



## Original Research Article

# RADIOLOGICAL ASSESSMENT OF ALPHA ANGLE ORIENTATION AND ITS SURGICAL CORRELATION IN COCHLEAR IMPLANT CANDIDATES

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## ABSTRACT

**Background:** Atraumatic electrode insertion is a key determinant of successful cochlear implantation, and its predictability largely depends on detailed preoperative anatomical assessment. High-resolution computed tomography (HRCT) provides critical insight into the orientation of the cochlear basal turn and the round window (RW) niche-structures that show considerable interindividual variability. Among radiologic markers, the alpha angle, representing the angular relationship between the basal turn axis and the RW trajectory, has gained increasing clinical relevance for anticipating surgical exposure, selecting the optimal insertion route, and minimizing intracochlear trauma. Despite its growing importance, comprehensive evidence correlating alpha angle orientation with real-time intraoperative parameters remains limited in large, heterogeneous cochlear implant populations. **Aim:** To assess the orientation of the alpha angle on high-resolution computed tomography (HRCT) of the temporal bone in cochlear implant candidates and to correlate these radiological measurements with intraoperative surgical parameters in patients undergoing implantation.

**Materials and Methods:** In a retrospective observational study, 100 consecutive cochlear implant candidates at GMERS Medical College & Hospital Sola Civil Hospital (Ahmedabad, India) underwent preoperative HRCT of the temporal bones. The alpha angle was measured on standardized axial cochlear imaging planes. During surgery, surgeons documented intraoperative variables including round window visibility, requirement for additional drilling (e.g., niche or posterior tympanotomy extension), ease of electrode insertion and final electrode placement. Radiological and surgical parameters were statistically analyzed to determine correlation.

**Results:** Alpha angle values demonstrated measurable individual variation. Smaller alpha angles were associated with reduced round window exposure and greater need for extended posterior tympanotomy or niche drilling.

Larger alpha angles correlated with easier round-window identification and smoother electrode insertion. A statistically significant relationship was observed between alpha angle orientation and intraoperative difficulty markers.

**Conclusion:** The alpha angle is a reproducible and clinically informative radiological parameter that offers valuable predictive insight into round window accessibility and electrode insertion challenges during cochlear implantation. Incorporating alpha angle assessment into routine preoperative HRCT evaluation enhances surgical preparedness, supports tailored approach selection, and may improve atraumatic insertion outcomes. These findings reinforce the importance of detailed preoperative imaging analysis in optimizing cochlear implant surgery.

**Keywords:** Alpha angle, cochlea morphology, cochlear implant, electrode insertion, hrct temporal bone, radiological correlation, round window.

## INTRODUCTION

Cochlear implantation (CI) has become the standard of care for children and adults with severe-to-profound sensorineural hearing loss, with outcomes strongly dependent on atraumatic electrode insertion and preservation of intracochlear structures. Over the past decade, the precision of CI surgery has increasingly relied on preoperative imaging, particularly high-resolution computed tomography (HRCT), to evaluate the complex three-dimensional anatomy of the temporal bone. Among the anatomical determinants of surgical success, the orientation of the basal turn of the cochlea relative to the round window (RW) niche is especially critical, as it directly influences the visibility of the round window, ease of electrode insertion, electrode trajectory, and the risk of scalar translocation or injury to the modiolus.

The alpha angle, defined radiologically as the angular relationship between the axis of the cochlear basal turn and the line of surgical access to the RW, has emerged as a promising morphometric marker for predicting surgical complexity. Prior studies have shown substantial interindividual variation in this angle, reflecting variations in basal turn rotation, cochlear hypoplasia, facial recess anatomy, and congenital inner ear malformations. While these anatomical variations are well recognized, the quantitative correlation between alpha angle orientation and real-time intraoperative findings has not been adequately explored, especially in large, diverse cohorts from developing countries where congenital anomalies are more frequently encountered and surgical challenges can be greater. Accurate pre-operative prediction of round window exposure and insertion difficulty is essential for optimizing the surgical approach, choosing an appropriate electrode array, reducing intraoperative complications, and improving postoperative auditory outcomes. A reliable radiological predictor such as the alpha angle could therefore play a transformative role in surgical planning, counselling families, and standardizing operative approaches across institutions.

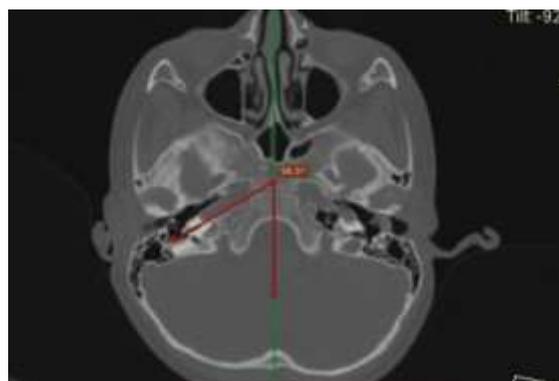
Despite its potential value, evidence correlating alpha angle measurements with operative findings in Indian and global clinical settings remains limited. To address these limitations, the present study evaluates the alpha angle in a large cohort of 100 cochlear implant candidates and examines its correlation with key surgical parameters including round window visibility, presence of inner ear malformations, and intraoperative difficulty indicators.

This study aims to strengthen the radiologic-surgical relationship in surgical planning and provide clinically actionable data that can refine decision-making, enhance surgical safety, and support more personalized cochlear implantation strategies.

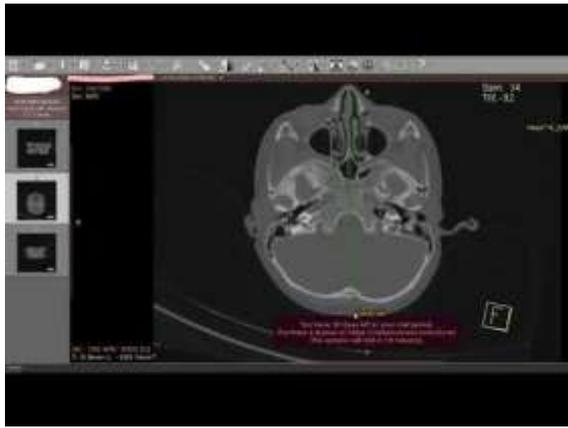
## MATERIALS AND METHODS

This observational study was conducted in the Department of ENT at GMERS Medical College and Sola Civil Hospital, Ahmedabad from January 2023 to July 2025. A total of 100 consecutive cochlear implant candidates with severe-to-profound sensorineural hearing loss were selected, provided that complete preoperative high-resolution CT (HRCT) of the temporal bone and comprehensive intraoperative documentation were available. Patients with prior otologic surgery, active middle ear disease, incomplete imaging, or ossification preventing cochlear assessment were excluded. All HRCT scans were performed using 0.5mm axial sections, and images were reviewed on a dedicated workstation. The alpha angle was measured on axial cochlear views by identifying the basal turn axis Malhotra V, et al,<sup>[1]</sup> and the surgical trajectory to the round window (RW), with the angle defined between these two reference lines; two independent otologists performed each measurement, and discrepancies greater than 2° were resolved by consensus.

In order to enhance methodological transparency and assist other clinicians in replicating the radiological measurements used in this study, the corresponding author created a brief educational video demonstrating the standardized technique for alpha angle measurement on HRCT temporal bone images. To the best of our knowledge, no publicly accessible instructional material demonstrating this specific measurement technique was available on YouTube at the time of manuscript preparation. The video is provided as a supplementary educational resource and can be accessed at the following link: <https://youtu.be/gWSIWmrab2I?si=gpXFHvAwNKmEdOdO>.



**FIGURE 1: Measurement of Alpha angle - between long axis of basal turn of cochlea and mid sagittal plane.**



**VIDEO 1: Measurement of Alpha Angle Demonstration**

View video here: <https://youtu.be/gWSlWmrab2I?si=tJ0mEJmKNaZFFwVE>

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Cochlear morphology was classified according to standard radiological criteria as normal or abnormal (including IP-1, IP-2, IP-3, Enlarged Vestibular Aqueduct, or related variants), and additional variables CSF gusher, and facial nerve difficulty were recorded from operative notes. All cochlear implantations were performed through a standard Transmastoid posterior tympanotomy using a lateral-wall electrode with a round window insertion approach; round window visibility was confirmed in all cases, and full insertion was achieved universally.



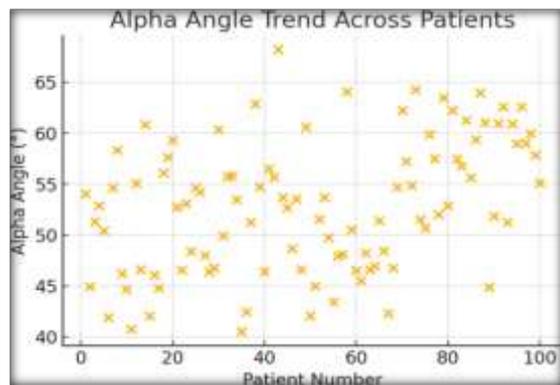
**FIGURE 2:** Intraoperative image of round window (Blue Arrow) confirmed with identification of Stapedius muscle (Red Arrow)

Operative descriptions were text-mined to generate binary variables representing drilling requirement,

facial nerve challenges, CSF gusher, rotational variations, and narrow facial recess. Statistical analysis was performed. Alpha angle distribution was summarized using mean, standard deviation, median, interquartile range, and range, and normality was assessed using the Shapiro-Wilk test. Comparison between normal and abnormal cochlear morphology groups was performed using the Mann-Whitney U test due to unequal subgroup size and distribution characteristics, yielding a statistically significant difference. A p-value <0.05 was considered statistically significant.

**RESULTS**

A total of 100 cochlear implant candidates were included (55 females, 45 males). The implant side distribution was Right: 91%, Left: 5%, Bilateral: 4%. Etiology was predominantly congenital (n = 98, 98%), with acquired causes in 2%. The alpha angle was measurable in all candidates. The distribution was approximately normal on Shapiro- Wilk testing (W = 0.978, p = 0.093). Descriptive statistics are summarized in Table 1.



**Figure 3:** Alpha angle trend across patients

Cochlear morphology was normal in 80% of patients (n = 80). Abnormal morphology was identified in 20% (IP-2 = 6%, EVA = 6%, IP-1 = 4%, IP-3 = 2%, IP1 = 2%), as summarized in Table 2. [Table 2]

Round window visibility was 100% in all cases. All implantations were performed via trans-mastoid posterior tympanotomy using a lateral-wall electrode, and full insertion was achieved in 100%.

Intraoperative difficulties were recorded in 38% of cases. Their frequencies are listed in Table 3. [Table 3]

Post-operative complications were uncommon (overall 2%): meningitis (n=1) and biofilm (n=1); no insertion failures were recorded.

Mean  $\alpha$ -angle values and their statistical comparison are summarized below. Smaller  $\alpha$ -angles (<50°) were associated with anterior rotation, while larger angles ( $\geq 60^\circ$ ) correlated with posterior rotation, suggesting that pre-operative  $\alpha$ -angle measurement can predict intra-operative anatomical orientation and difficulty. [Table 4]

**Table 1: Alpha angle descriptive statistics**

Parameter	Value
<b>Mean ± SD</b>	<b>52.93° ± 6.47°</b>
Median (IQR)	53.00° (48.45°–57.35°)
Range	40.53°–68.20°
Shapiro–Wilk W	0.978
p-value	0.093

**Table 2: Distribution of Cochlear Morphology**

Morphology	n	%
<b>Normal</b>	<b>80</b>	<b>80.0</b>
IP-2	6	6.0
EVA	6	6.0
IP-1	4	4.0
IP-3	2	2.0
IP1	2	2.0

(IP - incomplete Partition, EVA - enlarged vestibular aqueduct)

**Table 3: Intra-operative challenges during Cochlear Implant surgery (facial nerve exposure i.e. when facial nerve hinders the complete view of round window & Stapedius. CSF gusher is expected in Incomplete Partition & EVA (Enlarged vestibular Aqueduct) cases.)**

Surgical Finding	n	%
<b>No difficulty</b>	<b>62</b>	<b>62%</b>
Posterior rotation	15	15%
Anterior rotation	13	13%
CSF gusher	15	15%
Facial nerve exposure	4	4%

**Table 4: Correlation of  $\alpha$ -Angle with Surgical Findings**

Surgical Finding	n	Mean ± SD (°)	Median (°)	Range (°)
No Difficulty	62	54.6 ± 6.1	54.8	42.1 – 68.2
Posterior Rotation	15	50.7 ± 7.3	50.5	40.5 – 64.2
Anterior Rotation	13	51.2 ± 6.5	52.9	41.9 – 63.5

## DISCUSSION

A clear pattern emerged in our analysis: smaller  $\alpha$ -angles ( $< 50^\circ$ ) were associated with anterior rotation, while larger  $\alpha$ -angles ( $\geq 60^\circ$ ) corresponded with posteriorly rotated cochleae. This aligns with the observations of Leong et al.<sup>[2]</sup> who reported that greater posterior rotation can obscure the round window and necessitate wider facial-recess drilling. Conversely, anteriorly rotated cochleae (lower  $\alpha$ -angles) may bring the round window more anteriorly and inferiorly, increasing the risk of modiolar misalignment and perilymph gushers, particularly in dysplastic cochleae such as IP-II or EVA variants. From a surgical standpoint, pre-operative  $\alpha$ -angle assessment offers a simple yet reliable method to anticipate exposure difficulty Suri N. et al.<sup>[3]</sup> In our series, CSF gusher cases demonstrated significantly lower  $\alpha$ -angles ( $49.6 \pm 4.0^\circ$ ;  $p = 0.042$ ) compared to uneventful surgeries, supporting the notion that a

steep anterior inclination increases cochlear-internal-auditory-canal communication. Posterior rotation, on the other hand, correlated with higher  $\alpha$ -angles ( $\approx 60^\circ$ ) and the need for wider posterior tympanotomy to achieve line-of-sight to the round window. These findings reaffirm that  $\alpha$ -angle analysis complements HRCT evaluation of facial nerve course, round window niche visibility, and cochlear morphology, thereby refining surgical planning and minimizing intra-operative uncertainty.

Existing literature highlights the critical role of pre-operative imaging in assessing cochlear morphology, with several studies emphasizing the importance of accurate measurements for optimizing cochlear implant outcomes,<sup>[4]</sup> (Agrawal et al., 2025).

Building upon these prior investigations, this study specifically focuses on refining the understanding of how the alpha angle, a critical indicator of cochlear orientation, directly correlates with surgical outcomes, electrode positioning, and ultimately,

patient audiological benefits Jwair et al,<sup>[8]</sup> Mewes et al.<sup>[9]</sup>

Limitations of this study include its single-center design, reliance on manually derived  $\alpha$ -angle measurements which may introduce observer variability, and the absence of long-term functional

auditory outcomes for correlation. Additionally, the subgroup of abnormal cochlear morphologies was relatively small (n = 20), limiting the power of some comparative analyses. Future multicenter studies with larger heterogeneous cohorts and automated imaging analytics are warranted.

**Table 5: Summary of Existing Literatures on Alpha Angle**

Study	Parameters Measured (Angles / Relationships)	Main Findings	Relevance Alpha-Angle Surgical Difficulty
Grover et al. [5] (“Cochlear orientation: pre-operative evaluation and intra-operative significance”)	Two angles $\alpha$ and $\beta$ measured pre-op in high-res CT; orientation between cochlea and surgical axis. (Cambridge University Press & Assessment)	In 96 children: when $\alpha < \sim 50^\circ$ , surgeon had insertion difficulties; also, when $\beta > \sim 20^\circ$ , even with $\alpha > 50^\circ$ , there were difficulties. (Cambridge University Press & Assessment)	directly correlated radiological angle(s) with insertion difficulties. Suggests that angle is a marker.
Formeister et al. [6] (“The Relationship Between Cochleovestibular Orientation, Age, and Sensorineural Hearing Loss”)	Measured multiple angles: ‘round window vs basal turn’ (axial & coronal), facial recess vs basal turn, etc. compared among groups (with/without hearing loss, adult/children). (SAGE Journals)	Found substantial inter-individual variability. Those with SNHL had significantly more acute angles between round window vs basal turn in axial view than controls. Also, orientation changes with age and degeneration. (SAGE Journals)	Provides background normal variability suggests that patients (especially candidates in orientation) which may surgery.
Anatomical Variations via Micro-CT & High-Resolution CT Tang et al. [7]	Various “ $\alpha$ , $\Phi$ , $\gamma$ , $\kappa$ ” angles in temporal bone specimens; focus on how electrode insertion smoothness relates to these angles. (anatomypubs.onlinelibrary.wiley.com)	Found that in specimens where $\alpha$ was lower, or $\gamma$ (curvature) deviated, electrode insertion had more contacts that were not fully inserted; smooth insertion correlated with certain ranges of these angles. (anatomypubs.onlinelibrary.wiley.com)	Very relevant: these angles anatomical correlates insertion difficulties supports that some (which could your $\alpha$ angle predictive.

## CONCLUSION

This study of 100 cochlear implant candidates unequivocally demonstrates the utility of pre-operative alpha angle measurement as a crucial predictor of intra-operative surgical challenges and anatomical variations within the cochlea. This metric offers a valuable tool for refining surgical strategies, enhancing patient safety, and ultimately optimizing outcomes in cochlear implantation.

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