochlear positioning of cochlear implant (CI) electrode arrays (EAs) can be improved using custom templates to specify ideal insertion trajectory.

Background: Insertion trajectory affects final intracochlear CI positioning. Limited information is available intraoperatively regarding ideal insertion trajectory.

Methods: After IRB exemption, 3D reconstructions were created from CT scans of three cadaveric temporal bones. Insertion trajectories co-planar with each cochlea's basal turn were considered ideal. Templates were designed to fit against the mastoid and demonstrate ideal insertion trajectory with a hollow cylinder. Templates were 3D printed using stereolithography. Mastoidectomy was performed on all bones. A custom, roller-based insertion tool was used to constrain electrode insertions to intended trajectories. Insertions were performed with MED-EL Standard electrodes in three bones with three conditions: ideal trajectory with tool, non-ideal trajectory with tool, and ideal trajectory with forceps. For the final condition, the template was used to mark the mastoid as a trajectory guide. Insertion was stopped when buckling occurred.

Results: Insertions along ideal vs non-ideal trajectories averaged more intracochlear electrodes (ideal: 9, 8, 8; non-ideal: 7, 7, 8) and greater angular insertion depths (AID) (ideal: 377°, 341°, 320°; non-ideal: 278°, 302°, 290°). Insertions performed with forceps but using templates as a guide also achieved excellent results (intracochlear electrodes: 10, 7, 8; AID: 478°, 318°, 333°). No scalar translocations occurred.

Conclusions: Custom mastoid-fitting templates reliably specify a trajectory co-planar with the cochlea's basal turn and provide sufficient information for recreation of that trajectory with manual insertion after template removal. Secondarily, our roller-based insertion tool achieves results comparable to manual insertion.

Introduction

Cochlear implant (CI) surgery continues to grow in popularity. Hearing outcomes can vary significantly. Research suggests that the final intracochlear position of the CI electrode array, particularly in reference to the modiolus, is crucial in determining device performance [1]. A number of factors influence the final CI position including electrode type, angle of insertion, curl direction, depth of advance-off-stylet, and overall depth of insertion.

Angle or trajectory of the CI electrode during insertion is particularly problematic. The ideal trajectory is co-planar with the basal turn of the cochlea. Although the round window is visible intraoperatively, the cochlear duct itself is not. Therefore, the ideal insertion trajectory is difficult to determine intraoperatively.

Our group has previously shown that the final position of CI electrodes can be improved by providing surgeons with better information regarding entry site, entry vector, advance-off-stylet depth, and final insertion depth [2]. This information helped surgeons achieve a lower rate of scalar translocation and a more perimodiolar electrode position.

Methods and Materials

After IRB exemption, 3D reconstructions were created from CT scans of three cadaveric temporal bones. Trajectories co-planar with each cochlea's basal turn were considered ideal. Templates were designed to fit against the mastoid and demonstrate ideal insertion trajectory with a hollow cylinder (Figure 1). Templates were 3D-printed using stereolithography. Mastoidectomy was performed on all bones. Templates were secured with facial plating screws. A custom, roller-based insertion tool (Figure 2) was used to constrain electrode insertions to intended trajectories. Insertions were performed with MED-EL Standard electrodes (MED-EL, Innsbruck, Austria) in three bones with three conditions: ideal trajectory with tool, non-ideal trajectory with tool, and ideal trajectory with forceps. For the final condition, the mastoid was marked using the template as a guide. Insertion was stopped when buckling occurred.

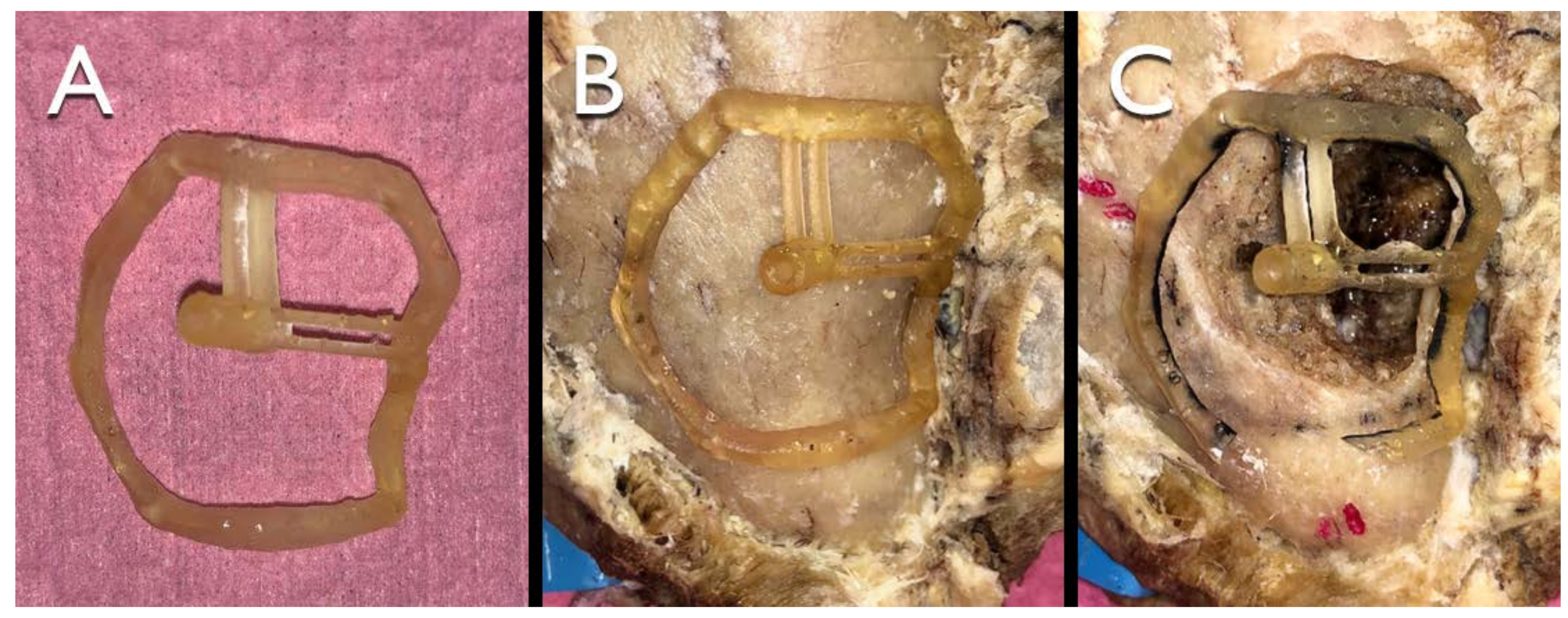

Figure 1. A sample mastoid template is shown both alone (Panel A), sitting against the temporal bone before mastoidectomy (Panel B), and sitting against the temporal bone after mastoidectomy (Panel C).

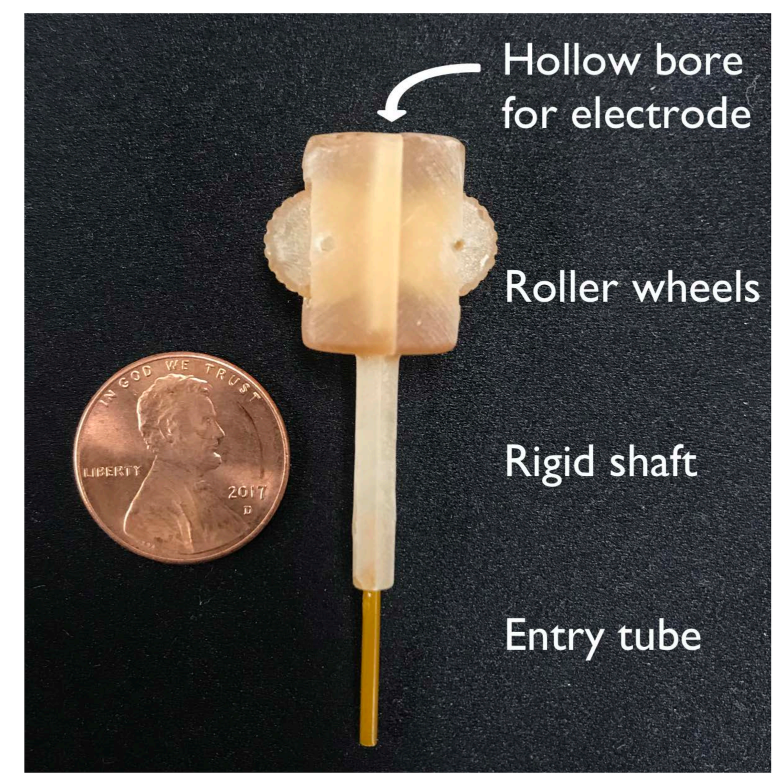

Figure 2. Electrode insertion tool ensured that electrodes were inserted in a linear vector matching the intended trajectory. Electrodes were placed in center of tool and opposing wheels were rolled by hand to push electrodes through shaft.

Results

With Insertion Tool

Templates with ideal trajectories resulted in more intracochlear electrodes (mean ± standard deviation: 8.3 ± 0.6) than templates with non-ideal trajectories (7.3 ± 0.6). AID was higher for ideal trajectories (mean: 346° ± 29°) compared to non-ideal trajectories (290° ± 12°). (Table 1)

Without Insertion Tool

Manual insertion with forceps resulted in similar numbers of intracochlear electrodes (mean ± standard deviation: 8.3 ± 1.5) when compared to insertion with the tool along an ideal trajectory (8.3 ± 0.6). AID was similar for forceps insertions (376° ± 88°) compared to tool insertions (346° ± 29°). (Table 2)

	Intracochlear Electrodes (#)		Angular Insertion Depth (°)	
Specimen	Ideal	Non-ideal	Ideal	Non-ideal
1	9	7	377	278
2	8	7	341	302
3	8	8	320	290

Table 1. Insertions with ideal trajectories compared to insertions with non-ideal trajectories.

	Intracochlear Electrodes (#)		Angular Insertion Depth (°)	
Specimen	Tool	Forceps	Tool	Forceps
1	9	10	377	478
2	8	7	341	318
3	8	8	320	333

Table 2. Insertions with insertion tool compared to manual insertions with forceps.

Summary

1. Custom mastoid-fitting templates reliably specify a trajectory co-planar with the basal turn of the cochlea.
2. Ideal insertion trajectories achieve more intracochlear electrodes and deeper angular insertion depths than non-ideal trajectories.
3. Roller-based insertion tool achieves results comparable to manual insertion.

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References

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Disclosures: R.F.L. is a consultant for Advanced Bionics, Ototronix, and Johnson & Johnson.