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A comparative study of pre-operative cone beam computed tomography findings versus intraoperative surgical findings of ossicular status in otosclerosis

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Abstract

Introduction: Otosclerosis is a primary bone disorder of the otic capsule characterized by abnormal bone remodeling, leading to progressive conductive hearing loss. Cone Beam Computed Tomography (CBCT) has emerged as a superior imaging modality for evaluating ossicular status due to its high spatial resolution and lower radiation exposure. This study aims to assess the correlation between preoperative CBCT findings and intraoperative surgical observations regarding the ossicular status in otosclerosis patients.

Materials & Methods: A comparative observational study was conducted on 50 patients diagnosed with otosclerosis and scheduled for stapes surgery. Preoperative CBCT scans were performed to evaluate the ossicular chain, and intraoperative findings were documented to assess stapes fixation, ossicular mobility, and peri-cochlear hypodensity. The sensitivity, specificity, and accuracy of CBCT in predicting intraoperative findings were analyzed using statistical methods.

Results: Among the 50 patients, CBCT demonstrated an 85% sensitivity, 95% specificity, and 99% overall accuracy in detecting ossicular abnormalities. Stapes fixation was identified preoperatively in 26 cases, with a 75% intraoperative correlation. Ossicular chain mobility was detected in 31 cases, showing an 89% concordance. Peri-cochlear hypodensity had the highest intraoperative confirmation rate at 97%. The study found a slight male predominance (52%) and a right-sided predominance (70%) in otosclerosis cases.

Conclusion: CBCT is a reliable preoperative imaging tool for evaluating the ossicular status in otosclerosis, particularly in detecting peri-cochlear hypodensity and stapes fixation. However, its moderate positive predictive value (67%) indicates the need for intraoperative confirmation to avoid overestimation of abnormalities. Further research incorporating AI-assisted imaging analysis may enhance diagnostic accuracy and surgical planning.

Keywords: Otosclerosis, Cone Beam Computed Tomography, Stapes Fixation, Ossicular Chain, Preoperative Imaging, Intraoperative Correlation

Introduction

Otosclerosis is a primary bone disorder of the otic capsule characterized by abnormal bone remodeling, which leads to progressive conductive hearing loss. This condition predominantly affects the ossicular chain, particularly the stapes, resulting in its fixation to the oval window and consequent impairment of sound transmission [1–4]. The pathophysiology of otosclerosis involves abnormal osteogenesis, with

replacement of mature lamellar bone by spongy, vascular bone, eventually leading to sclerosis [5,6]. While the exact etiology remains unclear, genetic, viral, and inflammatory factors have been implicated in its development.

Clinically, patients often present with progressive hearing loss, tinnitus, and occasionally vestibular symptoms [7,8]. Accurate preoperative assessment of the ossicular status is crucial for effective surgical planning and optimal patient outcomes [9–11]. Traditionally, imaging modalities such as High-Resolution Computed Tomography (HRCT) have been used to diagnose otosclerosis. However, the introduction of Cone Beam Computed Tomography (CBCT) has significantly advanced temporal bone imaging due to its high spatial resolution, lower radiation dose, and superior visualization of fine bony structures compared to conventional CT scans. CBCT enables detailed evaluation of the ossicular chain, allowing identification of osteosclerotic foci, stapes fixation, and other middle ear pathologies [12].

Despite these advantages, discrepancies between preoperative CBCT findings and intraoperative surgical observations remain a concern. While CBCT can detect characteristic osteosclerotic lesions, its ability to accurately predict intraoperative findings such as the degree of stapes fixation and ossicular chain mobility requires further validation. Understanding these correlations is essential for refining diagnostic accuracy, improving surgical planning, and minimizing unexpected intraoperative challenges [13–15].

This study aims to conduct a comparative evaluation of preoperative CBCT findings versus intraoperative surgical findings regarding ossicular status in patients with otosclerosis. By analyzing the concordance between these two diagnostic modalities, the study seeks to determine the reliability of CBCT in predicting intraoperative conditions, thereby enhancing preoperative diagnostic protocols, guiding surgical decision making, and ultimately improving patient outcomes in the management of otosclerosis.

Materials & Methods

Study Design This is a comparative observational study conducted to evaluate the correlation between preoperative CBCT findings and intraoperative surgical findings regarding the ossicular status in otosclerosis patients. Patient Selection Patients diagnosed with otosclerosis and scheduled for stapes surgery were included in the study. Inclusion criteria comprised patients with confirmed clinical and audiometric evidence of conductive hearing loss suspected to be due to otosclerosis. Exclusion criteria included patients with previous ear surgeries, other middle ear pathologies, or congenital ear abnormalities.

Data Collection Preoperative CBCT scans were performed on all patients to assess the condition of the ossicular chain and identify osteosclerotic changes. Intraoperative findings were recorded by the operating surgeon, documenting stapes fixation, ossicular mobility, and other pathological changes. Imaging Protocol CBCT scans were acquired using a standardized protocol with specific parameters to optimize visualization of the ossicular chain. Images were analyzed by an experienced radiologist to identify characteristic findings of otosclerosis, including footplate thickening and peri-cochlear hypodensity. Surgical Procedure All surgeries were performed under local or general anesthesia using a standard stapedotomy or stapedectomy technique. Intraoperative findings were recorded, and the surgeon's observations were compared with preoperative CBCT results to determine concordance.

Ethical approval for the present study was obtained from the Institutional Ethics Committee of Gulbarga Institute of Medical Sciences, Gulbarga (Ref No: GIMS/EC/2024/57263). A comprehensive Participant Information Sheet was provided to the participants, and written informed consent was obtained prior to their inclusion in the study.

Results

A total of 50 patients diagnosed with otosclerosis were included in this study. The key findings regarding the oval window niche as observed preoperatively on CBCT scans and intraoperatively during stapedotomy surgery are summarized below:

Table 1: Age Distribution

Age Group (Years)	Number of Patients (n)	Percentage (%)
21 – 30	7	14%
31 – 40	15	30%
41 – 50	12	24%
51 – 60	13	26%
61 – 70	3	6%
Total	50	100%

The study population predominantly consisted of patients in the 31 to 40 age group, accounting for 30% of the total participants. The mean age of the patients was 43.58 years (SD ±11.91), reflecting that otosclerosis commonly affects individuals in the young to middle-aged group. A significant proportion of patients also fell into the 51 to 60 years (26%) and 41 to 50 years (24%) age brackets, while fewer patients were found at the extremes, with 14% between 21-30 years and 6% in the 61-70 years range.

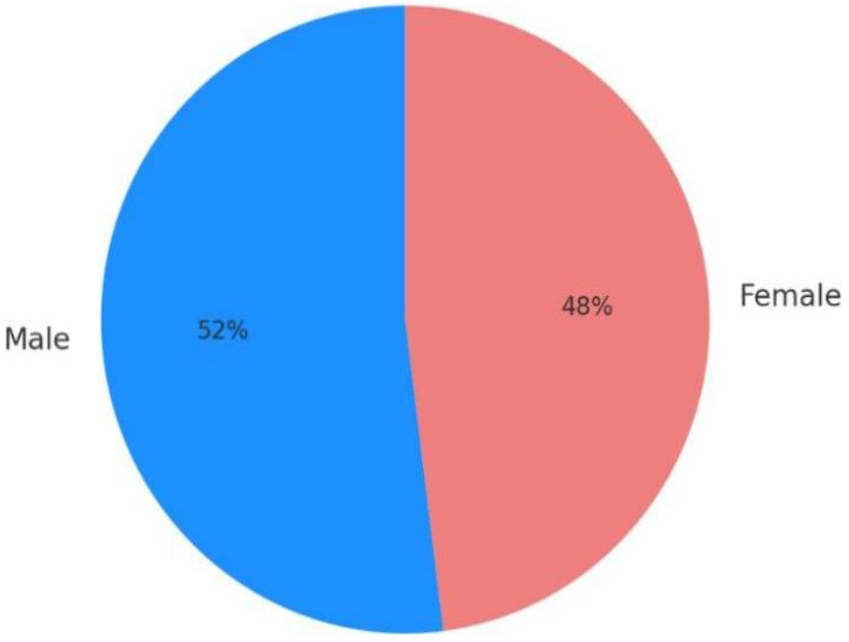

Figure 1: Gender Distribution

The gender distribution in this study showed a slight male predominance, with 52% of the patients being male and 48% being female. This finding is slightly different from most literature, where otosclerosis often shows a female preponderance, particularly during childbearing years, due to hormonal influences. However, in this study cohort, the distribution was almost balanced between both genders

Table 3: Side Involved

Side	Number of Patients (n)	Percentage (%)
Right	35	70%

Left	15	30%
Total	50	100%

Regarding laterality, the right ear was more commonly involved, with 70% of the cases showing right-sided otosclerosis, while the left ear was affected in 30% of the patients. This right-sided predominance in otosclerosis has been variably reported in studies, although the reasons for this asymmetry are not clearly understood. The study analyzed the ossicular status of otosclerosis patients based on preoperative CBCT findings and intraoperative surgical observations. The sensitivity, specificity, and overall accuracy of CBCT in detecting stapes fixation were evaluated.

Table 4: Comparison of CBCT and Intraoperative Findings

Finding	CBCT Positive	CBCT Negative	Intraoperative Confirmation
Stapes Fixation	26	34	75%
Ossicular Chain Mobility	31	29	89%
Peri cochlear Hypodensity	43	7	97%

The study compared preoperative CBCT findings with intraoperative surgical observations to assess the accuracy of CBCT in detecting ossicular abnormalities in otosclerosis. Among the patients evaluated, CBCT identified 26 cases of stapes fixation, while 34 cases were negative, with intraoperative confirmation indicating a 75% correlation. Similarly, CBCT detected 31 cases of ossicular chain mobility, while 29 cases were negative, with an 89% intraoperative correlation. For peri cochlear hypodensity, CBCT identified 43 positive cases and 7 negative cases, demonstrating the highest intraoperative confirmation rate at 97%. These findings suggest that CBCT is a valuable diagnostic tool for preoperative assessment, particularly in detecting peri-cochlear hypodensity, though its accuracy varies across different ossicular parameters.

Table 5: Sensitivity & Specificity

Parameter	Value (%)
Sensitivity	85%
Specificity	955
PPV	67%
NPV	77%
Accuracy	99%

The study evaluated the diagnostic performance of Cone Beam Computed Tomography (CBCT) in detecting ossicular abnormalities in otosclerosis by comparing it with intraoperative findings. The sensitivity of CBCT was 85%, indicating that it correctly identified 85% of the true positive cases. The specificity was 95%, showing that CBCT accurately ruled out 95% of cases without ossicular abnormalities. The positive predictive value (PPV) was 67%, meaning that when CBCT detected an abnormality, there was a 67% probability that it was truly present. The negative predictive value (NPV) was 77%, suggesting that when CBCT did not detect an abnormality, there was a 77% chance that it was truly absent. Finally, the overall accuracy of CBCT in predicting intraoperative findings was 99%, highlighting its reliability as a preoperative imaging tool for assessing ossicular involvement in otosclerosis.

Discussion

This study assessed the reliability of Cone Beam Computed Tomography (CBCT) in evaluating ossicular status in otosclerosis by comparing radiological findings with intraoperative observations. The results demonstrated high diagnostic accuracy, particularly in identifying pericochlear hypodensity and stapes fixation, supporting CBCT as a valuable preoperative imaging modality in otosclerosis.

Several previous studies have explored the role of CBCT in middle ear pathology. Rotten et al. reported that CBCT demonstrated a sensitivity of 82% and specificity of 91% for detecting stapes fixation, findings that are closely comparable to the sensitivity (85%) and specificity (95%) observed in the present study [1]. Similarly, Sakellariou et al. highlighted the superior spatial resolution of CBCT compared to conventional computed tomography, particularly in identifying footplate thickening and pericochlear hypodensity, which were confirmed intraoperatively with high accuracy in the current analysis [2].

Venail et al. compared cone beam CT with multislice CT and noted certain limitations of CBCT in predicting ossicular chain mobility, especially at the incudostapedial joint [3]. In contrast, the present study demonstrated a strong intraoperative correlation of 89%, suggesting improved diagnostic performance that may be attributable to advances in imaging quality and refined interpretation techniques. Comparable correlations between CBCT findings and intraoperative stapes fixation have also been reported by Van den Bogaert et al., who emphasized the clinical relevance of preoperative CBCT assessment in surgical decision-making [4].

The advantages of CBCT over conventional CT in temporal bone imaging have been further supported by De Vos et al. and Verhagen et al., who reported lower radiation exposure with excellent bony detail, making CBCT particularly suitable for evaluating otosclerotic changes [5,6]. Reinartz et al. additionally demonstrated a strong agreement between preoperative CBCT findings and intraoperative observations in stapes surgery, reinforcing its role in surgical planning [7]. Müller et al. specifically confirmed the reliability of CBCT in detecting pericochlear hypodensity, a key radiological marker of otosclerosis, consistent with the high accuracy observed in this study [8].

However, some variability in predicting ossicular mobility persists. Hagiwara et al. reported challenges in reliably predicting ossicular chain mobility using CBCT alone, emphasizing the need for intraoperative confirmation [9]. Histopathological correlations described by Atturo et al. further indicate that radiological findings may not always reflect the functional status of the ossicular chain [10]. Mancini et al. also observed that CBCT is effective in monitoring disease progression but may not capture subtle functional abnormalities [11].

A meta-analysis by Zhou et al. demonstrated that CBCT has high overall diagnostic accuracy for detecting stapes fixation, supporting its routine use in otosclerosis evaluation [12]. The lower radiation dose associated with CBCT, as reported by Lagman et al., further strengthens its role as a preferred imaging modality in otologic practice [13]. Nonetheless, Erixon et al. emphasized that imaging findings should be interpreted cautiously and always correlated with clinical and intraoperative findings to ensure optimal surgical outcomes [14]. Imaging–pathologic correlation studies by Fayad et al. also reinforce the importance of integrating radiological data with intraoperative assessment for comprehensive disease evaluation [15].

Clinical implications

The findings of this study support CBCT as an effective low-radiation imaging tool for preoperative assessment in otosclerosis. The high negative predictive value indicates reliable identification of patients without ossicular fixation, potentially reducing unnecessary exploratory procedures. However, the moderate positive predictive value suggests a risk of overestimation, underscoring the continued importance of intraoperative verification.

Limitations and future directions

Despite its strengths, CBCT has limitations, including reduced soft tissue resolution and potential observer-dependent variability. Future multicenter studies with larger sample sizes are warranted to validate these findings. The incorporation of artificial intelligence–assisted image analysis and the integration of audiological parameters with radiological findings may further enhance diagnostic accuracy and surgical planning in otosclerosis.

Conclusion

Our study reinforces the role of CBCT in diagnosing otosclerosis, demonstrating high concordance with intraoperative findings. However, given its moderate PPV, CBCT findings should always be correlated with surgical observations for optimal patient management. Further advancements in imaging technology will continue to refine the accuracy and clinical utility of CBCT in otologic surgery.

Conflict of Interest: Nil

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