The Journal of International Advanced Otology

J Int Adv Otol 2021; 17(3): 245–250 • DOI: 10.5152/iao.2021.9266

Original Article

Cadaveric Study of Crista Fenestra: Revisited

Fathi Abdel Baki, Yasser Shewel, Mohammed Eshhomi, Ahmed Mehanna

Department of Otolaryngology-Head and Neck Surgery Alexandria Medical School, Alexandria, Egypt

ORCID IDs of the authors: F.A.B. 0000-0003-0947-9508; Y.S. 0000-0003-1593-074; M.E. 0000-0002-5478-9161; A.M. 0000-0001-5790-6813

Cite this article as: Baki F, Shewel Y, Eshhomi M, Mehanna A. Cadaveric study of crista fenestra: Revisited. *J Int Adv Otol.* 2021;17(3):245-250.

OBJECTIVES: Since there is great confusion in the literature about the anatomy and terms of the crista fenestra (CF) and the crista semilunaris, this paper is confined to the anatomy of the inferior margin of the round window (RW).

METHODS: This study was carried out on 20 cadaveric temporal bones. We measured the maximal height of the RW and the maximum height of the inferior bony edge of the RW, (termed CF type A), in this study. The ratio of the maximum height of CF type A to the maximum height of the RW was calculated. After drilling the CF type A, the scala tympani was visualized using a sialendoscope, and any bony projection in the inferior wall of the scala tympani just behind the round window membrane (RWM) was assessed and reported (termed CF B in this study).

RESULTS: We identified CF type A in 19/20 of cases (95%), and it was absent in only 1 case (5%). Its height ranged from 0.228 to 1.329 mm with an average of 0.604±0.347 mm. The percentage of CF type A to RW ranged from 19 to 75%, with an average of 42%. CF type B was present in only 2 specimens (10%).

CONCLUSION: CF type A occupied a significant part of the RW in most specimens, and therefore its drilling was essential in a large percentage of cases. CF type B (inside the scala tympani) was present in 10% of the temporal bone samples, and curettage had to be done in these cases.

KEYWORDS: Round window, crista fenestra, cochlear implant, cochlea

INTRODUCTION

The morphology of the human cochlea is a "cochlear fingerprint" in each individual, and extremely variable in terms of dimensions. The location of the RW niche (RWN) and the size and shape of the round window membrane (RWM) also vary in each individual, and consequently have a bearing on the size and type of electrode inserted.[1]

Recently, the RW has become a focus of clinical and surgical interest as a route for delivery of medications to the inner ear to treat disease or a sudden sensorineural hearing loss, and also as an important site for insertion of the cochlear implant.[2,3]

The boundaries of the RWN are the tegmen superiorly, the postis posterior and the subiculum posteriorly, the postis anterior and sustentaculum anteriorly, and the fustis and area concamerata inferiorly.[4] RWN development starts in the 16th week of fetal life, with the appearance of anterior, superior, and posterior walls; the inferior wall is absent at this time. After 1 week, the inferior wall begins to develop with the growth of the bony process into the niche. At the 23rd fetal week, one of the most characteristic structures of the RWN develops, a bony process that helps to create the inferior wall—the so-called fustis—which is stick-shaped. It runs in the middle of the inferior wall pointing to the crest of the RW. This crest can be seen for the first time in the 18th week of fetal week life, when anterior and inferior walls join.[5]

Owing to the overhanging bone of the niche walls, the RWM is rarely fully visualized during facial recess approach. Once these bony overhangs have been removed and the round window membrane is fully exposed, a sharp bony crest is found at the anteroinferior boundary of the niche, which is referred to as the crista fenestrae or the crista semilunaris in cochlear implant literature.[6-10] The RWM emerges from the free edge of the crest. When this crest is large, the size of the RW is essentially reduced, and the insertion of the electrode is expected to be more difficult, with possible deflection of electrode toward the basilar membrane and modiolus.[6-8]

Corresponding author: Yasser Shewel, e-mail: yshwel@yahoo.com

Received: August 3, 2020 • **Accepted:** September 7, 2020

Available online at www.advancedotology.org

It should be noted that the term "crista fenestrae cochleae" was used in earlier descriptions of temporal bone anatomy to designate the entire extent of the bony ridge to which the vertical part of the RWM is attached, and the inferior portion of that ridge was termed the crista semilunaris.[11] In the more recent literature, these terms have been used in different ways by different authors. To avoid confusion in terminology, Roland et al.[3] have preferred to refer to the part of the bony annulus of the RW that may require drilling simply as the anteroinferior area of the annulus.

Since the literature shows great confusion about the anatomy and terms of crista fenestra (CF) and crista semilunaris, this paper is confined to the anatomy of the inferior margin of the RW using cadaveric dissection of temporal bones.

MATERIALS AND METHODS

This study was carried out on 20 cadaveric temporal bones with no signs of ear pathology. This was approved by the Ethics Committee of our institution. Cortical mastoidectomy was performed in all the temporal bone specimens, and we then gained access to the RWN by lowering the posterior canal wall to the level of the vertical portion of the facial nerve. The RWM was exposed after drilling the superior and the posterior bony overhangs of the RWN. The RWM was then carefully removed and the inferior margin (the CF) was visualized and photographed. It was completely removed using a small cutting burr, 0.5 mm in diameter. The RW area was then photographed. The entrance of scala tympani was visualized using a microscope and a 0.9 mm sialendoscope (Karl-Storz, Tuttlingen, Germany), and any bony prominence in its inferior wall just behind the RWM was documented and reported**.**

Measurement Procedure

The dissection was digitally captured. We used a small ruler graded into millimeters and placed near the RWN, as reference for measurement. The images were uploaded to the computer and analyzed. We used the Image J software created by the National Institutes of Health, the United States (http://www.imagej.gov/nih/ij), to process and analyze images. The images were scaled to convert pixels to millimeters.

For the purpose of describing the inferior bony margins of the RW, we have adopted the Baki-ElZayat classification.[12] In this classification, 2 bony edges were identified and studied: the main inferior bony edge to which the RWM is attached, designated in this study as CF A. The maximal height of this bony projection as well as the height of the RW was measured (Figure 1). The percentage of the height of CF A to the height of the RW was obtained. The cases were subdivided into:

- A1: Crista height less than 33% RW height.
- A2: Crista height between 33% and 66% RW height.
- A3: Crista height more than 66% RW height.

After removal of the CF type A, any inferior bony prominence in the inferior wall of the scala tympani in its entrance just behind the RW membrane was designated as CF type B). The cases were subdivided into:

- B0: No bony projection in the inferior wall of scala tympani just behind the RWM.

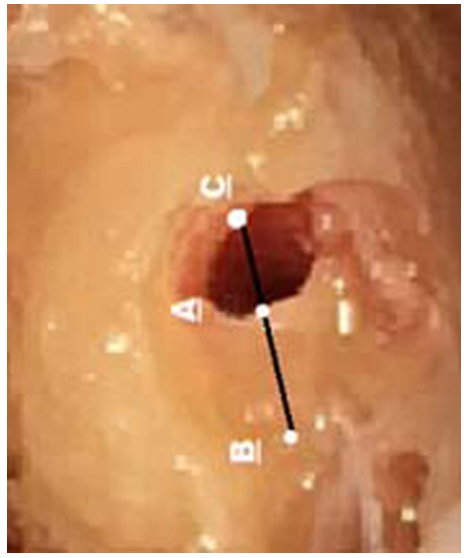

Figure 1. Measurement of the maximum height of RW from the inferior margin (B) to superior margin (C) and the maximum height of CF from point (B) to superior margin(A).

- B1: Small bony projection in the inferior wall of scala tympani just behind the RWM.
- B2: Large bony projection in the inferior wall of scala tympani just behind the RWM.

Data analysis was done using Microsoft Excel 365 for Windows.

RESULTS

This study was conducted on 20 cadaveric temporal bones (12 right and 8 left). The antero-inferior area of the RW was fully studied. For descriptive purposes, we adopted the Baki-ElZayat classification,[12] where we designated the term CF type A to the inferior bony prominence of RW to which the RWM was attached. The term CF type B was designated to refer to any bony prominence in the inferior wall of the scala tympani just behind the RWM. In this study, we identified CF type A in 19/20 (95%) cases, and it was absent in only 1 (5%) case. Its height ranged from 0.228 to 1.329 mm, with an average of 0.604 ± 0.347 mm. The RW ranged in height from 0.707 to 2.155 mm, with an average of 1.500 ± 0.432 mm. The percentage of CF type A to RW ranged from 19 to 75%, with an average of 42% (Table 1, Figures 2 and 3).

In the present study, we found that in 8/19 specimens (42.1%), the height of crista was less than 33% of RW and thus included in category A1 (Figure 4); and in 9/19 (47.38) specimens, the height of crista was between 33 and 66% of RW and thus included in category A2 (Figure 4). Only 2/19 specimens (10.52) had large crista exceeding 66% and thus were included in category A3 (Figure 4).

As for the CF type B, in the present study, we found no bony prominence in the inferior wall of scala tympani (B0) in 18/20 (90%) specimens, small bony prominence (B1) in only 1/20 specimens (5%), and large bony prominence (B2) in another specimen (5%) (Figure 5).

DISCUSSION

Currently, cochlear implant insertion through RW is the most common approach to scala tympani. However, this approach carries many

Table 1. Maximum Height of the RW and Crista Fenestra A Area ($n = 20$)

Specimen No.	Side	RW	Crista Fenestra A	Proportion (%)
1	RT	1.683	0.643	38%
2	LT	1.088	0.243	22
3	RT	1.189	0.289	2
4	RT	1.180	0.852	72
5	LT	1.748	0.460	26
6	RT	1.988	0.390	19
7	RT	0.707	0.228	32
8	RT	0.747	0.329	44
9	RT	1.371	0.000	0
10	LT	1.242	0.937	75
11	RT	1.013	0.413	40
12	LT	2.155	1.329	61
13	LT	1.846	1.132	62
14	RT	1.935	1.237	64
15	LT	1.902	0.957	50
16	RT	1.867	0.600	32
17	RT	1.872	0.363	19
18	LT	1.795	0.795	44
19	LT	1.246	0.428	34
20	RT	1.432	0.464	32

challenges, including the presence of posterosuperior bony overhangs, which may hide the RWM, and the existence of the bony crest at the anteroinferior border of the niche, which is called CF[5,6,8,10] or crista semilunaris[3,9,11] by different authors. As a result of its position in the inferior and anterior borders of the window, the crista could push the electrode toward the modiolus, increasing resistance to its insertion into scala tympani. Therefore, whenever the surgeon detects a notable crista, it may be appropriate to eliminate it with a fine curette to allow the proper and deep insertion of the electrode into the scala tympani. Otherwise, the electrode array may be displaced medially with subsequent injury to the spiral lamina and basilar membrane, resulting in poor hearing.[13]

In a study performed by Jain et al.,[1] the maximum height of the RW varied from 0.51 to 1.27 mm with a mean of 0.69 ± 0.25 mm. In addition, they reported that the height of RW was ≤1 mm in 82.35% of temporal bone specimens. Singla et al.[14] demonstrated in a study carried out on the Indian population that the average height of the RW was 1.62 ± 0.77, and the height of the RW was <1 mm in 12% of cases.

Angeli et al.[8] demonstrated that the average height of RW varied from 0.60 to 1.04 mm, with an average of 0.77 mm. Atturo et al.[7] reported that the mean longest diameter of RW was 1.90 mm while its smallest was 1.54 mm.

In our study, the RW height ranged from 0.707 to 2.155 mm with an average of 1.500 ± 0.432 mm.

In our opinion, the height of the RW itself is not the most important factor. We believe that the proportion of the height of the CF in relation to the height of the RW has more important implications than the absolute height of the RW.

Angeli et al.[8] demonstrated that the area of the RW ranged from 0.54 to 1.29 mm^2 (mean 0.91) before drilling of CF, and from 0.83 to 2.02 mm after drilling of CF. The ratio of the CF to the RW area varied from 23 to 50%. Atturo et al.[7] found that the average diameter of the CF was 1.31 mm. Roland et al.[3] dissected 15 temporal bones and visualized the RW from inside the scala tympani. They preferred to refer to the anterior-inferior bony margin of the RW as CF, while they referred to the bony crest in the inferior wall of scala tympani that arises near the cochlear aqueduct as crista semilunaris.

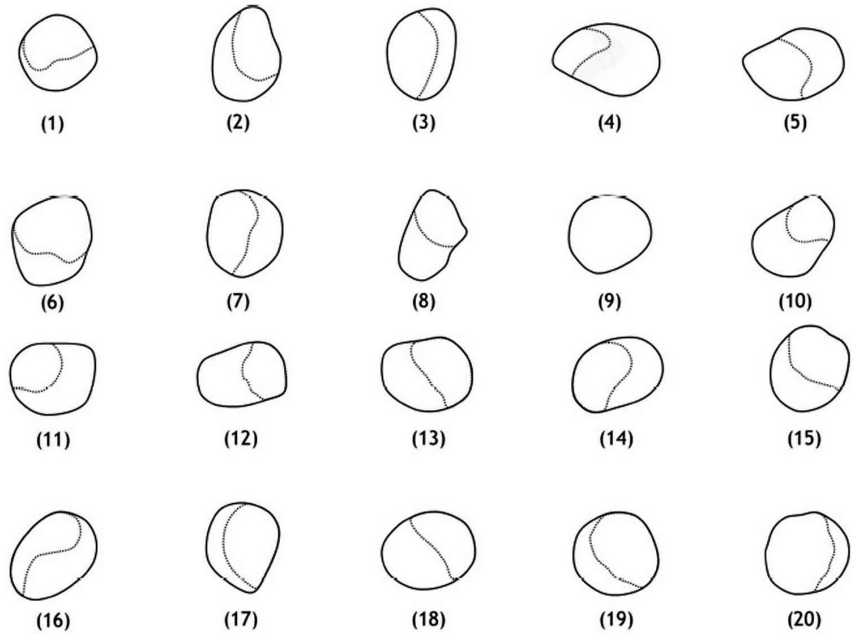

Figure 2. Diagrammatic presentation of different shapes of Crista Fenestra A.

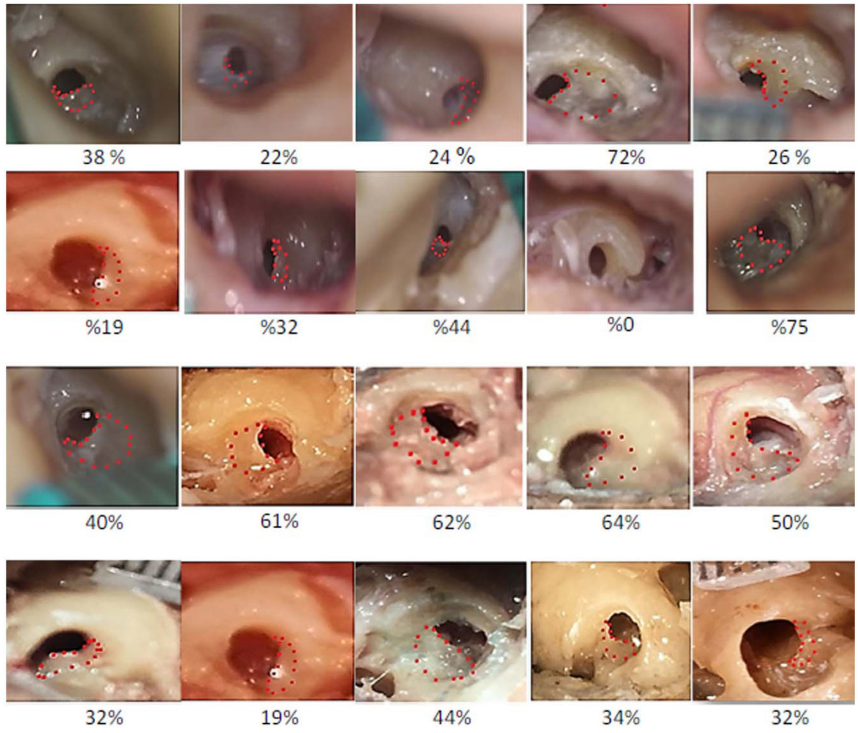

Figure 3. Different shapes and the ratio of Crista Fenestra A to RW. The dotted red line represents the boundary of Crista Fenestra A.

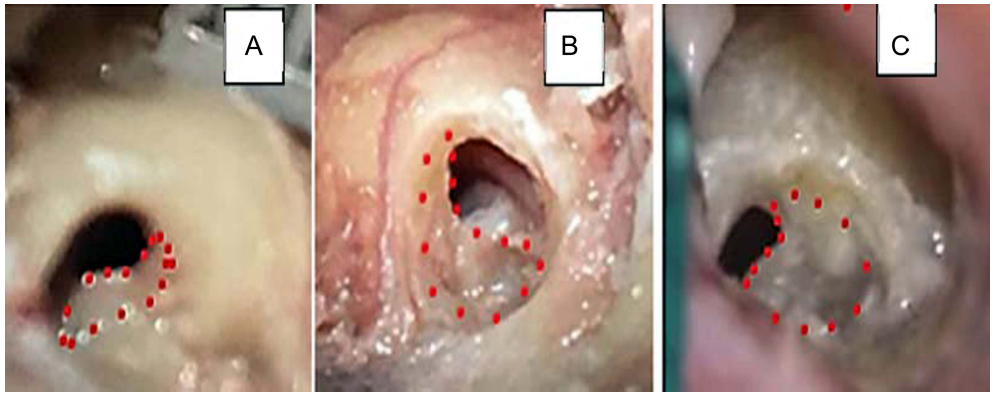

Figure 4. Different types of Crista Fenestra A. (A) Crista Fenestra A1, (B) Crista Fenestra A2, and (C) Crista Fenestra A3.

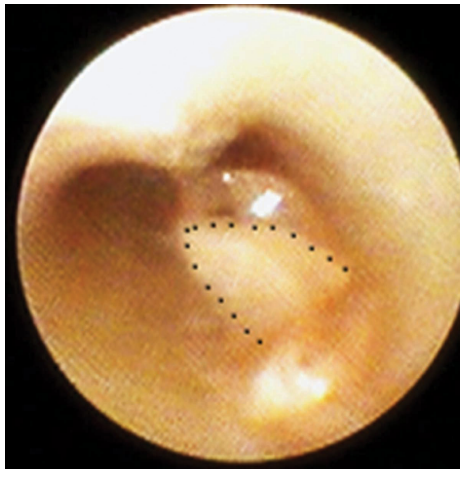

Figure 5. Crista Fenestra B (Black dots represent the boundary of CF).

Since the literature shows great confusion about the anatomy and terms of CF and crista semilunaris, we have adopted the Baki-ElZayat classification,[12] in this paper, where we designated the term Crista Fenestra A to the inferior bony prominence of RW to which the RWM is attached. The term CF B referred to any bony prominence in the inferior wall of the scala tympani just behind RWM.

In this study, CF type A was detected in 19/20 (95%) of the cases, and its height varied from 0.228 to 1.329 mm, with an average of 0.604 ± 0.347 mm. The percentage of CF type A to RW ranged from 19 to 75%, with an average of 42 %. According to the same classification, CF type A formed less of than one-third of RW (type A1) in 42.1% of the specimens; it formed between one-third and two-thirds of RW (type A2) in 47.38 %, and more than two-thirds of RW (type A3) in only 10.52% of temporal bones. Thus, the CF type A occupied a substantial part of the area of RW in 58% of temporal bones. Therefore, we suggest that drilling of anteroinferior part of the RW (CF) may be

required in at least 50% of cases for good exposure of RWM and scala tympani.

Concerning the bony crest in the inferior wall of scala tympani that arise near the cochlear aqueduct, Roland et al.[3] have found it in 30% of 15 temporal bones dissected. They termed it as crista semilunaris. Kuma et al.[10] showed a higher incidence of this crista semilunaris located immediately medial (juxta-luminal) to the RWM. It was present in 39 out of 48 cases (79.2%). However, Clifford and Gibson[9] found that the length of crista semilunaris was 0.2 mm and of little impact on insertion of the cochlear implant electrode. In the present study, we have found this bony projection in 10% of cases. We have termed it as CF type B. Marchioni el al.,[15] in their study, have explained the presence of this bony projection in a small percentage of cases. They described the endoscopic anatomy of the RW, including the fustis. They have classified the fustis into type A, in which fustis leads to scala tympani but does not extend in the scala tympani; and type B, in which the anterosuperior end of the fustis is situated just below the scala tympani and represents the floor of the scala tympani. Additionally, they have found fustis A in 71.4% of cases and fustis B in 28.6% of cases. We can speculate that in our present study, the presence of the bony prominence inside the scala tympani in only 2 out of 20 cases (10%) can represent fustis B of Marchioni et al.[15] We propose to suggest naming it the crista of scala tympani to avoid confusion with the CF in the inferior margin of RW.

As for the implications of the presence of these inferior bony projections in the inferior area of the RW, Franz et al.[6] considered that a better and wider view of the scala tympani of the basal turn of the cochlea could be obtained by elimination of the CF, which provides the surgeon with adequate space for deep and proper electrode insertion. Atturo et al.[7] emphasized the importance of the CF as a "doorstep" that could restrict the insertion of the electrode from the RW into the scala tympani. They showed that there was a great variation in the size and shape of CF that may be small and barely seen which, however, may be knife-sharp in some specimens.

Angeli et al.[8] have recommended avoiding removal of the crista, especially in patients with a residual hearing, because using a burr may result in cochlear damage and impaction of bone spicule in the scala tympani. They suggested performing cochleostomy when the CF is large and obstructs easy access to the RW and scala tympani.

In the present study, we have preferred to refer to the anterior-inferior bony margin which was found in 95% of our cases as CF A, or simply as CF. While we have referred to the bony crest in the inferior wall of scala tympani which was found in 10% of our cases as CF B, we suggest the term crista of scala tympani, to avoid any possible confusion.

The present study emphasized drilling the anterior-inferior margin of the RW (CF type A) if it is prominent and crista forms more than one-third of the RW. It also recommends removing type B (crista of scala tympani), if present, by a small curette to allow proper insertion of the electrode without deflection toward the modiolus. Drilling and or curettage should be done cautiously to avoid surgical inner ear trauma and or injury to the cochlear aqueduct and its vein.

CONCLUSION

In the present study, we have identified 2 bony prominences in the inferior area of RW. The first one represented the anteroinferior overhang of RW. It was termed the CF type A and it was present in 95% of temporal bone specimens. It occupied a significant part of RW in 58% of specimens, and therefore, anteroinferior drilling of CF was essential in a large percentage of cases.

The second bony prominence was present inside the scala tympani. It was termed CF type B or crista of scala tympani. It was present in 10% of the temporal bones, and curettage had to be done in such cases.

Ethics Committee Approval: All procedures performed in this study were in accordance with the ethical standards of our institution (Approved by the ethical committee of the Faculty of Medicine, Alexandria University, and Ethical Number: 0105810).

Informed Consent: N/A.

Peer Review: Externally peer-reviewed.

Author Contributions: Concept – F.A.B.; Design - F.A.B., Y.S., M.S.; Supervision - F.A.B., Y.S., M.S.; Resource -F.A.B., Y.S., M.S.; Materials -F.A.B., Y.S., M.S,AM; Data Collection and/or Processing -F.A.B., Y.S., M.S,A.M.; Analysis and/or Interpretation - F.A.B., Y.S., M.S,A.M.; Literature Search - F.A.B., Y.S., M.S,A.M.; Writing - F.A.B., Y.S., M.S,A.M.; Critical Reviews - F.A.B., Y.S., M.S,A.M.

Acknowledgments: Thanks to Emad Magdy, MD Otolaryngology, for his help in capturing some figures.

Conflict of Interest: The authors have no conflict of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

REFERENCES

1. Jain S, Gaurkar S, Deshmukh PT, et al. Applied anatomy of round window and adjacent structures of tympanum related to cochlear implantation. *Braz J Orl.* 2019;85(4):435-446. [CrossRef]
2. Bowe SN, Jacob A. Round window perfusion dynamics: implications for intracochlear therapy. *Curr Opin Otolaryngol Head Neck Surg.* 2010;18(5):377-385. [CrossRef]
3. Roland PS, Wright CG, Isaacson B. Cochlear implant electrode insertion: the round window revisited. *Laryngoscope.* 2007;117(8):1397-1402. [CrossRef]
4. Proctor B, Bollobas B, Niparko JK. Anatomy of the round window niche. *Ann Otol Rhinol Laryngol.* 1986;95(5 Pt 1):444-446. [CrossRef]
5. Tóth M, Alpár A, Patonay L, Oláh I. Development and surgical anatomy of the round window niche. *Ann Anat.* 2006;188(2):93-101. [CrossRef]
6. Franz BK, Clark GM, Bloom DM. Surgical anatomy of the round window with special reference to cochlear implantation. *J Laryngol Otol.* 1987;101(2):97-102. [CrossRef]
7. Atturo F, Barbara M, Rask-Andersen H. Is the human round window really round? An anatomic study with surgical implications. *Otol Neurotol.* 2014;35(8):1354-1360. [CrossRef]
8. Angeli RD, Lavinsky J, Setogutti ET, Lavinsky L. The crista fenestra and its impact on the surgical approach to the scala tympani during cochlear implantation. *Audiol Neurootol.* 2017;22(1):50-55. [CrossRef]

9. Clifford AR, Gibson WPR. Anatomy of the round window with respect to cochlear implant surgery. *Ann Otol Rhinol Laryngol.* 1987;96(Suppl):17-19. [CrossRef]
10. Kumar R, Singh A, Sagar P, Behera C, Kumar R. Access to round window niche via posterior tympanotomy and impact of drilling its overhangs: a cadaveric descriptive study. *Indian J Otolaryngol Head Neck Surg.* 2018;70(4):510-514.
11. Anson BJ. The development of the otic capsule in the region of the cochlear fenestra. *Ann Otol Rhinol Laryngol.* 1953;62(4):1083-1116. [CrossRef]
12. Baki ElZayat S, Hassan H. Surgical morphological variants of Crista Fenestra: novel clinical classification–Otology scientific paper session, vol. 19. In *OTOALEX International Conference*. 2019;1-3. (Available at: [CrossRef])
13. Atturo F, Barbara M, Rask-Andersen H. On the anatomy of the 'hook' region of the human cochlea and how it relates to cochlear implantation. *Audiol Neurootol.* 2014;19(6):378-385. [CrossRef]
14. Singla A, Sahni D, Gupta AK, Loukas M, Aggarwal A. Surgical anatomy of round window and its implications for cochlear implantation. *Clin Anat.* 2014;27(3):331-336. [CrossRef]
15. Marchioni D, Soloperto D, Colleselli E, et al. Round window chamber and fustis: endoscopic anatomy and surgical implications. *Surg Radiol Anat.* 2016;38(9):1013-1019. [CrossRef]