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ORIGINAL RESEARCH

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The parietal notch (Brammer's pointer): Accuracy of a surface landmark for temporal bone surgery

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Abstract

Hypothesis: The parietal notch is a reliable surface landmark of the sigmoid sinus at the sinodural angle.

Background: Currently no surface landmark approximates the anterior border of the sigmoid sinus. Additionally, the temporal line may not accurately identify the tegmen near the sinodural angle. This study examines the reliability of the parietal notch as a surface landmark of the sigmoid sinus at the sinodural angle.

Methods: Forty-seven cadaveric temporal bones were used to identify the parietal notch by two observers. The parietal notch and sinodural angle were labeled with radiopaque markers, mounted on foam, and CT imaged in the axial plane. The horizontal and vertical distances between the labeled landmarks were measured using PACS software.

Results: The parietal notch location was identified in 43/47 specimens. The notch was posterior to the sinodural angle in 90.6% and superior in 65% of the specimens. The average horizontal and vertical distance between the two landmarks was 6.1 mm (SD = 5.4) and 0.8 mm (SD = 8.7), respectively. In 60% of the specimens the parietal notch was within 6 mm of the sinodural angle in the horizontal dimension.

Conclusions: The parietal notch is identified in most temporal bones. It also approximates the anterior boarder of the sigmoid sinus and level of the tegmen due to its proximity to the sinodural angle. The parietal notch helps to define the posterosuperior margins of a mastoid dissection and may assist surgeons during mastoid surgery.

KEYWORDS
parietal notch, sigmoid sinus, sinodural angle, squamosal-parietomastoid suture, temporal bone landmarks

1 | INTRODUCTION

Lateral skull base anatomy is complex and learning the surgical anatomy of the temporal bone is one of the most challenging elements of otolaryngology residency. Otologic surgeons must have a three-dimensional understanding of temporal bone anatomy that will allow them to use landmarks in a systematic, stepwise fashion to locate critical structures inside the lateral skull base. Anatomic variation further adds to this challenge and can be intimidating to inexperienced surgeons, fearing injury to the dura mater of the middle cranial fossa, the sigmoid sinus or the facial nerve.[1–3]

Mastoidectomy is performed to treat inflammatory disease of the middle ear and mastoid, allow access for cochlear implantation and exposing neoplasms of the temporal bone and lateral skull base.[4]

Certain landmarks on the temporal bone surface serve as guides during mastoidectomy such as the external auditory canal, suprameatal crest, and the temporal line. The temporal line helps to approximate the floor of the middle cranial fossa.[5] Unfortunately, the temporal line cannot be used to identify the level of the mastoid tegmen near the sinodural angle accurately and none of these landmarks approximates the anterior border of the sigmoid sinus. Currently, there is no reliable external landmark to locate the sigmoid sinus at the sinodural angle.[6]

In the 1980s Dr. Robert E. Brammer, a neurotologist at Walter Reed Army Medical Center, suggested that the parietal notch might be a reliable surface landmark to identify the position of the sigmoid sinus at the sinodural angle. This landmark became known to those who trained under Dr. Brammer, including the senior author of this report, as Brammer's pointer and his idea prompted this investigation.

The parietal notch is a surface landmark on the posterosuperior aspect of the mastoid process of the temporal bone and is defined as the point where the squamous suture line meets the parietomastoid suture line (Figures 1 and 2(A)) It is located anterior to the asterion, the point on the lateral skull base where the lambdoid, occipitomastoid and parietomastoid sutures meet. The asterion is sometimes used by neurosurgeons during retrosigmoid craniotomy to help identify a burr-hole site posterior to the sigmoid sinus and inferior to the lateral sinus.[7–9]

The aim of this study was to answer two questions. First, is the parietal notch a reliable surface landmark that can be identified on most temporal bones? Second, is the parietal notch an accurate surface landmark to find the sigmoid sinus and the mastoid tegmen at the sinodural angle? In temporal-bone surgery, the sinodural angle defines the area where the petrous ridge on the floor of the middle cranial fossa is juxtaposed to the anterior border of the sigmoid sinus and the posterior boundary of Trautmann's triangle.[10] If the parietal notch were to act as a reliable surface landmark for the sinodural angle, it could potentially improve surgical efficiency and safety during mastoid surgery.

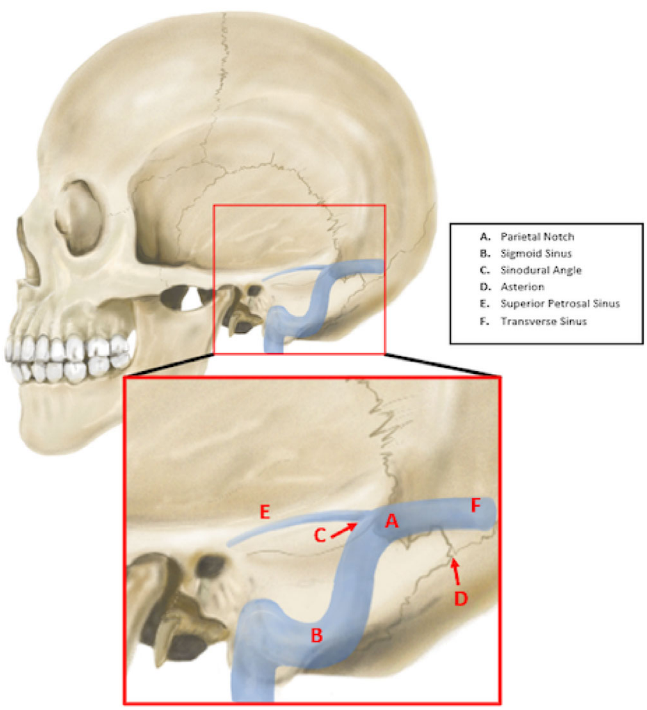

FIGURE 1 Orientation of the landmarks of the posterior-lateral skull base: The parietal notch (A) sigmoid sinus (B), sinodural angle (C), superior petrosal sinus (E), and transverse sinus (F). The sinodural angle is defined as point C where the superior petrosal sinus enters the origin of the sigmoid sinus. Illustration by Colton Baines

2 | MATERIALS AND METHODS

This study was approved by the Human Research Protections Program at the University of New Mexico (# 18-377).

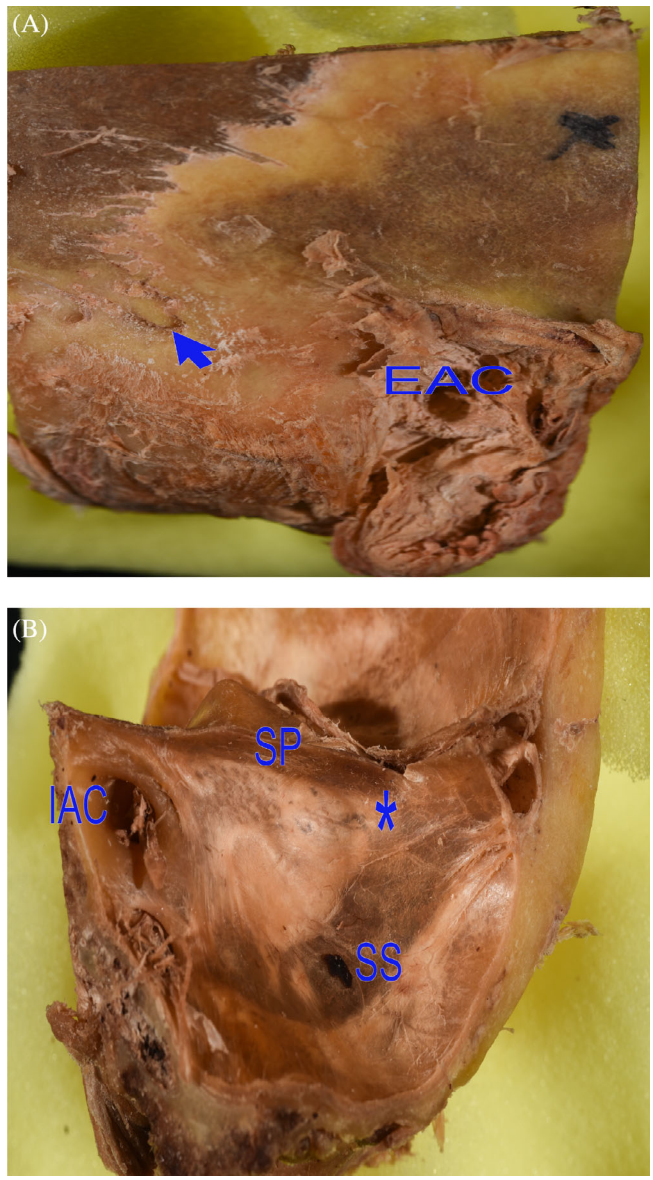

FIGURE 2 (A) Lateral view of the temporal bone with arrow on the parietal notch (arrow). EAC = external auditory canal. (B) Medial view of the temporal bone. Asterisk = sinodural angle, SS = sigmoid sinus, IAC = internal auditory canal, and SP = superior petrosal sinus

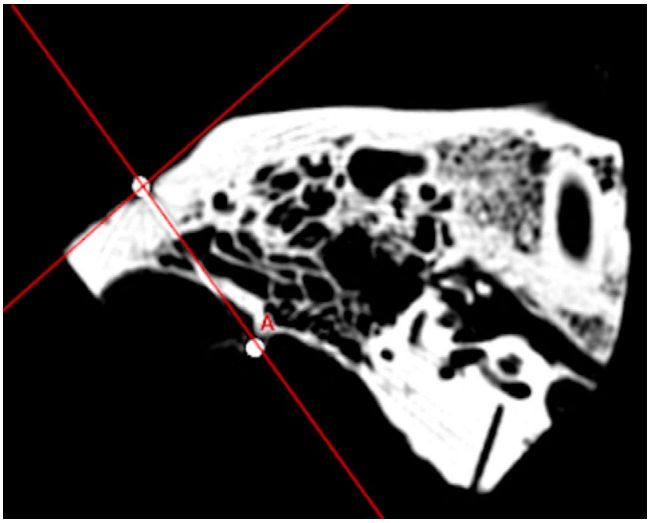

FIGURE 3 The PACS line and ruler tools were used to create a plane that was tangential to the cortex of the mastoid process. Perpendicular lines to this plane where placed through the center of the parietal notch (top left bead) and the horizontal distance between this line and the boney prominence of the sinodural angle (A) were measured. The bottom right bead was only used as a guide rather than the actual point used for measurement

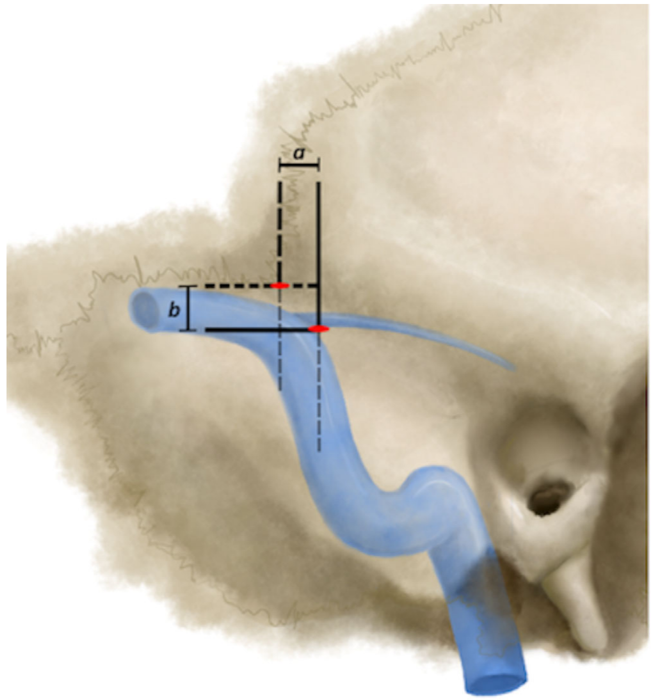

FIGURE 4 Methodology for measuring vertical and horizontal image distances between the parietal notch and sinodural angle. Bracket A represents the horizontal distance while bracket B represents the vertical distance. Illustration by Colton Baines

Forty-seven randomly selected adult cadaveric temporal bones were selected from the University of New Mexico Temporal Bone Surgery Simulation Laboratory. The soft tissue was removed from the lateral surface of the specimens to expose the bony anatomy. Two independent observers examined the lateral surface of each specimen, to identify the parietal notch by finding the point where the parieto-mastoid suture intersects the squamous suture on the posterosuperior border of the mastoid process (Figures 1 and 2(A)).

Agreement was established when both observers identified the parietal notch at the same location on the skull. In specimens where there was not agreement, bones were excluded from the imaging portion of the study. If observers agreed on the location of the parietal notch a 1.5-mm radiopaque mammography bead (Beekley Medical, Bristol, CT) was attached to the surface of the temporal bone at the apex of the parietal notch. Remnants of the dura mater and the sigmoid sinus were left on the intracranial surfaces of temporal bones to aid in the identification of the exact location of the sinodural angle and a second radiopaque marker was placed adjacent to the bony prominence on the anterior border of the sigmoid sinus at the entry point of the superior petrosal sinus (Figures 3 and 4). Once marked, the specimens were mounted on foam with the lateral surface of the temporal bone facing upward. The temporal bones were imaged using a Philips Brilliance Big Bore 16-Slice CT scanner. Axial DICOM images, approximating the Frankfurt plane, with a slice thickness of 0.65 mm were analyzed using PACS software.

With PACS software, the horizontal and vertical distance between radiopaque markers was measured on the imaged specimens. The horizontal distance between the markers was determined by creating a virtual plane that was tangential to the cortex of the mastoid process. Lines perpendicular to this plane were placed through the center of each marker and the horizontal distance between these lines was measured with the PACS ruler tool (Figures 3 and 4). The vertical distance between markers was measured by finding the axial slice positioned at the center of each marker, counting the number of images that separated these slices and multiplying the number of slices by 0.65 mm, the thickness of each slice.

The convention used for the horizontal measurements in this study was as follows: when the marker on the parietal notch was posterior to the marker on the sinodural angle, the measurement value was a positive number. For vertical measurements, when the parietal notch marker was superior to the sinodural marker it was recorded as a positive number. The measurements were made in increments of 0.05 mm.

Distance measurements are reported using means, standard deviations, medians and selected percentiles. Statistical analyses were conducted using SAS v9.4 software. The consistency of the measurements of horizontal and vertical distances between the parietal notch and sinodural angle made by the investigators was evaluated using scatter plots, Pearson correlation (r_P) and summaries of observer-paired differences. Scatter plots were used to visualize agreement between observers and to assess whether the relationship measurements was linear over the range of values. Pearson correlations are used to quantify agreement between two continuous measures, which in this case are distance measurements by observer 1 and observer 2. A correlation of 1.0 is perfect linear association between two continuous variables, and correlation of 0.0 is no association or

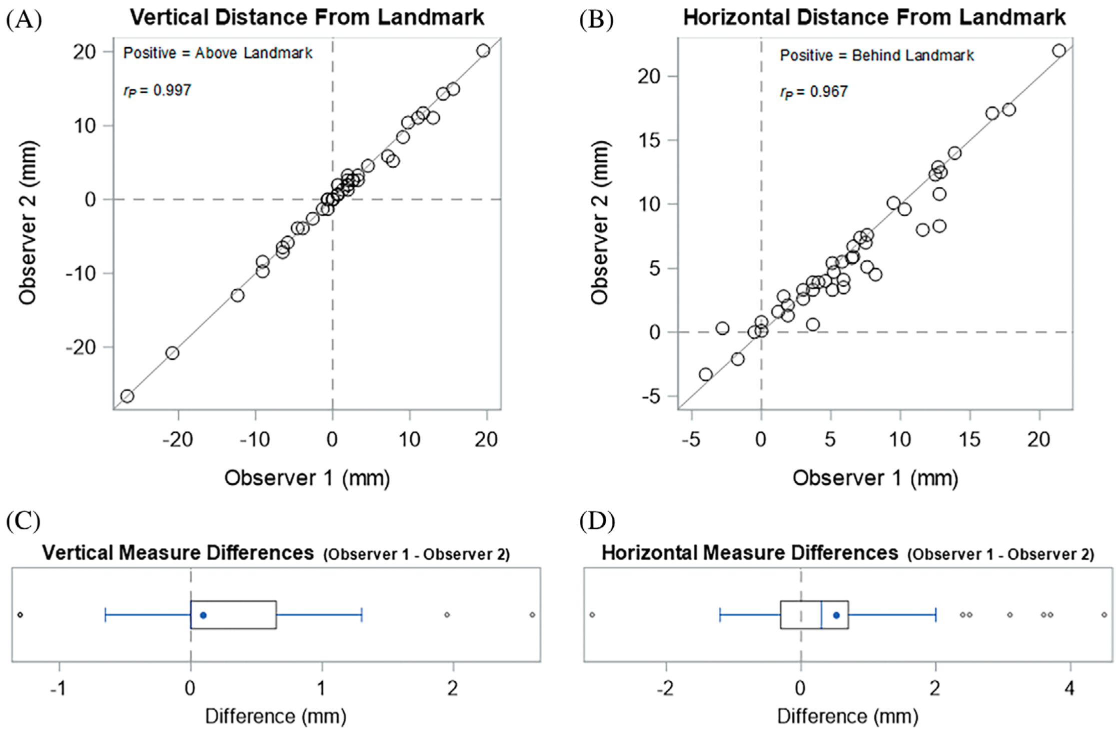

FIGURE 5 Measures of interobserver reliability. Agreement between observer 1 and 2 vertical (A) and horizontal (B) distance from the parietal notch landmark. (C) and (D) shows the difference for vertical (C) and horizontal (D) observer measurement

agreement. Differences between pairs of observer measurements provided another quantitative assessment of the magnitude of their agreement, because measurements may have strong correlation (high Pearson correlation) even though one observer consistently measures lower or higher than the other. When the two observers agree perfectly, the difference is zero. Box plots were used to visualize distributions of interobserver differences and nonparametric Wilcoxon signed-rank tests were used to test whether median differences between paired interobserver differences were different from zero. Nonparametric tests were used because differences may not be normally distributed. Significance level for testing was set at $p < 0.05$.

3 | RESULTS

The parietal notch was identified by both observers in 45 out of 47 (96%) specimens. Of the 45 temporal bones where the parietal notch was identified, there was agreement on its precise location in 43 (96%) of specimens.

3.1 | Interobserver measurement reliability

Comparing horizontal measurements made by the observers, the average paired difference between the horizontal measurements was 0.5 mm (SD = 1.4), and 76% of the horizontal measures within 1.5 mm for all specimens (Median = 0.3 mm, Wilcoxon signed rank test $p = 0.042$; Figure 5(D)). The positive median difference between observers for horizontal differences (0.3 mm) is <5% of the range in

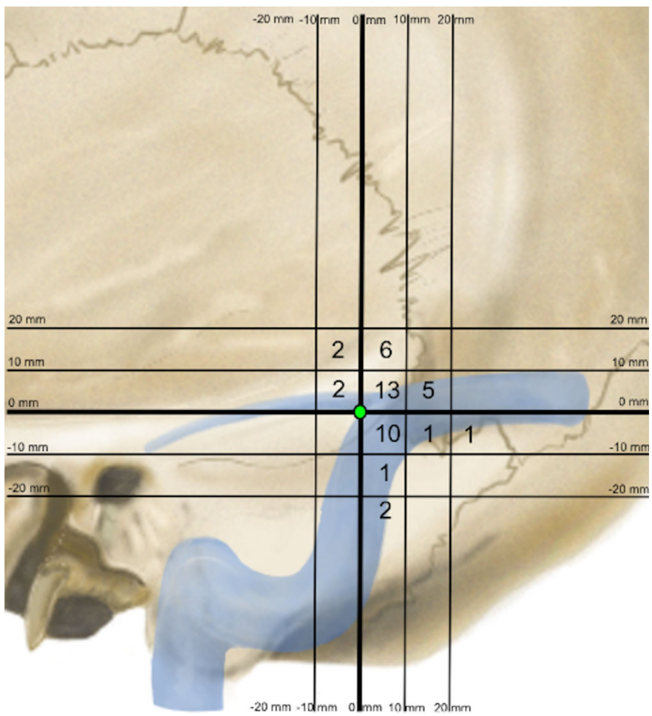

FIGURE 6 The anatomical relationship of the parietal notch and the sinodural angle (green dot). Each number represents the frequency of parietal notch specimens located in a 10 × 10 mm grid. Illustration by Colton Baines

horizontal measurements. Box plots show seven potential outlier values (open circles) for horizontal measurements and three for vertical suggesting additional training could improve repeatability of measurements. However, given the observed alpha reliability coefficients and small average observer differences, we believed it justifiable to average the two observer measurements for our analyses above.

Interobserver agreement between observers was very good for vertical measurements (Pearson correlation >0.99) and horizontal measurements (Pearson correlation = 0.97; Figure 5(A,B)). Interobserver differences in vertical measurements were consistent with an average paired difference of <0.1 mm (SD = 0.7, Median = 0.0 mm, Wilcoxon signed rank test $p = 0.892$; Figure 5(C)). More than 95% of the independent vertical measures were within 1.5 mm for all 43 temporal bones despite the measured distances spanning a range of >40 mm between specimens.

3.2 | Horizontal measurement of landmarks

The average horizontal distance between landmarks was 6.1 mm (SD = 5.4). The notch was positioned posterior to the sinodural angle in 39 of 43 specimens (90.6%) (Figure 6). Furthermore, in 32 of these 39 specimens the parietal notch was located within 10 mm of the sinodural angle. In over half (53%) of the specimens, the parietal notch was within 6 mm of the sinodural angle (Figure 6). In one specimen, the parietal notch was located more than 20 mm from the sinodural angle (Figure 6). This specimen did not have any unusual physical features except for a longer than average parietomastoid suture line. However, other specimens with similar parietomastoid suture line lengths did not have nearly as large of a measurement discrepancy between the two landmarks.

3.3 | Vertical measurement of landmarks

The parietal notch was positioned above the sinodural angle with an average vertical distance between landmarks of 0.8 mm (SD = 8.7). The notch was positioned superior to the sinodural angle in 28/43 (65%) specimens. Of the 28 specimens where the parental notch was positioned superior to the sinodural angle, 20 were located within 10 mm of the sinodural angle. When assessing the overall vertical proximity, in 32 of the measured specimens the parietal notch was within 10 mm of the sinodural angle (Figure 6). Overall, in 26 (60%) of the specimens the parietal notch was within 6 mm of the sinodural angle when measured vertically. The parietal notch was located more than 20 mm from the sinodural angle in 2 specimens (5%). There was nothing anatomically remarkable about these two specimens and they were outliers in vertical measurements only.

4 | DISCUSSION

This study demonstrates the accuracy and reliability of using the parietal notch to locate the position of the sigmoid sinus at the sinodural angle (Figures 1 and 2(A,B)). The parietal notch is a surface landmark that is easily identified in the majority of temporal bones. Although there was some variability, especially when vertical measurements were analyzed, the notch was fairly reliable in locating the sigmoid sinus position by identifying a point 6 mm posterior to the sinodural angle in the majority of specimens. This degree of accuracy is adequate as an initial guide for drilling with a 6 mm burr.

The external auditory canal, temporal line and general configuration of the mastoid cortex are critical surface landmarks that surgeons routinely use as initial guides during mastoidectomy.[5,11] However, the parietal notch is another landmark that can be helpful in estimating the anterior to posterior dimension of the mastoid process near the temporal line. The close relationship between the notch on the surface of the skull and the venous sinuses on the inner surface of the skull is probably not coincidental. Studies of skull base embryology suggest that cranial growth and suture location are influenced by meningeal attachments.[12] Endocranial structures such as the falx and the tentorium act as meningeal tensors that distribute force during growth of the skull base. It is plausible that the attachment of the tentorium at the junction between the transverse and sigmoid venous sinuses helps define the posterior border of the petrous temporal bone as well as the adjacent borders of the occipital and parietal skull. Two factors might explain why the parietal notch is positioned posterior to the sinodural angle rather than directly over it. First, if the venous sinuses influence the location of the overlying suture lines, it is reasonable to assume that the notch would be positioned directly over the junction of the transverse and sigmoid sinuses and not over the anterior border of the junction at the sinodural angle. Second, during development, the squamous portion of the temporal bone grows and extends posteriorly and superiorly on the surface of the skull.[13] This process displaces the suture lines and the notch posteriorly relative to the sinodural angle, which is fixed at the posterior edge of the petrous temporal bone. Developmental skull base growth is integrated such that each portion of the skull base develops interdependently and the growth can be influenced by numerous factors such as local compressive forces, growth factor exposure, and differences in favorable angiogenic, odontogenic or neurogenic factors. This accounts for the anatomic variability of surface landmarks within one individual and between different individuals.

While not an essential surface landmark, the parietal notch can potentially reduce the risk of sinus or dural injuries during surgery and enhance surgical efficiency especially for those who do not routinely perform mastoid surgery. The parietal notch for more experienced surgeons would not be identified routinely, but in select cases may prove useful as another reference point when an anterior placed sigmoid is suspected and in cases when identifying the sinodural angle is more important. Careful drilling using the external auditory canal and temporal line as initial guides usually allows for safe dissection, but surgeons may encounter a sigmoid sinus that is anteriorly positioned or middle fossa dura that is low lying and dehiscent. The anterior border of the sigmoid sinus is approximately 13 mm posterior to the external auditory canal in an average mastoid, but it can range from 8 to 22 mm.[14] The temporal line is a reliable landmark for the middle fossa dura except at the posterior aspect of the mastoid process. Alhussaini et al.[15] evaluated this relationship by drilling a series of perpendicular holes along the temporal line in 32 cadaveric specimens starting near the suprameatal crest and tracking posteriorly. They found that the middle fossa dura was inferior to the temporal line in less 10% of specimens when measured at the suprameatal spine and 9 mm posteriorly along the landmark, but the temporal line was less reliable 12 mm posterior to the crest. These findings suggest that the parietal notch can be used in conjunction with the temporal line to avoid dural injury during mastoidectomy especially when working posteriorly.

The first report that described the parietal notch as a surface landmark was published in 1996.[16] Their detailed dissection of cadaveric specimens showed that the squamosal-parietomastoid suture junction (parietal notch) lay over the anterior border of the proximal sigmoid sinus and that a line drawn from the notch to the mastoid tip defined the axis of the sigmoid sinus. The overall architecture of the mastoid process can also help to predict the location of the sigmoid sinus. Piromchai et al.[17] measured the distance between temporal bone surface landmarks and compared these measurements to distances between internal temporal bone structures on 112 high-resolution CT scans. They found a strong correlation between the height of the mastoid process, and the position of the sigmoid sinus. They also found an anteriorly displaced sigmoid sinus was associated with reduced height of the mastoid process.

A limitation of our study is measurement inaccuracies related to orientation of the specimen during scanning, especially vertical measurements. We were able to create a digital tangential plane on the mastoid cortex and place perpendicular markers on the landmarks to take horizontal measurements. This method made it possible to account for variations in the orientation of the specimens across a vertical axis allowing more consistency between specimens. Vertical measurements, on the other hand, were calculated by counting slices between markers and this measurement relied solely on the orientation of the axial slice in the scanner, which varied between specimens. We attempted to orient the specimens with axial slices in the Frankfurt horizontal plane, but because we did not have whole skulls we could only estimate the plane. Measurements from coronal and sagittal slices were attempted, but with no anatomical reference plane to work from, precision was not improved. An additional potential limitation is our assumption that the ease of identification of the parietal notch on a cadaver and during surgery is equal. It is possible that the parietal notch is more difficult to appreciate during routine mastoid surgery. Furthermore, given the degree of variability in the location of the parietal notch the soft tissue dissection may be too great on some bones for it to be worthwhile. This however could be avoided by obtaining 3D CT scan reconstructions of temporal bones with presurgical planning. One could see if the location of the notch would be close to the area of dissection and could be incorporated or not in the dissection based on the scan. The last major limitation and not addressed by our study is the question of does the parietal notch approximate the sinodural angle more or less accurately in sclerotic diseased bones compared to healthy temporal bones. In reality the landmark would be much more useful in the scenario of sclerotic and diseased mastoids. Unfortunately, the design of this study was with disease free temporal bones and the ability to address this question is beyond the scope of this study.

5 | CONCLUSION

Otologic surgeons use both surface and deep anatomic landmarks along with important neurovascular structures housed in the temporal bone to preserve the organs of hearing and balance during surgery. We have demonstrated that the parietal notch is surface landmark in that it is easy to identify, is present on most bones, and more than half the time is found just posterior and slightly superior to the sinodural angle at the sigmoid sinus. Although we do not recommend its routine use, we believe it has utility as another reference point to define the posterior edge of mastoid dissection. It may also be used to approximate the location of the middle cranial fossa if used in concert with the temporal line, both of which would be useful for surgeons especially in cases where aberrant anatomy is more likely.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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