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ASSESSMENT OF MRI ACCURACY FOR EVALUATING TUMOR DEPTH IN ORAL TONGUE SQUAMOUS CELL CARCINOMA: CORRELATION WITH HISTOPATHOLOGY

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Abstract

Background: *Accurate preoperative assessment of tumor depth in oral tongue squamous cell carcinoma (OTSCC) is challenging, as histopathology is post-operative. MRI offers a non-invasive alternative, but variable results exist. This study evaluates MRI accuracy and its correlation with histopathology to guide treatment.*

Objectives: *To determine the accuracy of magnetic resonance imaging (MRI) in evaluating tumor depth in patients with oral tongue squamous cell carcinoma and to assess its correlation with histopathological depth of invasion.*

Duration: *Six months w.e.f 01-05-2023 to 31-10-2023*

Methodology: *Following ethical approval, patients meeting inclusion criteria provided written informed consent. All underwent standardized preoperative contrast-enhanced MRI, with tumor depth measured by a radiologist blinded to histopathology. Surgical specimens were resected and analyzed by a blinded pathologist. MRI findings were compared with histopathological measurements, considered the gold standard, with all procedures performed in a single institution to ensure accuracy, minimize bias, and maintain confidentiality.*

Results: *In 100 OTSCC patients, MRI showed a strong positive correlation with histopathology in tumor depth assessment ($r = 0.881$, $p < 0.001$) and high diagnostic accuracy, with 92.4% sensitivity and 87% overall accuracy. Results were consistent across age and gender subgroups, confirming MRI as a reliable non-invasive tool for preoperative evaluation.*

Conclusion: *MRI demonstrated high accuracy and strong correlation with histopathology in assessing tumor depth and detecting deep invasion in OTSCC. Its diagnostic performance remained consistent across age and gender subgroups, supporting MRI as a reliable, non-invasive tool for preoperative evaluation and surgical planning in patients with oral tongue squamous cell carcinoma.*

INTRODUCTION

Oral tongue squamous cell carcinoma (OTSCC) is the most common malignant neoplasm of the oral cavity, accounting for over 90% of all oral malignancies. It predominantly affects the tongue and floor of the mouth, with the highest prevalence in males over 50 years of age.[1] OTSCC originates from oral mucosal keratinocytes and develops due to DNA mutations, which may occur spontaneously but are amplified by chemical, physical, and microbial carcinogens.[2] Key risk factors include the use of tobacco in various forms (cigarettes, bidis, hookah, cigars), alcohol consumption, and chewing of substances such as areca nut, betel leaf, and slaked lime.[3,4] The histopathology of OTSCC is heterogeneous, with six recognized variants, including verrucous carcinoma, squamous basaloid cell carcinoma, spindle cell carcinoma, adeno-squamous carcinoma, and adenoid squamous carcinoma.[5] Globally, oral squamous cell carcinoma is the seventh most prevalent cancer, accounting for 4.5% of all cancers and approximately 450,000 deaths annually.[6] In Pakistan, it represents roughly 15% of all cancers, with an age-standardized rate of 28 per 100,000 in urban populations.[7]

Management and prognosis of OTSCC depend on tumor site and histological differentiation.[8] Histopathological features such as tumor budding, depth of invasion (DOI), and lymphovascular invasion are critical prognostic indicators. Imaging modalities including CT, MRI, and ultrasound help localize tumors, but MRI is preferred for preoperative assessment due to superior soft tissue resolution.[9,10] MRI allows accurate measurement of clinical DOI, aiding in tumor staging according to the TNM system and guiding treatment planning. Surgical excision remains the primary treatment for early-stage OTSCC, while advanced stages often require surgery combined with adjunctive therapy.[11,12,13]

Das et al.[11] in India reported a very high correlation between MRI and histopathology with r = 0.999, Huopainen et al.[12] in Finland reported r = 0.898, and Ravikanth et al.[13] in India reported r = 0.822, highlighting variation in reported accuracy of MRI for tumor assessment. This study was conducted to address inconsistencies in previously reported results regarding MRI accuracy in evaluating tumor depth and staging in OTSCC. Variations in correlation across studies, likely due to differences in MRI protocols, imaging quality, and patient populations, underscore the need to systematically assess MRI's diagnostic performance and its correlation with histopathological findings in a local cohort.

METHODOLOGY

This study was a cross-sectional investigation conducted in the Department of Radiology at INMOL Cancer Hospital. The study duration was six months, following approval of the topic from CPSP. A total of 100 cases were included, calculated with an α value of 0.05, β of 0.20, and an expected correlation of 0.990.[13]

Non-probability consecutive sampling was used to enroll patients. Inclusion criteria comprised patients aged 18–70 years, with histologically confirmed oral tongue squamous cell carcinoma (OTSCC), who underwent preoperative MRI and subsequent surgical resection. Patients with prior surgery, radiotherapy, or chemotherapy to the oral cavity, recurrent tumors, poor-quality or non-diagnostic MRI scans, or those unfit for surgery were excluded.

Oral tongue squamous cell carcinoma was defined as histologically confirmed squamous cell carcinoma arising from the anterior two-thirds of the tongue. Tumor depth on MRI was defined as the maximum perpendicular distance from the adjacent normal mucosal surface to the deepest point of tumor invasion on contrast-enhanced images. Depth ≥4 mm was considered deep invasion, while <4 mm was superficial.

Histopathological depth of invasion (DOI) was measured from the basement membrane of adjacent normal mucosa to the deepest point of tumor invasion in the surgical specimen. Depth ≥4 mm was considered positive for deep invasion and taken as the gold standard. MRI diagnostic accuracy was defined as the ability of MRI to correctly identify deep tumor invasion compared to histopathology, including sensitivity,

specificity, positive predictive value, negative predictive value, and overall accuracy.

After ethical approval, patients meeting the inclusion criteria were enrolled, and written informed consent was obtained. All patients underwent preoperative contrast-enhanced MRI of the oral cavity. Scans were reviewed by a consultant radiologist blinded to histopathological findings, and tumor depth measurements were recorded in millimeters on a standardized proforma. Patients then underwent surgical resection, and specimens were analyzed by an experienced histopathologist blinded to MRI results. Histopathological depth of invasion was recorded and categorized based on the predefined cutoff. MRI findings were compared with histopathology, which was considered the reference standard. All investigations were performed within the same institution to reduce inter-observer and technical bias, and patient confidentiality was maintained throughout.

Data were entered and analyzed using SPSS version 22. Numerical variables, including age, MRI tumor depth, and histopathological depth, were expressed as mean ± standard deviation. Pearson correlation coefficient was calculated to assess correlation between MRI and histopathology. Diagnostic accuracy parameters were calculated, and a p-value ≤0.05 was considered statistically significant. Stratification was performed for age and gender to assess potential effect modifiers.

RESULTS

A total of 100 patients with OTSCC were included in the study. The mean age of the participants was 46.63 ± 12.47 years. Among them, 28 patients (28.0%) were aged between 18 and 40 years, while 72 patients (72.0%) were older than 40 years. Regarding gender distribution, 62 patients (62.0%) were male and 38 patients (38.0%) were female as shown in Table 1.

Deep invasion of OTSCC was assessed using MRI and confirmed by histopathology. MRI indicated deep invasion in 80 patients (80.0%). Histopathological examination revealed deep invasion in 79 patients (79.0%) as given in Table 2.

Deep invasion on histopathology was observed in 78.6% of patients aged 18–49 years and 80.6% of those aged 50–65 years ($p = 0.824$). By gender, 79.0% of males and 81.6% of females showed deep invasion ($p = 0.757$). Differences were not statistically significant, as given in Table 3.

The mean tumor depth measured by MRI was 5.28 ± 2.07 mm, while histopathology revealed a mean depth of 5.04 ± 1.72 mm. A strong positive correlation was observed between MRI and histopathology measurements ($r = 0.881$), and this correlation was statistically significant ($p < 0.001$), as given in Table 4.

Using histopathology as the reference standard, MRI demonstrated 73 true positives, 6 false negatives, 14 true negatives, and 7 false positives in assessing deep invasion of OTSCC. This yielded a sensitivity of 92.41%, specificity of 66.67%, overall accuracy of 87.00%, a positive predictive value of 91.25%, and a negative predictive value of 70.00%, as shown in Table 5.

Stratification of the correlation between MRI and histopathology findings showed similarly significant results across age and gender subgroups. Likewise, stratification of diagnostic accuracy by age and gender yielded comparable outcomes.

Table 1: Demographic Characteristics of Patients with OTSCC

Characteristics	**Participants (n=100)**
Age (years)	46.63±12.47
• **18-40 years**	28 (28.0%)
• **>40 years**	72 (72.0%)
Gender	
• **Male**	62 (62.0%)

• **Female**	38 (38.0%)

Table 2: Frequency of Deep Invasion of OTSCC on MRI and Histopathology

Modality	Deep Invasion	Frequency (n)	Percent (%)
MRI	Yes	80	80.0 %
	No	20	20.0 %
	Total	100	100.0 %
Histopathology	Yes	79	79.0 %
	No	21	21.0 %
	Total	100	100.0 %

Table 3: Comparison of Frequency of Deep Invasion of OTSCC upon Histopathology across Various Subgroups of Patients included in the Study

Subgroups	n	Deep Invasion n (%)	P-value
Age (years)			
• **18-49 years**	28	22 (78.6%)	0.824
• **50-65 years**	72	58 (80.6%)	
Gender			
• **Male**	62	49 (79.0%)	0.757
• **Female**	38	31 (81.6%)	

Chi-square test, observed difference was statistically insignificant

Table 4: Correlation between MRI and Histopathology in Assessing Depth of OTSCC

Estimation of OTSCC Depth (mm)	Mean± Std. Deviation	Pearson Correlation (r)	P-value
As per MRI	5.28±2.07	0.881	0.01
As per Histopathology	5.04±1.72		

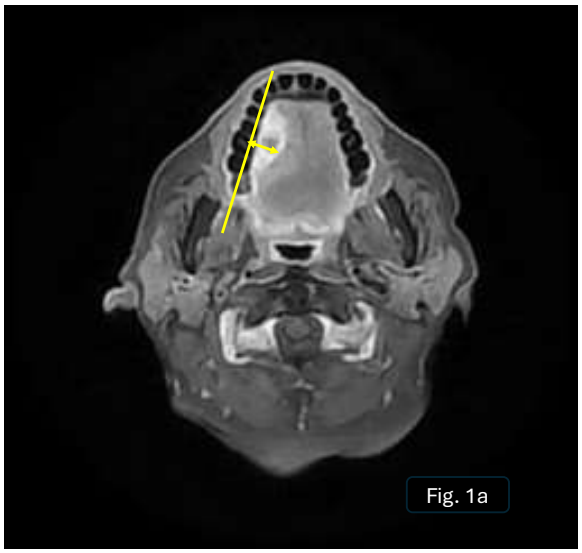
* The observed correlation was statistically significant (p-value<0.001)

Table 5: 2x2 Contingency Table to Determine Diagnostic Performance of MRI in Diagnosing Deep Invasion of OTSCC taking Histopathology Findings as Gold Standard

MRI	Histopathology		Total
	Deep Invasion of OTSCC	No	
Deep Invasion of OTSCC	73[a]	7[c]	80
No	6[b]	14[d]	20
Total	79	21	100

[a]True Positive = 73, [c]False Positive =7, [b]False Negative = 6, [d]True Negative = 14

Statistic	Formula	Value
Sensitivity	$\frac{a}{a+b}$	92.41%
Specificity	$\frac{d}{c+d}$	66.67%
Accuracy	$\frac{a+d}{a+b+c+d}$	87.00%
Disease prevalence	$\frac{a+b}{a+b+c+d}$	79.0%
Positive Predictive Value	$\frac{a}{a+c}$	91.25%
Negative Predictive Value	$\frac{d}{b+d}$	70.00%



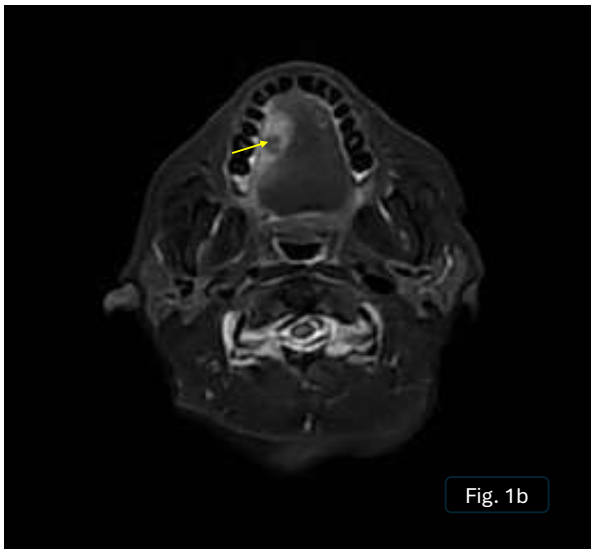
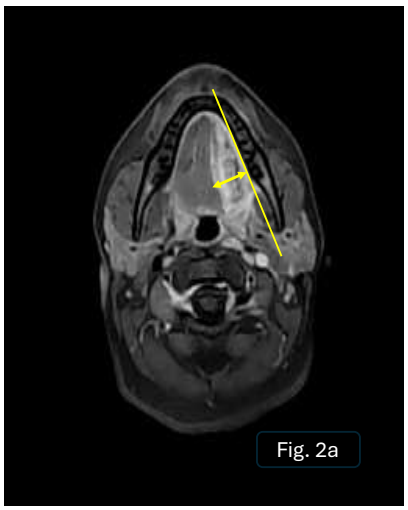
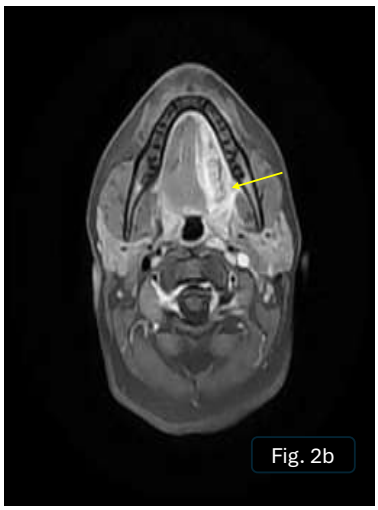


Fig. 1 A 74-year-old female with oral ulcer on right lateral aspect of tongue underwent Mult sequential CE-MRI face and neck
Fig. 1a T1W FS CE axial MRI at the level of tongue showed an enhancing lesion along right lateral aspect that showed hyperintense signals on axial STIR images as well (Fig. 1b). The depth of invasion on CE-MRI was measured 10 mm (Double arrowhead). Histopathological examination lateral revealed DOI of 9 mm.





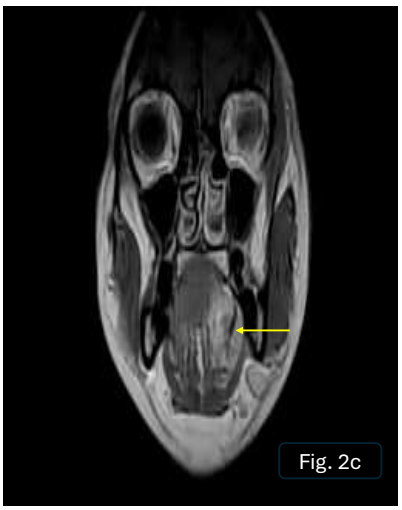


Fig. 2 A 31-year-old female with oral ulcer on left lateral aspect of tongue underwent Mult sequential CE-MRI face and neck
Fig. 2a and 2c T1W FS CE axial and coronal MRI slices at the level of tongue showed an enhancing heterogeneous lesion along left lateral aspect that showed hyperintense signals on axial STIR images as well(Fig. 2b). The depth of invasion on CE-MRI was measured 18 mm (Double arrowhead). Histopathological examination lateral revealed DOI of 15 mm.

DISCUSSION

Accurate assessment of tumor depth in OTSCC is critical for staging, surgical planning, and prognosis. Histopathology remains the gold standard but is inherently post-operative, limiting preoperative decision-making.[2,14,15] MRI has emerged as a non-invasive modality capable of evaluating tumor depth preoperatively, yet existing literature reports variable accuracy and correlation with histopathology. Differences in

study populations, MRI techniques, and tumor characteristics contribute to these inconsistencies.[11,12,13] To address these gaps, this study was planned to assess the accuracy of MRI in measuring tumor depth in OTSCC and to determine its correlation with histopathological findings, providing reliable preoperative guidance.

Das et al. in India reported a very high correlation between different methodologies for assessing tumor thickness and depth of invasion. They found that tumor thickness and depth increased with poorer histological differentiation, and greater invasion correlated with wider spread into tongue musculature, the lingual septum, and adjacent spaces. The correlation coefficients were high for both tumor tissue thickness ($r = 0.99$, $p < 0.05$) and depth of invasion ($r = 0.82$, $p < 0.05$), demonstrating the reliability of imaging techniques in reflecting pathological characteristics.[11]

In China, Tang et al. evaluated depth of invasion derived from e-THRIVE MRI sequences and observed an excellent correlation with pathological depth ($r = 0.936$, $p < 0.001$). The study also demonstrated that MRI-derived DOI could reliably distinguish T1 from T2 stage and T2 from T3 stage, with areas under the curve of 0.969 and 0.974, respectively. Using MRI-based cutoffs of 6.2 mm and 11.4 mm for staging, they achieved an overall staging accuracy of 86.9%, suggesting that MRI can closely approximate pathological staging when standardized protocols are followed.[16]

Huopainen et al. in Finland similarly reported significant correlations between MRI and histology for both maximum tumor diameter ($r = 0.874$, $p < 0.001$) and depth of invasion ($r = 0.898$, $p < 0.001$). Subgroup analysis showed significant correlation for T2 and T3 stages but not T1. MRI demonstrated a sensitivity of 60% and specificity of 83% in detecting pathologically positive nodes, with a moderate correlation observed between MRI and histological nodal status ($r = 0.44$, $p = 0.03$). These findings indicate that while MRI reliably measures tumor dimensions, its accuracy for nodal staging remains moderate.[12]

Ravikanth et al. in India studied 30 patients with tongue carcinoma and reported a male predominance of 92%. They found moderate agreement between clinical and MRI T staging ($k = 0.512$) and fair agreement for N staging ($k = 0.218$). Good agreement was noted between MRI and histopathology for both T and N staging ($k = 0.822$ and $k = 0.767$, respectively), whereas clinical-histopathology agreement was poor. The mean tumor depth measured by histology and MRI was 14.22 mm and 16.12 mm, respectively. A cutoff of 5 mm for MRI depth correlated strongly with nodal metastasis, further supporting MRI as a useful preoperative assessment tool.[13]

In Bangladesh, Sharmin et al. reported a mean patient age of 51.8 ± 8.1 years, with 70% males. Most patients presented with painless non-healing ulcers, and 46.7% had lymph node involvement. MRI detected a mean tumor depth of 10.16 ± 5.07 mm, while histopathology measured 9.37 ± 3.68 mm. Using a cutoff of <5 mm, MRI demonstrated sensitivity of 85.7%, specificity of 91.3%, PPV of 75%, NPV of 95.5%, and overall accuracy of 90% in diagnosing deep invasion. A strong positive correlation was observed between MRI and histopathology ($r = 0.819$).[17]

Alharbi et al. in Saudi Arabia reported a Pearson correlation coefficient of 0.86 between MRI-measured and pathological DOI, indicating high consistency. MRI measurements tended to slightly overestimate depth by 1.72 mm. They identified cutoffs for MRI DOI and pathological DOI predicting nodal metastasis at 7.08 mm and 9.04 mm, respectively, demonstrating that MRI could serve as a reliable predictor of tumor spread to regional lymph nodes.[18]

Overall, these studies collectively support that MRI provides a reliable, non-invasive method for estimating tumor depth in OTSCC. Variations in correlation and accuracy across studies are likely due to differences in MRI sequences, imaging protocols, patient populations, and tumor characteristics. Nonetheless, most studies consistently demonstrate strong correlation between MRI and histopathology, reinforcing the utility of MRI in preoperative planning, T staging, and assessment of nodal metastasis risk.

These findings highlight the clinical value of MRI as a complementary tool alongside histopathology for comprehensive evaluation of oral tongue cancers.

CONCLUSION

MRI demonstrated high accuracy and strong correlation with histopathology in assessing tumor depth and detecting deep invasion in OTSCC. Its diagnostic performance remained consistent across age and gender subgroups, supporting MRI as a reliable, non-invasive tool for preoperative evaluation and surgical planning in patients with oral tongue squamous cell carcinoma.

LIMITATIONS & RECOMMENDATIONS

This study demonstrated that MRI provides a reliable, non-invasive assessment of tumor depth in OTSCC, showing strong correlation with histopathology and high diagnostic accuracy. Strengths included standardized MRI protocols, blinded assessments, and stratification by age and gender. Limitations involved a single-center design, small sample size, and limited evaluation of nodal metastasis. Future research should include multicenter studies, advanced MRI techniques, and long-term outcomes to enhance accuracy, staging, and personalized treatment planning for OTSCC patients.

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Authors Contribution

Author 1: Conceived and designed the study; acquired, analyzed, and interpreted data; drafted the manuscript; approved the final version; and agreed to be accountable for all aspects of the work.

Authors 2–4: Contributed to study conception and design; performed data analysis; drafted and critically revised the manuscript for important intellectual content; approved the final version; and agreed to be accountable for all aspects of the work.

Authors 5–6: Contributed substantially to data analysis and interpretation; critically revised the manuscript for important intellectual content; approved the final version; and agreed to be accountable for all aspects of the work.

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