

T-N Tract Involvement in Locally Advanced Oral Tongue Squamous Cell Carcinoma: A Prospective Observational StudyGyanendra¹, Gupta Aditi², Gupta Meenu³¹Senior Resident, Department of Surgical Oncology, Mahatma Gandhi Medical College and Hospital, Jaipur, Rajasthan, India²Assistant Professor, Department of Pathology, Mahatma Gandhi Medical College and Hospital, Jaipur, Rajasthan, India³Assistant Professor, Department of Pathology, Mahatma Gandhi Medical College and Hospital, Jaipur, Rajasthan, India

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Abstract**Background:** Oral tongue squamous cell carcinoma (OTSCC) is among the most common head and neck malignancies, with neck lymph node metastasis being a critical prognostic factor. Compartmental tongue surgery (CTS) achieves en bloc resection of the hemitongue together with the fibro-fatty tissue connecting the primary tumour to regional lymph nodes — the tumour-node (T-N) tract. The prognostic significance of T-N tract involvement in locally advanced OTSCC has not been widely characterised in the Indian context.**Objectives:** To determine the incidence of T-N tract involvement and evaluate its association with tumour stage, tumour grade, nodal status, and etiological risk factors in patients undergoing CTS.**Methods:** A hospital-based prospective and retrospective observational study enrolled 75 consecutive patients with biopsy-proven locally advanced OTSCC who underwent CTS at a tertiary cancer centre (2020–2023). T-N tract status was assessed on standardised histopathological examination. Associations with clinicopathological variables were evaluated using chi-square test ($p < 0.05$ significant).**Results:** T-N tract involvement was detected in 19/75 patients (25.3%). It was significantly associated with T4 stage ($p = 0.001$), N3 nodal burden ($p = 0.0001$), poorly differentiated histology ($p = 0.004$), and alcohol consumption ($p = 0.029$). Perineural invasion, lymphovascular invasion, extracapsular extension, and extrinsic muscle involvement were each independently associated with T-N tract positivity (all $p < 0.05$). Age, sex, and depth of invasion > 10 mm showed no significant association.**Conclusion:** T-N tract involvement affects approximately one in four patients with locally advanced OTSCC and clusters with adverse pathological features. Routine histopathological assessment of the T-N tract after CTS is warranted and should inform adjuvant treatment planning.**Keywords:** Oral tongue cancer, T-N tract, Compartmental tongue surgery, Squamous cell carcinoma, Neck metastasis, Prognostic factor.**DOI:** 10.25258/ijcpr.18.4.97

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Introduction

Oral squamous cell carcinoma (OSCC) is one of the most prevalent malignancies worldwide, with the oral tongue representing the most frequently affected subsite. Tongue squamous cell carcinoma (SCC) accounts for the majority of oral cavity cancers and carries a five-year survival rate below 50% in newly diagnosed patients. [1]

The regional lymph node status is among the most powerful determinants of prognosis in OTSCC; however, nodal metastases are frequently occult at initial presentation, particularly in early-stage disease. [2] Heavy tobacco use and alcohol

consumption remain the principal aetiological risk factors for tongue SCC, while betel quid chewing, human papillomavirus (HPV) infection, poor oral hygiene, immunosuppression, and genetic predisposition are recognised secondary contributors. [3,4] An emerging epidemiological trend documents rising OTSCC incidence among young non-smoking individuals, particularly women, suggesting the existence of yet-uncharacterised aetiological pathways. [1,5]

Standard surgical treatment has consisted of tumour excision with macroscopically clear margins

combined with separate neck dissection. This approach, however, does not remove the tissue bridge that anatomically connects the primary tumour to the cervical lymphatic chain — the so-called tumour-node (T-N) tract. The T-N tract comprises the fibro-fatty tissue on the internal surface of the mylohyoid muscle, encompassing the lingual nerve, lingual artery and vein, sublingual gland, and lingual lymph nodes. [6,7] Leaving this tissue in situ risks abandoning occult micro metastases or macroscopic tumour deposits along the neural and vascular pathways that cancer cells must traverse during migration from the tongue to cervical nodes. [8]

Compartmental tongue surgery (CTS), developed by Calabrese et al., addresses this concern through en bloc resection of the hemitongue compartment, the T-N tract, and the draining lymph nodes. [9]

When compared with conventional wide excision, CTS has demonstrated significant improvements in five-year local disease-free, locoregional disease-free, and overall survival. [10] Despite these advances, data characterising the histopathological incidence and clinicopathological correlates of T-N tract involvement remain limited, particularly from high-volume centres in South Asia where OTSCC is strongly linked to tobacco and betel quid use.

The present study was designed to determine the incidence of T-N tract involvement in patients with locally advanced OTSCC undergoing CTS and to examine its associations with tumour stage, tumour grade, nodal status, and etiological risk factors.

Materials and Methods



Figure 1: Resected specimen of near total glossectomy with bilateral mandibular lymph node dissection from level I-V

Histopathological Assessment: Resected specimens — hemitongue, T-N tract, and level I–V nodes — were fixed in buffered formalin for 24 hours, sectioned at 0.5 cm intervals in the frontal

Study Design and Setting: This was a hospital-based prospective non-randomised observational study conducted at a tertiary care Hospital. Written informed consent was obtained from all participants.

Participants: Patients with histopathologically confirmed, locally advanced OTSCC who had received no prior surgery or radiotherapy and who underwent CTS between 2020 and 2023 were eligible. Patients with early (T1–T2 cN0) or metastatic disease, recurrent tumours, or those undergoing discontinued neck dissection were excluded. Minimum sample size of 67 was calculated using $N = Z^2 p(1-p)/E^2$, assuming disease proportion of 7 per 100,000, 95% confidence interval, and 2% margin of error; 75 patients were enrolled.

Surgical Technique: All patients underwent CTS under general anaesthesia with a prophylactic tracheostomy. The resection comprised en bloc removal of the hemitongue compartment in continuity with the T-N tract and levels I–V neck lymph nodes. (Figure 1) Compartment boundaries were defined as the lingual septum (medial), periosteum of the mandible (lateral and anterior), stylohyoid muscle and ligament (posterior), and the mylohyoid muscle along its entire length (inferior, coinciding with the inferior edge of the T-N tract). The approach progressed 'from the bottom up', maintaining continuity between neck contents and the primary lesion. Bilateral neck dissection was performed when preoperative imaging indicated contralateral nodal disease.

plane, paraffin-embedded, cut into 5-micron sections, and stained with haematoxylin and eosin. All T-N tract sections were examined for tumour (Figure 2) in the lingual nerve, lingual artery and

vein, sublingual gland, and lingual lymph nodes (Figure 3).

T-N tract status was recorded as positive or negative. Additional parameters included tumour grade (well, moderately, or poorly differentiated),

pathological T and N classification per 8th edition AJCC/TNM, depth of invasion (DOI), perineural invasion (PNI), lymphovascular invasion (LVI), extrinsic muscle involvement, and extracapsular extension (ECE).

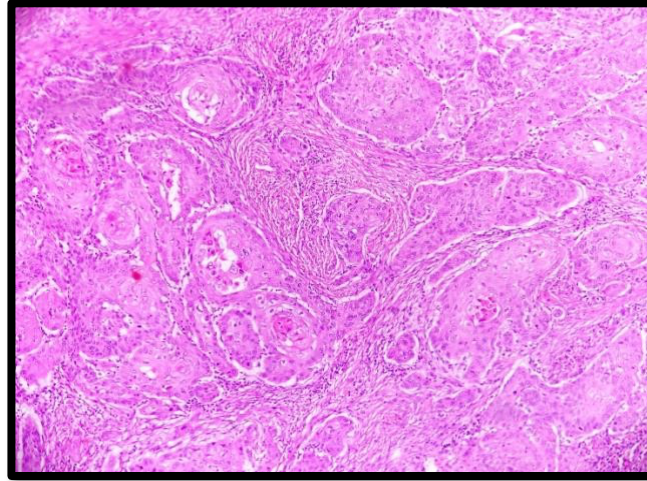


Figure 2: Hematoxylin and eosin stained slide of primary tumor of tongue at 10X. Tumor islands invaded connective tissue stroma.

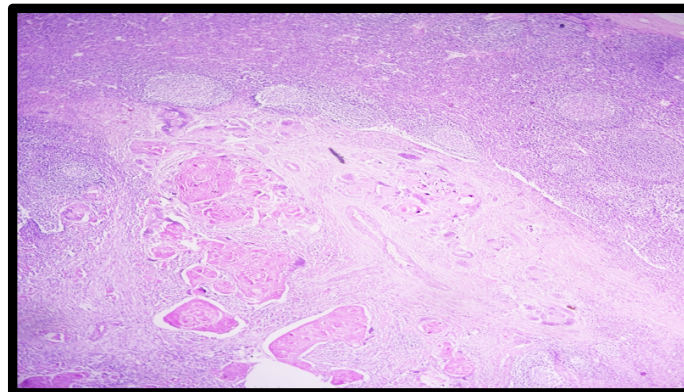


Figure 3: Hematoxylin and eosin stained slide of lymph node at 10X. Tumor is seen in the lymph node.

Statistical Analysis: Data were analysed using SPSS version 21 (IBM Inc.). Categorical variables were compared using the chi-square test. A p-value < 0.05 was considered statistically significant.

Results

Seventy-five patients with locally advanced OTSCC undergoing CTS were analysed. The

overall incidence of T-N tract involvement was 25.3% (19/75). Males constituted 62.7% (47/75) and females 37.3% (28/75).

The majority of patients (77.3%; 58/75) were older than 40 years. Forty-nine patients (65.3%) reported a history of smoking and 30 (40.0%) reported alcohol consumption.

Table 1: Distribution of study population according to etiological risk factors and T-N tract involvement

Risk Factor	T-N Tract Positive n (%)	T-N Tract Negative n (%)	Total n (%)	p-value
Smoking – Yes	13 (68.4)	36 (64.3)	49 (65.3)	0.788 (NS)
Smoking – No	6 (31.6)	20 (35.7)	26 (34.7)	
Alcohol – Yes	12 (63.2)	18 (32.1)	30 (40.0)	0.029 (S)
Alcohol – No	7 (36.8)	38 (67.9)	45 (60.0)	

NS = non-significant; S = significant; Chi-square test

As shown in Table 1, smoking was not significantly associated with T-N tract involvement (p = 0.788). In contrast, alcohol consumption was significantly more prevalent among T-N tract-positive patients: 63.2% of positive patients consumed alcohol compared with 32.1% of those without tract involvement (p = 0.029).

Table 2: Distribution of study population according to SCC grading and T-N tract involvement

SCC Grade	T-N Tract Positive n (%)	T-N Tract Negative n (%)	Total n (%)	p-value
Grade 1 – Well differentiated	0 (0.0)	3 (5.4)	3 (4.0)	0.004 (S)
Grade 2 – Moderately differentiated	5 (26.3)	29 (51.8)	34 (45.3)	
Grade 3 – Poorly differentiated	14 (73.7)	24 (42.9)	38 (50.7)	
Total	19 (25.3)	56 (74.7)	75 (100.0)	

S = significant; Chi-square = 10.25

Table 2 demonstrates a significant association between histological grade and T-N tract involvement ($p = 0.004$). No well-differentiated tumour showed T-N tract positivity. Among moderately differentiated tumours, 5 of 34 (26.3%)

were T-N tract positive, while 14 of 38 (73.7%) T-N tract-positive patients had poorly differentiated carcinoma, confirming a progressive increase in tract involvement with worsening tumour differentiation.

Table 3: Distribution of study population according to pathological tumour (pT) stage and T-N tract involvement

pT Stage	T-N Tract Positive n (%)	T-N Tract Negative n (%)	Total n (%)	p-value
T3	1 (5.3)	27 (48.2)	28 (37.3)	0.001 (S)
T4	18 (94.7)	29 (51.8)	47 (62.7)	
Total	19 (25.3)	56 (74.7)	75 (100.0)	

S = significant; Chi-square = 11.187

Table 3 illustrates a strong association between advanced pT stage and T-N tract involvement. Among T3 tumours, only 1 of 28 patients (5.3%) had T-N tract involvement. By contrast, 18 of 47

T4 tumours (38.3%) demonstrated tract positivity ($p = 0.001$), underscoring the relevance of tumour bulk and local extent in determining likelihood of disease within the T-N tract.

Table 4: Distribution of study population according to pathological nodal (pN) status and T-N tract involvement

pN Stage	T-N Tract Positive n (%)	T-N Tract Negative n (%)	Total n (%)	p-value
N0	0 (0.0)	25 (44.6)	25 (33.3)	0.0001 (S)
N1	1 (5.3)	10 (17.9)	11 (14.7)	
N2	1 (5.3)	20 (35.7)	21 (28.0)	
N3	17 (89.5)	1 (1.8)	18 (24.0)	
Total	19 (25.3)	56 (74.7)	75 (100.0)	

S = significant; Chi-square = 60.166

The association between pN stage and T-N tract involvement was highly significant ($p = 0.0001$), as shown in Table 4. Strikingly, no patient with pN0 disease had T-N tract involvement, while 17 of 18 patients with pN3 disease (94.4%) were positive. The progressive increase in T-N tract positivity from N0 to N3 strongly supports the concept that the T-N tract is a critical conduit for tumour migration from the primary site to the cervical lymphatic system.

Additional pathological parameters significantly associated with T-N tract involvement included PNI (63.2% of T-N tract-positive vs 10.7% of negative patients; $p = 0.0001$), LVI (63.2% vs 5.4%; $p = 0.0001$), ECE (94.7% vs 5.4%; $p = 0.0001$), and extrinsic muscle involvement (89.5% vs 51.8%; $p = 0.014$). Depth of invasion greater than 10 mm was not significantly associated with T-N tract positivity ($p = 0.328$), likely reflecting the near-universal presence of DOI > 10 mm in this locally advanced cohort.

Discussion

The present study reports a T-N tract involvement rate of 25.3% in patients with locally advanced OTSCC undergoing CTS, consistent with the 16% figure reported by Tagliabue and Navach et al. in a comparable Italian cohort. [11]

The higher rate observed in our study may reflect the preponderance of T4 tumours (62.7%) and N3 disease (24.0%) in our patient population, driven in part by late presentation, which is characteristic of OTSCC in the Indian subcontinent.

The T-N tract is defined as the fibro-fatty tissue connecting the primary tumour to the cervical lymphatic chain, encompassing the lingual neurovascular bundle, sublingual gland, and lingual lymph nodes on the internal surface of the mylohyoid muscle. [6] During migration from the tongue to cervical nodes, cancer cells must traverse the T-N tract via the lingual lymphovascular network. Matrix metalloproteinases (MMP-1, MMP-3, MMP-9), highly expressed in head and

neck tumours, degrade extracellular matrix collagen and proteoglycans, enabling cancer progression through the basement membrane and into the stromal and fibro-fatty tissues of the T-N tract. [12] Once tumour cells reach this region — rich in connective tissue and devoid of the limiting barrier of dense muscle fibre bundles — accelerated neoangiogenesis, perineural invasion, and lymphovascular dissemination are facilitated.

The strong association between T-N tract positivity and nodal burden ($p = 0.0001$, with 94.4% of N3 patients tract-positive) reinforces this mechanistic understanding. Woolgar demonstrated that tongue tumours exhibit an erratic pattern of nodal metastasis including skip lesions, a phenomenon that could plausibly be mediated by disease within the T-N tract bypassing standard first-echelon nodes. [13] Lingual lymph nodes — inconstant in-transit nodes along the lymphatic drainage pathway — harbour metastases in 1.3% to 17.1% of tongue SCC patients and are not currently included in standard staging or treatment protocols. [14]

Our findings corroborate those of Fang et al., who demonstrated a five-year locoregional control rate of 45% in patients with lingual lymph node metastasis versus 65% in those without ($p < 0.05$), emphasising the oncological consequences of failing to resect the T-N tract. [15]

Tumour grade was significantly associated with T-N tract involvement ($p = 0.004$), with poorly differentiated tumours accounting for 73.7% of positive cases. This is biologically consistent with greater invasive capacity and higher MMP expression in poorly differentiated HNSCC. [12] The relationship with T-stage ($p = 0.001$) is similarly intuitive: larger tumours with greater depth of invasion and extrinsic muscle involvement provide more opportunity for neoplastic cells to access the fibro-fatty tissue of the T-N corridor.

The significant association between alcohol consumption and T-N tract involvement ($p = 0.029$) — but not smoking per se — is a noteworthy observation. Alcohol is metabolised to acetaldehyde, which impairs DNA repair and promotes mucosal permeability, potentially facilitating earlier lymphovascular dissemination. [3] The lack of significance for smoking may reflect the heterogeneity of smoking history (type, duration, pack-years) within our cohort, which was not stratified in this analysis.

Perineural invasion, lymphovascular invasion, and extracapsular extension each showed highly significant associations with T-N tract positivity (all $p = 0.0001$). These pathological features cluster with T-N tract involvement, delineating a high-risk phenotype warranting aggressive adjuvant treatment. This is supported by Alterio et al., who

demonstrated that postoperative radiotherapy (PORT) improved overall survival and locoregional recurrence-free survival specifically in T-N tract-positive patients, while conferring no significant benefit in tract-negative patients. [16] The T-N tract should therefore be regarded not merely as a surgical specimen component, but as a pathological parameter formally informing adjuvant therapy decisions.

Depth of invasion greater than 10 mm was not significantly associated with T-N tract involvement ($p = 0.328$), likely reflecting a ceiling effect: 92% of patients had DOI > 10 mm, leaving insufficient statistical power to detect a differential within this advanced group. In earlier-stage cohorts, DOI is a well-validated predictor of occult nodal disease and its relationship to T-N tract status warrants evaluation in future studies.

Limitations of this study include its single-institution, non-randomised design, the absence of survival follow-up data, and lack of adjustment for potential confounders in multivariable analyses. Prospective multicentre studies with long-term oncological outcome data are needed to establish T-N tract status as a formal staging or stratification criterion.

Conclusion

T-N tract involvement is identified in approximately one in four patients with locally advanced OTSCC undergoing compartmental tongue surgery and is significantly associated with poorly differentiated histology, advanced T and N stage, alcohol consumption, perineural invasion, lymphovascular invasion, and extracapsular extension.

These findings support the routine pathological assessment of the T-N tract in all CTS specimens and its incorporation into multidisciplinary treatment planning as a prognostic parameter to guide adjuvant therapy decisions, particularly postoperative radiotherapy. Compartmental tongue surgery, by ensuring en bloc resection of the T-N tract, represents the optimal surgical strategy for locally advanced oral tongue squamous cell carcinoma.

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