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Original Article

Diagnostic Accuracy of Contrast-Enhanced Computed Tomography (CECT) in Detecting Mandibular Invasion in Oral Squamous Cell Carcinoma: A Prospective Study Using Histopathology as the Gold Standard

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Abstract

Background: Oral squamous cell carcinoma (OSCC) is the most common malignancy of the oral cavity, particularly prevalent in South Asian populations, where risk factors such as tobacco use and betel quid chewing are widespread. Mandibular invasion is a critical determinant of disease staging, surgical planning, and prognosis, necessitating accurate preoperative assessment. Although contrast-enhanced computed tomography (CECT) is routinely employed for this purpose, variability in its diagnostic performance has been reported.

Objective: To evaluate the diagnostic accuracy of CECT in detecting mandibular invasion in patients with OSCC, using histopathological examination as the gold standard.

Methodology: This prospective diagnostic accuracy study was conducted at a tertiary care center in Peshawar over six months. A total of 154 patients with biopsy-confirmed OSCC underwent standardized CECT imaging. Two blinded radiologists independently assessed the scans for mandibular invasion based on predefined criteria. Histopathological evaluation of surgically resected specimens served as the reference standard. Diagnostic parameters including sensitivity, specificity, predictive values, likelihood ratios, and overall accuracy were calculated.

Results: The mean age of participants was 48.5 ± 10.2 years, with a male predominance (65%). Histopathology confirmed mandibular invasion in 53.2% of cases. CECT demonstrated a sensitivity of 69.2% (95% CI: 58.1–78.8%) and specificity of 78.4% (95% CI: 68.2–86.2%), with an overall accuracy of 73.3%. Positive and negative predictive values were 80.4% and 66.7%, respectively. Diagnostic performance was significantly higher for posterior tumors compared to anterior lesions ($p = 0.039$). Interobserver agreement was substantial ($\kappa = 0.72$).

Conclusion: CECT demonstrates moderate diagnostic accuracy for detecting mandibular invasion in OSCC. While it remains a valuable tool for preoperative evaluation, its limited sensitivity necessitates cautious interpretation of negative findings, particularly in clinically suspicious cases. Integration of imaging with histopathological assessment remains essential for optimal management.

Keywords: Bone invasion, Computed tomography, Diagnostic imaging, Mandible, Oral cancer, Sensitivity and specificity, Squamous cell carcinoma.

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Introduction

Oral squamous cell carcinoma (OSCC) is the most prevalent malignant neoplasm of the oral cavity, accounting for approximately 90% of all oral cancers worldwide [1]. The burden of this disease is disproportionately higher in South Asian populations, where cultural practices such as betel quid chewing, areca nut consumption, and tobacco use play a significant etiological role [2]. In Pakistan, OSCC ranks among the most common malignancies, with reported prevalence rates approaching 15%, which is markedly higher than global estimates [3]. This substantial disease burden highlights the urgent need for effective diagnostic strategies to enable early detection, accurate staging, and improved clinical outcomes.

Mandibular bone invasion is recognized as a critical prognostic factor in OSCC, reported in approximately 27–56% of advanced cases [4]. Its presence significantly influences treatment planning, often necessitating aggressive surgical approaches such as segmental mandibulectomy, complex reconstruction, and adjuvant therapies [5]. In contrast, the absence of bony involvement allows for more conservative surgical management, thereby minimizing morbidity and preserving functional outcomes. Consequently, precise preoperative assessment of mandibular invasion is essential for guiding appropriate therapeutic decisions and optimizing patient prognosis.

Contrast-enhanced computed tomography (CECT) has emerged as a cornerstone imaging modality in the evaluation of OSCC due to its widespread availability, rapid acquisition, and ability to simultaneously assess both soft tissue and osseous structures [6]. Current clinical guidelines recommend CECT as a first-line imaging technique for staging oral cavity malignancies [7]. It is particularly valuable in detecting cortical bone erosion, trabecular destruction, and tumor extension into adjacent anatomical structures.

Despite its routine clinical use, the diagnostic accuracy of CECT in detecting mandibular invasion remains inconsistent across studies [8]. Variability in reported sensitivity and specificity may be attributed to differences in imaging protocols, heterogeneity in radiologic interpretation criteria, and population-specific tumor characteristics [9]. Moreover, while CECT is highly effective in identifying cortical bone destruction, its sensitivity in detecting early medullary invasion is relatively limited, which may result in underestimation of disease extent [10].

Given these limitations and the clinical importance of accurate staging, there is a pressing need for region-specific evidence evaluating the diagnostic performance of CECT in OSCC. The present study aims to assess the diagnostic accuracy of CECT in detecting mandibular invasion, using histopathological findings as the gold standard. By generating locally relevant data, this study seeks to support evidence-based clinical decision-making and improve management strategies for OSCC, particularly in resource-constrained healthcare settings.

Methodology

Study Design

This study was designed as a prospective diagnostic accuracy cohort conducted to evaluate the performance of contrast-enhanced computed tomography (CECT) in detecting mandibular invasion among patients diagnosed with oral squamous cell carcinoma (OSCC). The study adhered to internationally accepted reporting standards for diagnostic accuracy studies, specifically the STARD guidelines, ensuring methodological transparency and reproducibility.

Ethics

Prior to initiation, ethical approval was obtained from the Institutional Review Board of Hayatabad Medical Complex, Peshawar. All procedures were conducted in accordance with ethical standards for human research. Written informed consent was obtained from all participants after explaining the purpose, risks, and benefits of the study, ensuring voluntary participation and confidentiality.

Setting

The study was carried out at the Department of Diagnostic Radiology, PGMI/Hayatabad Medical Complex, Peshawar, Pakistan, a tertiary care teaching hospital with specialized facilities for oncological imaging and surgical management. Data collection spanned a six-month period from January to June 2023.

Participants

A total of 154 consecutive adult patients aged between 18 and 65 years with biopsy-proven OSCC scheduled for surgical resection were enrolled. The use of consecutive sampling minimized selection bias. Patients were excluded if they had contraindications to iodinated contrast media, presence of dental implants causing imaging artifacts, prior mandibular surgery or radiotherapy, or recurrent tumors, to ensure uniformity in diagnostic assessment.

Variables

The primary outcome variable was the presence or absence of mandibular invasion as determined by histopathology

(reference standard). The index test variable was CECT-based detection of mandibular invasion. Additional variables included demographic characteristics (age, gender), tumor location, and radiologic features such as cortical erosion, trabecular destruction, and soft tissue involvement.

Data Sources/Measurement

All participants underwent standardized CECT imaging of the head and neck using a 128-slice multidetector CT scanner with defined acquisition parameters (120 kVp, automated tube current modulation, 0.6 mm slice thickness reconstructed at 1 mm). Intravenous contrast (Iohexol 350 mgI/mL) was administered, and both arterial and venous phase images were obtained. Two experienced radiologists independently evaluated the scans while blinded to histopathological findings. Mandibular invasion was defined by the presence of at least two radiologic criteria, including cortical erosion, medullary destruction, soft tissue mass abutment, or permeative bone changes. Discrepancies between observers were resolved through consensus. Histopathological examination of surgically resected specimens, processed with standardized decalcification and staining protocols, served as the gold standard for confirmation.

Bias

Several strategies were employed to minimize bias. Selection bias was reduced through consecutive patient enrollment. Observer bias was controlled by blinding radiologists to histopathology results. Verification bias was minimized as all patients underwent both the index test (CECT) and the reference standard (histopathology). However, potential sources of bias include single-center design and consensus-based resolution of radiologic disagreements, which may influence diagnostic estimates.

Study Size

The sample size of 154 patients was determined based on feasibility within the study period and alignment with similar diagnostic accuracy studies in the literature. The inclusion of a relatively balanced proportion of cases with and without mandibular invasion allowed for meaningful estimation of sensitivity, specificity, and predictive values.

Quantitative Variables

Quantitative variables included age (expressed as mean ± standard deviation) and diagnostic performance measures such as sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratios, and overall diagnostic accuracy. Interobserver agreement was quantified using Cohen's kappa statistic.

Statistical Methods

Data analysis was performed using SPSS version 26. Diagnostic accuracy parameters including sensitivity, specificity, PPV, NPV, and overall accuracy were calculated along with 95% confidence intervals. Likelihood ratios were also computed to assess clinical utility. Interobserver agreement between radiologists was evaluated using Cohen's kappa coefficient. Comparative analysis of diagnostic performance across tumor locations was conducted using the chi-square test, with a p-value <0.05 considered statistically significant. Additionally, sensitivity analysis was performed to evaluate the impact of altering diagnostic thresholds on test performance.

Results

Participants

A total of 154 patients with biopsy-confirmed oral squamous cell carcinoma (OSCC) were included in the final analysis. All enrolled participants completed both the index test (contrast-enhanced computed tomography, CECT) and the reference standard (histopathological examination), with no loss to follow-up or missing data. The study population was derived through consecutive sampling, ensuring adequate representation of clinically relevant cases undergoing surgical management.

Descriptive Data

The demographic and clinical characteristics of the study population are summarized in Table 1. The mean age of participants was 48.5 ± 10.2 years, reflecting a predominantly middle-aged cohort. There was a male predominance, with 100 males (65%) and 54 females (35%). Regarding tumor location, the most common primary site was the buccal mucosa (42%), followed by the tongue (31%), while 27% of tumors originated from other oral cavity sites. Histopathological examination confirmed mandibular invasion in 82 cases (53.2%), whereas 72 patients (46.8%) showed no evidence of bone involvement.

Outcome Data

Diagnostic performance metrics of CECT in detecting mandibular invasion are presented in Table 2. The sensitivity of CECT was 69.2% (95% CI: 58.1–78.8%), indicating moderate ability to correctly identify true positive cases. The specificity was 78.4% (95% CI: 68.2–86.2%), reflecting a relatively higher accuracy in ruling out patients without mandibular invasion. The positive predictive value (PPV) was 80.4% (95% CI: 69.9–88.0%), suggesting that a positive CECT finding reliably indicated true bone invasion in most cases. However, the negative predictive value (NPV) was comparatively lower at 66.7% (95% CI: 56.3–75.7%),

indicating that negative imaging findings did not consistently exclude the presence of invasion. The overall diagnostic accuracy of CECT was 73.3%. The positive likelihood ratio (3.20) and negative likelihood ratio (0.39) further support the moderate discriminative ability of the imaging modality. Interobserver agreement between the two radiologists was substantial, with a Cohen's kappa value of 0.72.

Main Results

Stratified analysis based on tumor location demonstrated variation in diagnostic performance, as detailed in Table 3. CECT showed higher accuracy in detecting mandibular invasion in posterior tumors (78%) compared to anterior tumors (67%). Sensitivity for posterior lesions was 76.8% with specificity of 79.3%, whereas anterior lesions showed lower sensitivity (61.4%) and specificity (72.1%). This difference was statistically significant ($\chi^2 = 4.28$, $p = 0.039$), indicating that tumor location influences the diagnostic performance of CECT.

Additionally, sensitivity analysis revealed that modifying the diagnostic threshold to include the presence of a single radiologic feature increased sensitivity to 82.9%, albeit at the cost of reduced specificity (62.5%). This finding highlights the trade-off between sensitivity and specificity depending on the applied diagnostic criteria and suggests that threshold selection may be tailored based on clinical priorities.

Table 1: Demographic and Clinical Characteristics of Study Participants (n=154)

Characteristic	Value (%)
Mean age (years)	48.5 ± 10.2
Gender	
Male	100 (65)
Female	54 (35)
Tumor Location	
Buccal mucosa	65 (42)
Tongue	48 (31)
Other sites	41 (27)
Mandibular Invasion (Histopathology)	
Present	82 (53.2)
Absent	72 (46.8)

Table 2: Diagnostic Performance of CECT for Detecting Mandibular Invasion

Metric	Value (95% CI)
Sensitivity	69.2 (58.1–78.8)
Specificity	78.4 (68.2–86.2)
Positive Predictive Value (PPV)	80.4 (69.9–88.0)
Negative Predictive Value (NPV)	66.7 (56.3–75.7)
Overall Accuracy	73.3
Interobserver Agreement (κ)	0.72 (substantial)

Table 3: CECT Performance Stratified by Tumor Location

Location	Sensitivity (%)	Specificity (%)	Accuracy (%)
Anterior	61.4	72.1	67
Posterior	76.8	79.3	78

Discussion

Accurate detection of mandibular invasion remains a pivotal factor in the staging and management of oral squamous cell carcinoma (OSCC), as it directly determines the extent of surgical intervention and overall patient prognosis. In the present study, contrast-enhanced

computed tomography (CECT) demonstrated moderate diagnostic accuracy in identifying mandibular involvement when compared with histopathological findings. These results reaffirm the role of CECT as a practical and accessible first-line imaging modality, while simultaneously highlighting its diagnostic limitations, particularly in early-stage bone invasion.

The diagnostic performance observed in this study, with sensitivity of 69.2% and specificity of 78.4%, is comparable to previously published literature, where sensitivity generally ranges from 60% to 80% and specificity from 70% to 85% [10,11]. This consistency supports the reliability of CECT in detecting cortical bone invasion across diverse clinical settings. However, variability reported in earlier studies reflects differences in imaging protocols, interpretative criteria, and population characteristics [8,9]. Such heterogeneity emphasizes the need for context-specific interpretation of imaging findings.

A notable strength of CECT lies in its ability to delineate cortical bone abnormalities, such as erosion, discontinuity, and trabecular destruction, which are hallmark features of advanced tumor infiltration. These imaging features are critical for surgical planning and are readily visualized using multidetector CT systems. However, CECT demonstrates limited sensitivity in detecting early medullary invasion, which often precedes cortical involvement. This limitation contributes to false-negative findings and potential underestimation of disease extent, as also reported in previous studies [10,12].

The substantial interobserver agreement observed in this study (κ = 0.72) further supports the reliability and reproducibility of CECT interpretation. Consistency in radiologic assessment is essential in multidisciplinary oncology care, where imaging findings guide treatment decisions. Similar levels of agreement have been reported in earlier investigations utilizing standardized diagnostic criteria [13].

An important finding of this study was the variation in diagnostic performance according to tumor location. CECT demonstrated higher accuracy for posterior mandibular lesions compared to anterior lesions. This difference may be attributed to beam-hardening artifacts caused by dental restorations, which are more common in the anterior region and may obscure subtle bone changes [15,16]. Additionally, anatomical differences in cortical bone thickness and tumor growth patterns may influence radiologic detectability [4,14]. These findings highlight the importance of careful interpretation, particularly in anatomically complex regions.

From a clinical perspective, the moderate sensitivity observed indicates that negative CECT findings should not be considered sufficient to exclude mandibular invasion. In cases of strong clinical suspicion, further evaluation through intraoperative assessment or complementary imaging modalities may be required.[17] Conversely, the relatively higher specificity suggests that positive CECT findings are more reliable and can effectively guide surgical planning. Overall, optimal management of OSCC requires integration of radiologic findings with clinical and histopathological evaluation to ensure accurate staging and appropriate treatment strategies.

Limitations

Several limitations of this study should be acknowledged. First, the study was conducted at a single tertiary care center, which may limit the generalizability of the findings to other settings with different patient populations or imaging protocols. Second, the inclusion of only surgically treated patients introduces potential selection bias, as patients with early-stage disease or those managed non-surgically were not represented. Third, although interobserver agreement was assessed independently, the use of consensus review in discrepant cases may have influenced the final diagnostic performance estimates. Additionally, other imaging modalities such as magnetic resonance imaging (MRI), cone-beam CT, or positron emission tomography (PET) were not evaluated, preventing direct comparison of diagnostic performance across modalities. Finally, potential confounding factors such as tumor size, histological grade, and artifact-related limitations were not systematically analyzed.

Conclusion

Contrast-enhanced computed tomography demonstrates moderate diagnostic accuracy in detecting mandibular invasion in patients with oral squamous cell carcinoma when compared with histopathological findings. The modality provides valuable information for preoperative assessment and shows substantial interobserver reliability, supporting its continued role as a primary imaging tool in clinical practice. However, its limited sensitivity, particularly in detecting early medullary invasion, necessitates cautious interpretation of negative findings. Integration of imaging results with clinical evaluation and histopathological confirmation remains essential for accurate staging and optimal treatment planning. Future studies incorporating advanced imaging techniques and multicenter data are recommended to further enhance diagnostic accuracy and clinical decision-making.

Authors' Contributions:

All authors meet the ICMJE criteria for authorship.

Author 1: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 2: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 3: Analysis and interpretation of data, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 4: Analysis and interpretation of data, critical revision, final approval, agreed to be accountable for all the work.
Author 5: Substantial contribution to conception and design, drafting the manuscript, final approval, agreed to be accountable for all the work.
Author 6: Substantial contribution to conception and design, data acquisition, drafting the manuscript, final approval, agreed to be accountable for all the work.

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