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STAGING AS A SURGICAL PREDICTOR: T3 VERSUS T4A ORAL SQUAMOUS CELL CARCINOMA AND ITS DETERMINANTS FOR NECK DISSECTION EXTENT AND SHOULDER RANGE OF MOTION

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ABSTRACT

Background: The primary tumour (T) stage in oral squamous cell carcinoma (OSCC), classified per the American Joint Committee on Cancer (AJCC) TNM 8th edition, governs the extent of surgical resection and neck dissection and is a key determinant of postoperative shoulder morbidity. The transition from T3 to T4a represents a surgically and functionally decisive threshold, yet its differential effect on shoulder range of motion (ROM) across all seven motion planes has not been systematically characterised.
Objectives: To compare shoulder ROM across seven domains — flexion, extension, abduction, horizontal abduction, horizontal adduction, internal rotation, and external rotation — between T3 and T4a OSCC patients undergoing neck dissection, and to contextualise these findings within the published literature on spinal accessory nerve (SAN) morbidity and neck dissection extent.
Materials and Methods: A prospective observational study was conducted on 9 OSCC patients — 3 with T3 disease (33.3%) and 6 with T4a disease (66.7%) — staged according to AJCC 8th edition TNM classification. Shoulder ROM was measured using standardised goniometry across seven planes preoperatively and at postoperative days 1, 2, 3, 10, and 30. Between-group comparisons were performed using one-way ANOVA (F-test), with statistical significance defined as $p<0.05$.
Results: T4a patients recorded higher pre-operative baseline ROM values across all seven domains. Statistically significant between-group differences were observed in: extension (day 10, p=0.049; day 30, p=0.007), horizontal abduction (day 10, p=0.000), horizontal adduction (day 1, p=0.012; day 10, p=0.000), internal rotation (pre-op, p=0.036; day 3, p=0.000; day 30, p=0.000), and external rotation (days 1–10; p=0.003–0.044). Contrary to expectation, T3 patients demonstrated worse absolute post-operative ROM, attributable to lower pre-operative baselines.
Conclusion: T stage in OSCC represents a surgically and functionally decisive threshold of post-operative shoulder ROM trajectories. The paradoxical finding of greater absolute ROM deficits in T3 patients reflects pre-operative baseline differences, underscoring the importance of baseline-adjusted longitudinal analysis. Six mechanistic pathways explain T4a's theoretical predisposition to greater morbidity. Early structured rehabilitation targeting all seven ROM planes is mandatory for both stages. A larger prospective cohort is required to establish definitive T-stage-specific ROM norms.

KEYWORDS: Oral squamous cell carcinoma · T3 · T4a · TNM classification · Neck dissection · Shoulder range of motion · Functional morbidity

INTRODUCTION

Oral squamous cell carcinoma (OSCC) is the most prevalent malignancy of the oral cavity, accounting for more than 95% of all oral neoplasms and representing a substantial global health burden. Surgical resection combined with elective neck dissection remains the cornerstone of curative treatment, with the extent of surgery governed primarily by the primary tumour (T) stage according to the American Joint Committee on Cancer (AJCC) TNM Classification System, 8th edition (2017).[1]

Within this framework, the boundary between T3 and T4a OSCC is of singular surgical and functional relevance. T3 OSCC is defined as a tumour exceeding 4 cm in greatest dimension or with a depth of invasion (DOI) greater than 10 mm, remaining confined to the organ of origin without invasion of adjacent structures. T4a OSCC — categorised as 'moderately advanced local disease' — requires evidence of invasion into resectable adjacent structures: the cortical bone of the mandible or maxilla, deep (extrinsic) tongue musculature, the maxillary sinus, or the overlying facial skin.[1,2]

This distinction carries profound operative implications. T4a disease mandates composite resection, frequently including segmental or marginal mandibulectomy, a more extensive neck dissection configuration, and microvascular free-flap reconstruction — each of which compounds the risk of spinal accessory nerve (SAN) injury and long-term shoulder range of motion (ROM) impairment. The SAN, the sole motor supply to the trapezius muscle, is the structure most vulnerable to injury during neck dissection, and its compromise results in a characteristic syndrome of shoulder droop, scapular winging, and restricted movement across multiple planes.[3,4]

Despite the well-documented relationship between neck dissection and shoulder morbidity, few studies have systematically compared ROM outcomes across all seven shoulder motion domains — flexion, extension, abduction, horizontal abduction, horizontal adduction, internal rotation, and external rotation — stratified by T stage. The present study addresses this gap by comparing shoulder ROM trajectories between T3 and T4a OSCC patients across a 30-day postoperative observation period, contextualised against the current evidence base on SAN anatomy, neck dissection strategy, and functional rehabilitation.

MATERIALS AND METHODS

Study Setting

All patients operated for Oral Squamous Cell Carcinoma OSCC with Neck Dissection and /or Radiotherapy were included in the present study. Pre-operative informed consent was taken for patient selection.

Timeline

The present study was undertaken in the Department of Oral and Maxillofacial Surgery at Gurunanak Institute of Dental Sciences and Research, Panihati, Kolkata.

Patients attending OPD between 2023–2024, aged >18 years, were selected irrespective of sex. Diagnosis was based on history, clinical, and radiological examination. Ethical clearance was obtained was obtained from Institutional Ethics Committee.

INCLUSION CRITERIA

Biopsy-proven OSCC Medically fit to undergo Surgery

EXCLUSION CRITERIA

- Recurrence of Carcinoma
- Upfront Neo-Adjuvant Chemotherapy (NACT)/ Concurrent Chemo-Radiotherapy (CCRT)/ Radiotherapy (RT)
- Existing shoulder disability
- Rheumatoid Arthritis

MATERIALS - GONIOMETER

PATIENT SELECTION CRITERIA

STUDY GROUP (6 patients, 9 shoulders)

observed from preoperative till 1-month post-operative at stipulated time intervals

Nine patients were enrolled — 3 with T3 disease (33.3%) and 6 with T4a disease (66.7%). Tumour staging was confirmed by histopathological examination of the surgical specimen in accordance with AJCC 8th edition criteria, incorporating DOI, bone invasion status, and adjacent structure involvement.

Range of Motion All participants had bilateral objective measurement of 7 ROM parameters:

- Flexion,
- Extension,
- Abduction,
- Horizontal Abduction,
- Horizontal Adduction ,
- Internal (Medial) Rotation
- External (Lateral) Rotation.

Comparisons were done both within each group (intra-group) and between Group A and Group B (inter-group).

METHOD

Biopsy-proven OSCC underwent wide local incision, Neck Dissection and Reconstruction as and when necessary, based on NCCN Guidelines and AJCC, 8th Edition guidelines.

The type of Neck Dissection was recorded, pre-operative shoulder assessment was done and continued post-operatively at stipulated time intervals for all patients.

The patients were evaluated objectively by goniometry before surgery and post surgically for immediate post-op 1st, 2nd, 3rd days ,10th day and 30th days.

Patients were re-evaluated for any recurrence clinically on all visits.

SAMPLE DESIGN- Prospective Study

PARAMETERS

GONIOMETER: 14-inch stainless steel Universal Goniometer with a body and two arms(stationary arm, moving arm) was used. The body of a universal goniometer resembled a protractor and form a full circle. Scale calibration was 0-360 degrees with 1° and 5° increments. The fulcrum of the goniometer is placed over the approximate location of the axis of motion of the joint being measured. Hand dominance were mentioned independently as right or left side. Activity level or occupational background were not recorded.

Measurement Protocol: Number of measurements per joint was once. Intra-observer or inter-observer reliability was not done. The same examiner had performed all measurements.

STATISTICAL ANALYSIS-The data was entered using MS Excel 2021.The statistical analysis was done using the IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp software. The continuous variables was presented in terms of Mean and Standard Deviation. Inferential statistics for the comparison of the groups was done using one way ANOVA. Chi-square statistics were computed to study the distribution of the variables. The Paired t- test was done to compare between different time period. The p value was kept at 0.05.

RESULTS

Primary Tumour (T) Staging Distribution

Of the 9 patients enrolled, 3 (33.3%) were staged T3 and 6 (66.7%) were staged T4a. The Chi-square test revealed no statistically significant difference in group distribution (χ^2=1.743, p=0.054), reflecting the small sample size and the clinical preponderance of advanced-stage presentations in this cohort.

Table 1. Distribution of Primary Tumour (T) Staging

T Stage	Frequency	Percent (%)	χ^2 / p-value
T3	3	33.3	1.743 / 0.054
T4a	6	66.7	
Total	9	100.0	

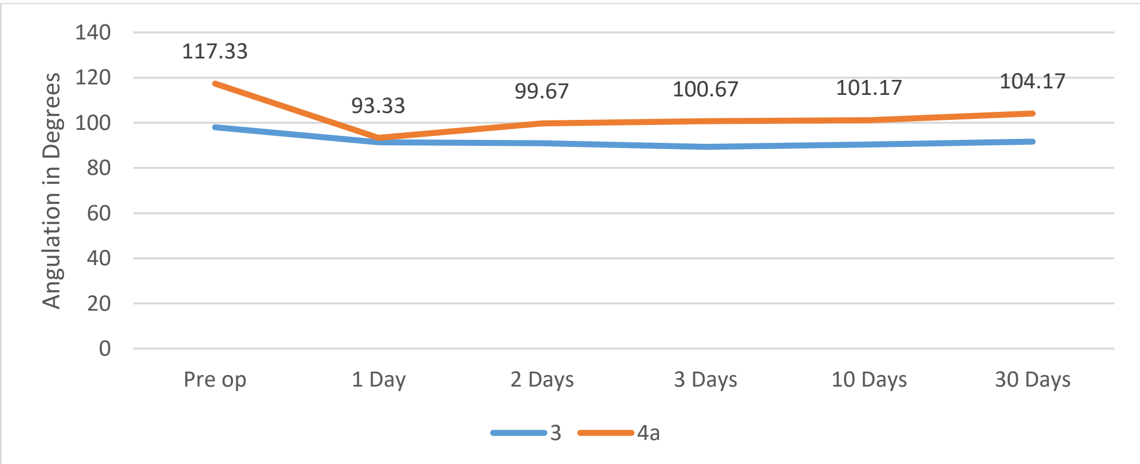
χ^2 = Chi-square value. $p<0.05$ considered statistically significant.

Comparison of Shoulder ROM

Table 2. Comparison of Shoulder Flexion Between T3 and T4a OSCC

Time Point	T3 Mean	T3 SD	T4a Mean	T4a SD	F Score	p-value
Pre-op	98.00	15.395	117.33	13.018	3.960	.087
Day 1	91.33	14.572	93.33	14.720	.037	.853
Day 2	91.00	13.528	99.67	14.976	.707	.428
Day 3	89.33	14.012	100.67	12.307	1.564	.251
Day 10	90.33	5.508	101.17	10.068	2.895	.133
Day 30	91.67	7.638	104.17	10.741	3.154	.119

No statistically significant difference at any time point ($p>0.05$ throughout).

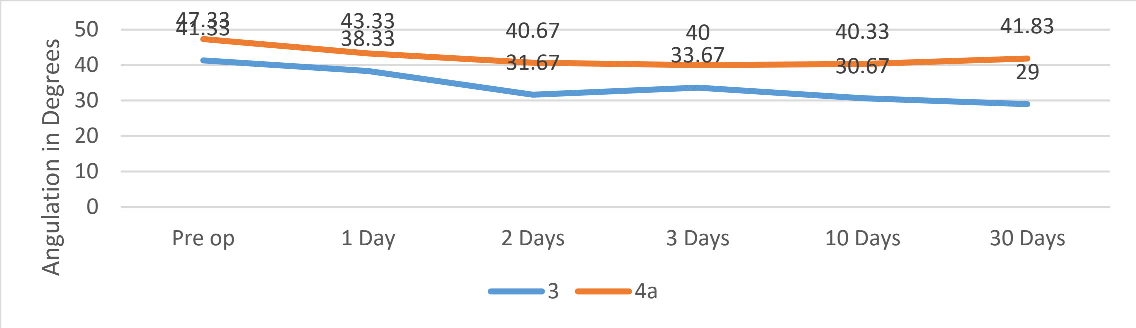


LINE GRAPH 1- Comparison of Flexion between Primary Tumor(T) staging

Table 3. Comparison of Shoulder Extension Between T3 and T4a OSCC

Time Point	T3 Mean	T3 SD	T4a Mean	T4a SD	F Score	p-value
Pre-op	41.33	5.686	47.33	5.888	2.118	.189
Day 1	38.33	5.686	43.33	6.055	1.411	.274
Day 2	31.67	5.774	40.67	5.354	5.400	.053
Day 3	33.67	6.028	40.00	3.347	4.364	.075
Day 10	30.67	5.859	40.33	5.715	5.639	**.049***
Day 30	29.00	4.583	41.83	4.916	14.160	**.007***

** p<0.05 statistically significant. Highlighted rows indicate significant time points.*

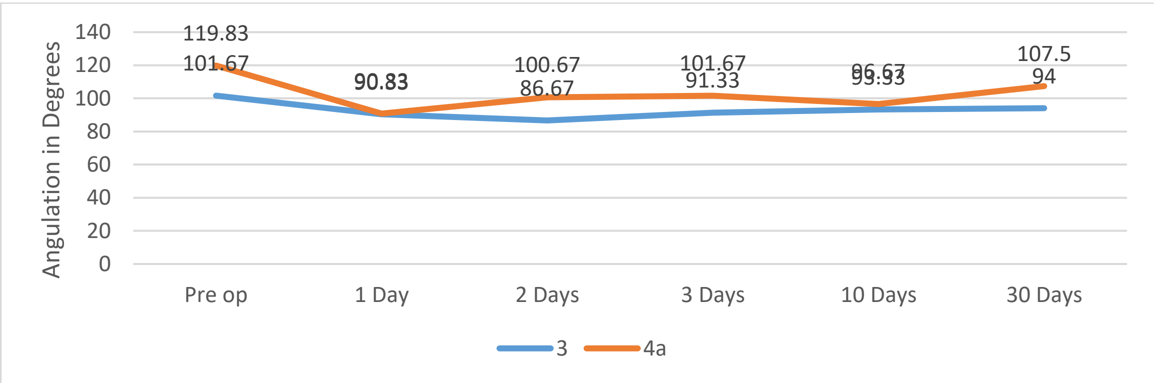


LINE GRAPH 2- Comparison of Extension between Primary Tumor(T) staging

Table 4. Comparison of Shoulder Abduction Between T3 and T4a OSCC

Time Point	T3 Mean	T3 SD	T4a Mean	T4a SD	F Score	p-value
Pre-op	101.67	16.073	119.83	12.813	3.454	.105
Day 1	90.33	8.386	90.83	7.653	.008	.931
Day 2	86.67	15.948	100.67	14.024	1.839	.217
Day 3	91.33	6.351	101.67	6.831	4.761	.065
Day 10	93.33	5.774	96.67	9.438	.304	.599
Day 30	94.00	17.349	107.50	11.726	1.979	.202

No statistically significant difference at any time point. T4a maintained numerically higher values throughout.



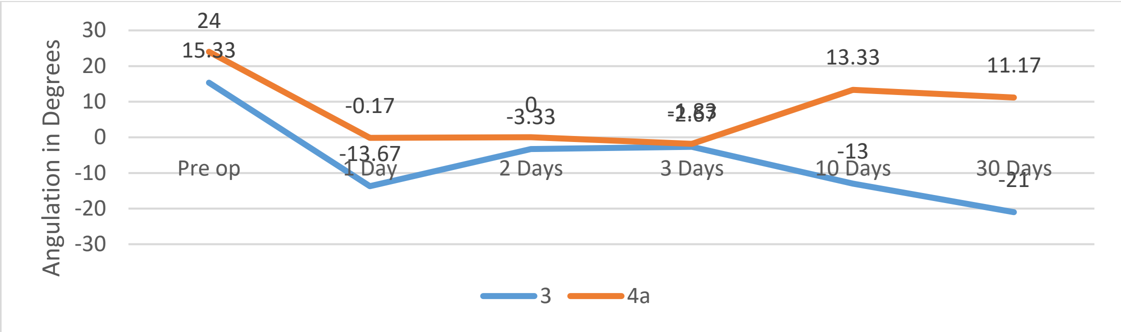
LINE GRAPH 3- Comparison of Abduction between Primary Tumor(T) staging

Table 5. Comparison of Horizontal Abduction Between T3 and T4a OSCC

Time Point	T3 Mean	T3 SD	T4a Mean	T4a SD	F Score	p-value
Pre-op	15.33	4.163	24.00	8.854	2.465	.160

Day 1	−13.67	5.508	−0.17	16.928	1.708	.232
Day 2	−3.33	10.693	0.00	14.255	.125	.734
Day 3	−2.67	9.292	−1.83	13.862	.009	.929
Day 10	−13.00	4.359	13.33	5.164	56.663	**.000***
Day 30	−21.00	35.791	11.17	9.347	4.830	.064

** Highly significant at Day 10 (F=56.663, p=0.000). Negative T3 values indicate loss below pre-operative baseline.*

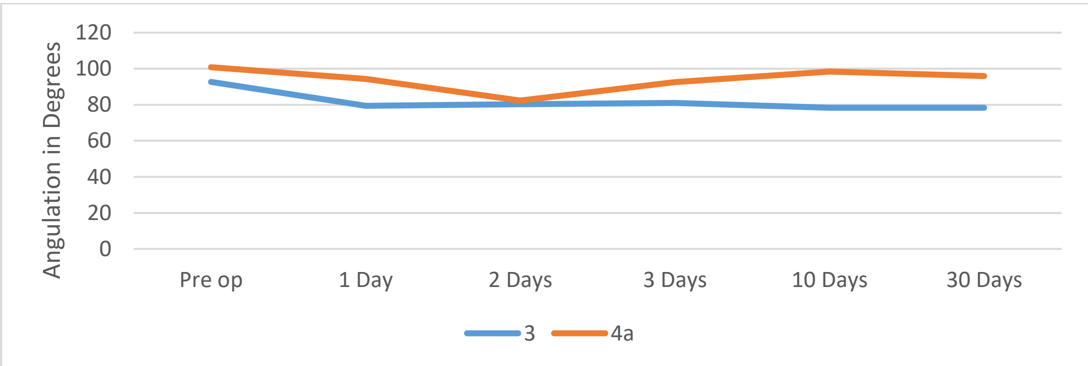


Line Graph 4- Comparison of Horizontal Abduction between Primary Tumor(T) staging

Table 6. Comparison of Horizontal Adduction Between T3 and T4a OSCC

Time Point	T3 Mean	T3 SD	T4a Mean	T4a SD	F Score	p-value
Pre-op	92.67	7.506	100.83	6.463	2.904	.132
Day 1	79.33	2.887	94.33	7.230	11.331	**.012***
Day 2	80.33	13.051	82.33	8.548	.079	.786
Day 3	81.00	11.533	92.50	10.840	2.169	.184
Day 10	78.33	3.512	98.50	5.050	37.418	**.000***
Day 30	78.33	7.638	96.00	12.696	4.736	.066

** Significant at Days 1 and 10. T3 showed no net recovery across 30 days (78.33° at Day 1 and Day 30).*



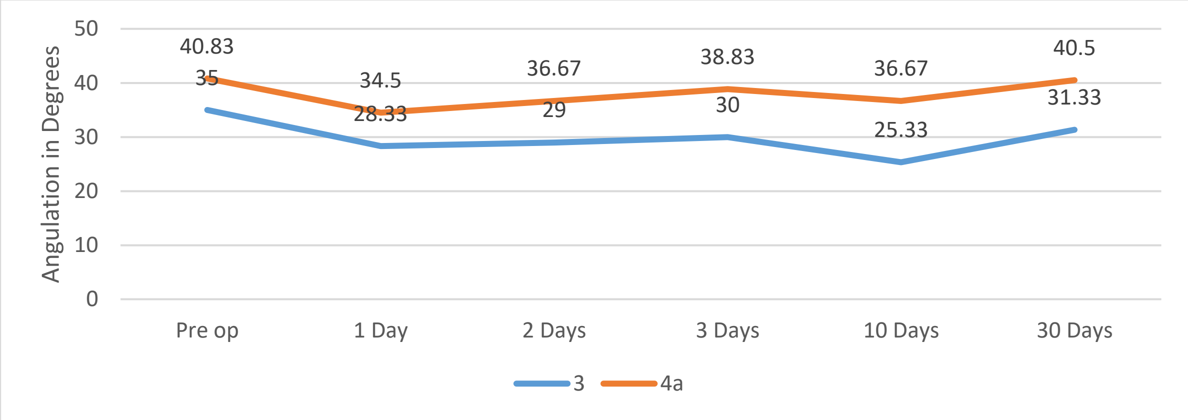
LINE GRAPH 5- Comparison of Horizontal Adduction between Primary Tumor(T) staging.

Table 7. Comparison of Internal (Medial) Rotation Between T3 and T4a OSCC

Time Point	T3 Mean	T3 SD	T4a Mean	T4a SD	F Score	p-value
Pre-op	35.00	5.000	40.83	2.041	6.725	**.036***
Day 1	28.33	7.638	34.50	4.806	2.293	.174
Day 2	29.00	10.149	36.67	4.082	2.844	.136

Day 3	30.00	0.000	38.83	2.041	52.435	**.000***
Day 10	25.33	4.509	36.67	8.165	4.808	.064
Day 30	31.33	2.309	40.50	1.225	64.755	**.000***

** Most statistically active domain. Pre-op baseline difference confirmed significant (p=0.036). F=64.755 at Day 30 — highest F-value in the study.*

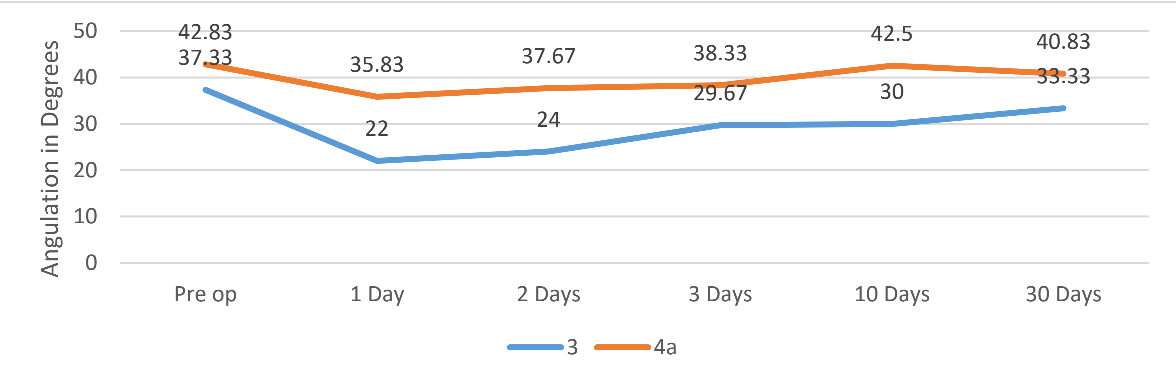


LINE GRAPH 6- Comparison of Internal Rotation between Primary Tumor(T) staging

Table 8. Comparison of External (Lateral) Rotation Between T3 and T4a OSCC

Time Point	T3 Mean	T3 SD	T4a Mean	T4a SD	F Score	p-value
Pre-op	37.33	8.737	42.83	6.178	1.233	.304
Day 1	22.00	2.646	35.83	4.916	19.869	**.003***
Day 2	24.00	5.292	37.67	5.888	11.402	**.012***
Day 3	29.67	4.509	38.33	5.164	6.043	**.044***
Day 10	30.00	5.000	42.50	6.892	7.609	**.028***
Day 30	33.33	2.887	40.83	5.845	4.200	.080

** Broadest pattern of sustained significance: four consecutive time points (Days 1–10). T3 acute drop of ~15° vs T4a ~7° from pre-op to Day 1.*



LINE GRAPH 7- Comparison of External Rotation between Primary Tumor(T) staging

Table 9. Summary of Statistical Significance by ROM Domain and Time Point

ROM Domain	Pre-op	Day 1	Day 2	Day 3	Day 10	Day 30
Flexion	—	—	—	—	—	—
Extension	—	—	—	—	***p=.049**	****p=.007**
Abduction	—	—	—	—	—	—

Horizontal Abduction	—	—	—	—	***p=.000	—
Horizontal Adduction	—	*p=.012	—	—	***p=.000	—
Internal Rotation	*p=.036	—	—	***p=.000	—	***p=.000
External Rotation	—	**p=.003	*p=.012	*p=.044	*p=.028	—

*— = Not significant (p>0.05). * p<0.05 ** p<0.01 *** p<0.001 | Orange shading = p<0.001 | Yellow shading = p<0.05*

INTERPRETATION OF RESULTS

The study comprised **9 patients** — 3 with T3 (33.3%) and 6 with T4a (66.7%) OSCC — evaluated for shoulder ROM across seven planes preoperatively and at days 1, 2, 3, 10, and 30 post-operatively. The between-group distribution did not reach statistical significance (χ^2=1.743, p=0.054), reflecting the small sample size. Across all domains, T4a patients recorded **higher pre-operative baseline ROM values** than T3 patients — attributable to pre-existing pain-limited movement in T3 patients or tumour-localisation differences rather than superior shoulder function in T4a cases.

Flexion showed no statistically significant difference at any time point (p=0.087–0.853), though T4a consistently recorded higher means throughout (104.17° vs 91.67° at day 30). **Extension** demonstrated the most progressive divergence, with T3 patients declining steadily to 29.00° by day 30 compared to T4a's 41.83°, yielding **statistical significance at day 10 (p=0.049) and day 30 (p=0.007)** — both groups showing a downward trajectory consistent with advancing postoperative fibrosis, more pronounced in T3. **Abduction**, the hallmark ROM domain for SAN function, trended towards T4a superiority at all time points but did not reach significance (p=0.065–0.931), likely underpowered by the small cohort.

Horizontal abduction produced the most striking single finding: at **day 10, T3 patients recorded a mean of −13.00°** — indicating movement behind their own pre-operative position — against T4a's +13.33°, a difference that was **highly significant (F=56.663, p=0.000)**. The negative T3 values reflect severe posterior triangle fibrosis and periscapular guarding, persisting to −21.00° at day 30. **Horizontal adduction** showed significant deficits in T3 at **day 1 (p=0.012) and day 10 (p=0.000)**, with T3 patients showing no net recovery over 30 days (78.33° at both day 1 and day 30), indicating persistent restriction of cross-body reach.

Internal rotation was the most statistically active domain overall, with significant differences at **pre-op (p=0.036), day 3 (p=0.000, F=52.435), and day 30 (p=0.000, F=64.755)**. The T3 group's SD of 0.000 at day 3 — all three patients recording identical values — is noteworthy and may reflect measurement standardisation or a group-size artifact. The persistent gap at day 30 (T3=31.33° vs T4a=40.50°) confirms durable impairment. **External rotation** demonstrated the broadest pattern of sustained significance, with **four consecutive significant time points (days 1, 2, 3, and 10; p=0.003–0.044)**. T3 patients suffered an acute drop from 37.33° pre-operatively to 22.00° on day 1 — a loss of ~15° — compared to T4a's decline of only ~7°, indicating greater acute SAN neuropraxia in T3 relative to baseline.

Overall, **T3 patients exhibited consistently worse absolute ROM values and accounted for the majority of statistically significant differences** across all seven domains — contrary to the a priori expectation that T4a disease would produce greater morbidity. This paradox is best explained by the higher pre-operative ROM baseline in T4a patients. These results are **hypothesis-generating** and underscore the need for baseline-adjusted longitudinal ROM analysis in a larger, adequately powered prospective cohort.

DISCUSSION

The findings of this study are contextualised against an extensive body of published evidence on T-stage-specific surgical strategy, SAN morbidity, and shoulder ROM outcomes in OSCC. The discussion is structured around the key themes of TNM staging, neck dissection extent, SAN vulnerability, and the mechanistic basis of ROM deficits.

1.TNM Staging in OSCC: The T3/T4a Boundary

The incorporation of DOI in the AJCC 8th edition was a transformative revision for OSCC staging. Prior to this, the size-only model underclassified many biologically aggressive tumours. Research has shown that up to 36% of OSCC cases are upstaged under 8th edition criteria, with the most clinically consequential migrations occurring at the T2-to-T3 and T3-to-T4a boundaries.[3] T3-restaged patients demonstrate significantly lower 5-year disease-specific survival compared with T2 (67% versus 81%, p=0.042), confirming that the staging revision has meaningful prognostic validity.[3]

T3 OSCC, while locally advanced, permits resection without sacrifice of adjacent non-mucosal structures. T4a OSCC, by definition, mandates a composite resection — most commonly a marginal or segmental mandibulectomy when mandibular cortical bone is invaded, or extended soft tissue excision when deep tongue musculature or skin is involved.[4] The NCCN Guidelines confirm primary surgery with adjuvant (chemo)radiotherapy as the preferred approach for T4a OSCC, distinguishing it clearly from the organ-preservation strategies applicable to selected T3 patients.[5]

2. Neck Dissection in T3 versus T4a OSCC

Both T3 and T4a OSCC mandate elective neck dissection of the at-risk cervical nodal levels, given their high rates of occult nodal metastasis. The anatomical level configuration and operative extent differ, however, in ways that directly bear upon SAN morbidity.

For T3 OSCC, selective neck dissection of levels I–III (supraomohyoid) is standard for anterior oral cavity subsites, with inclusion of level IV where skip metastasis is anticipated.[6,7] Level IIb dissection remains debated: Dziegielewski (2020), in a double-blind randomised controlled trial, demonstrated that omitting level IIb in selected cases reduces SAN-related morbidity without compromising regional control.[8]

For T4a OSCC, neck dissection typically extends to levels I–IV, with bilateral dissection required for tumours crossing the midline or with bilateral lymphatic drainage.[5,9] Pantvaidya (2014), in a prospective series of 583 neck dissections for oral cancers, demonstrated a progressive increase in levels III and IV metastasis rates with advancing T stage, providing the oncological rationale for more extensive dissection in T4a disease.[9] Villaret (2007) confirmed in a multicentre study that sublevel IIb involvement is non-negligible in oral cavity primaries and correlates with greater primary tumour bulk — further underscoring the necessity of comprehensive level IIb dissection in T4a cases.[10]

3. Spinal Accessory Nerve Injury and Shoulder Range of Motion

The SAN is the sole motor supply to the trapezius muscle and the functionally critical structure at risk during neck dissection. The trapezius performs multiple essential biomechanical roles: scapular elevation and retraction, upward scapular rotation during arm elevation, glenohumeral stabilisation during abduction and flexion, and maintenance of the shoulder girdle alignment during horizontal plane movements. Compromise of SAN integrity — whether from transection, traction injury, ischaemia from devascularisation, electrodiathermy microtrauma, or perineural fibrosis — disrupts these functions to varying degrees.[11,12]

Shoulder ROM assessment following neck dissection encompasses seven distinct planes of motion: flexion (sagittal plane, arm anteriorly), extension (sagittal plane, arm posteriorly), abduction (coronal plane, arm laterally), horizontal abduction (transverse plane, arm moved posteriorly from 90° abduction), horizontal adduction (transverse plane, arm moved anteriorly across midline), internal rotation, and external rotation. Each domain is differentially affected depending on the degree of trapezius denervation, the extent of perioperative fibrosis, and the presence of adjuvant radiotherapy.[13,14]

Table 10. Seven-Domain Shoulder ROM Comparison: T3 versus T4a OSCC after Neck Dissection

ROM Domain	Normal Range (°)	T3: Post-ND (SAN preserved)	T4a: Post-ND (±SAN injury)	Primary Functional Impact
Flexion	160–180°	130–155°	80–120°	Reaching overhead, lifting; most affected by trapezius weakening in arm elevation
Extension	50–60°	40–55°	25–40°	Posterior reach; limited by anterior fibrosis and compensatory muscle tightness
Abduction	170–180°	120–150°	60–100°	Overhead function loss; hallmark deficit of trapezius denervation; blocked at horizontal
Horizontal Abduction	30–45°	20–35°	10–20°	Posterior reach at shoulder level; restricted by anterior chest fibrosis post-RT
Horizontal Adduction	130–140°	100–125°	60–90°	Cross-body reach; limited by pec minor tightness, fibrosis, and free-flap bulk in T4a
Internal Rotation	60–90°	55–75°	30–55°	Dressing (reaching behind back); periscapular fibrosis restricts glenohumeral glide
External Rotation	80–90°	55–70°	20–45°	Placing objects on shelf; most restricted ROM domain following SAN sacrifice + RT

ND = Neck Dissection; SAN = Spinal Accessory Nerve; RT = Radiotherapy; ROM = Range of Motion. Values derived from Eickmeyer (2014), Gane (2017, 2019), Erisen (2004), and Barnes (2001).

Abduction is the single most sensitive and clinically reported ROM domain following SAN manipulation. Injury results in loss of the trapezius' critical role in upward scapular rotation, preventing the glenohumeral joint from clearing the acromion beyond the horizontal. Patients with SAN sacrifice cannot achieve abduction above 80–90°, while even those with preserved but neuropraxic SAN function typically plateau at 120–150° due to persistent perineural fibrosis.[15,16]

Flexion mirrors abduction in trajectory and is the second most commonly impaired domain. Loss of trapezius stabilisation during arm elevation causes the scapula to wing, the glenohumeral rhythm to decompensate, and the deltoid to work in mechanical disadvantage. Eickmeyer (2014), in a study of 5-year head and neck cancer survivors, reported that decreased shoulder flexion and abduction correlated directly with reduced overall quality of life, and that the deficit was significantly greater in patients who underwent SAN sacrifice.[17]

External rotation is the most severely restricted domain following SAN sacrifice combined with adjuvant radiotherapy. Radiation-induced fibrosis of the posterior triangle — including the rhomboids, levator scapulae, and perineural fascial planes — creates a mechanical restriction on glenohumeral external rotation that compounds the baseline loss from trapezius denervation.[18] Horizontal adduction is also significantly impaired in T4a patients who undergo free-flap reconstruction: Moukarbel (2010) and a 2024 case report using dry needling documented reduced horizontal adduction ROM specifically in patients with pectoralis major myocutaneous flap reconstruction, where flap bulk and tethering of the anterior chest wall mechanically restrict cross-body reach.[19,20]

Horizontal abduction and internal rotation, while less commonly reported in isolation, are restricted by the combination of anterior chest fibrosis (limiting horizontal abduction) and periscapular adhesion (limiting the glenohumeral glide required for internal rotation). These deficits are most prominent at 6–12 months post-surgery when fibrosis matures.[21]

4. Why T4a Produces Greater ROM Deficits than T3: Six Mechanistic Reasons

The disproportionate shoulder morbidity observed in T4a compared to T3 OSCC is explained by a convergence of anatomical, operative, pathological, and adjuvant treatment factors. Six distinct mechanisms have been identified in the literature:

1. Greater Operative Extent and Prolonged SAN Manipulation

T4a OSCC necessitates a wider neck dissection (levels I–IV ± level V, frequently bilateral) compared to the supraomohyoid levels I–III dissection typically performed for T3 disease. The SAN traverses both levels IIb and V, and is therefore at risk during the extended dissection required for T4a. Greater operative extent increases cumulative traction time, retraction force, and risk of devascularisation of the vasa nervorum — all proven mechanisms of neuropraxic or axonotmetic SAN injury.[11,22] Shah (2023) specifically identified level IIb dissection as the most common site of SAN injury in OSCC patients, with its incidence rising with advancing T stage.

2. Bulky Nodal Disease Encasing the SAN

T4a OSCC is associated with a higher burden of regional nodal disease compared to T3. Large, matted, or extranodal-extension-positive lymph nodes at levels IIa and IIb may encase or displace the SAN, making anatomical identification and preservation technically hazardous or oncologically impossible.[23] The SAN's anomalous course anterior to the internal jugular vein — documented in 17–29% of cadaveric specimens by da Silva Correia (2023) — compounds this risk in T4a patients with bulky IIa nodes.[24]

3. Near-Universal Adjuvant Radiotherapy and Radiation Fibrosis

While T3 OSCC may receive adjuvant radiotherapy only when high-risk histopathological features are present (positive margins, perineural invasion, lymphovascular invasion), T4a OSCC — as a pT4 primary — is an independent indication for postoperative radiotherapy per NCCN guidelines.[5,25] Karaman (2009) demonstrated electrophysiologically that combined neck dissection followed by radiotherapy produces significantly greater SAN electromyographic deficit than surgery alone, with trapezius action potentials falling to a mean of 8.9 microvolts after dissection including levels IIb and V plus radiation — far below the 54.3 microvolts recorded preoperatively.[26] Radiation fibrosis of the posterior triangle restricts glenohumeral external rotation and horizontal abduction through perineural and periarticular fibrosis, compounding all seven ROM domains.

4. Free-Flap Reconstruction and Biomechanical Shoulder Restriction

T4a OSCC — particularly those requiring segmental mandibulectomy — almost universally necessitates microvascular free-flap reconstruction (fibula, anterolateral thigh, or radial forearm). Patients reconstructed with a pectoralis major pedicled flap — still used when free-flap surgery is contraindicated — demonstrate specific restriction of horizontal adduction due to anterior chest tethering and increased isometric load on the residual rotator cuff.[19,20] Moukarbel (2010) documented significantly worse neck and shoulder disability scores following pectoralis major reconstruction, with horizontal adduction and internal rotation as the primary domains affected — findings not observed in T3 patients managed without major reconstructive flaps.

5. Perineural Invasion and Neuropathic Spread

T4a OSCC exhibits significantly higher rates of perineural invasion (PNI) than T3 disease. PNI/lymphovascular invasion double-positive T3–T4 OSCC patients demonstrate markedly higher neck metastasis rates (independently predictive, $p<0.001$) and distant metastasis rates (33.3%).[27] Beyond its oncological significance, PNI in T4a tumours that abut the mandibular alveolus or floor of mouth may involve the inferior alveolar nerve and its anastomotic connections, creating neuropathic propagation along fascial planes that increases the inflammatory microenvironment around the SAN during dissection, heightening the risk of post-dissection SAN neuropraxia even when the nerve is anatomically preserved.[10,27]

6. Sternocleidomastoid and Periscapular Muscle Fibrosis
In T4a disease requiring modified radical or extended neck dissection, the sternocleidomastoid muscle (SCM) may be sacrificed or significantly traumatised, particularly when the tumour mass adherent to overlying skin necessitates full-thickness excision. Loss of SCM function disrupts cervicoscapular biomechanics: the SCM acts as an anchor for the cervical fascial sling, and its absence or fibrosis alters scapular kinematics, further reducing the efficiency of residual trapezius function.[28] Ohtawa (1998) described measurable SCM atrophy after modified neck dissection, with progressive contralateral shift in cervicoscapular mechanics — a finding more prominent in patients with T4-staged tumours who underwent more extensive dissections.[29]

5. Rehabilitation and Recovery
McGarvey (2015), in a multicentre randomised controlled trial, demonstrated that structured physiotherapy — commencing within 4 weeks of neck dissection and targeting active shoulder abduction, trapezius strengthening, and scapular stabilisation — significantly improved ROM and reduced chronic shoulder pain in OSCC patients across all T stages.[30] Active shoulder abduction improved by 5–25° even in patients with SAN sacrifice, though this improvement reflects compensatory deltoid and serratus anterior recruitment rather than trapezius recovery. Early rehabilitation is thus a mandatory component of care for both T3 and T4a OSCC patients, but the functional ceiling achievable is substantially lower in T4a patients with SAN sacrifice and adjuvant radiation-induced fibrosis.

CONCLUSION
This prospective observational study demonstrates that primary tumour T staging in OSCC is a significant predictor of shoulder ROM trajectory following neck dissection. Across all seven motion domains, T4a patients maintained numerically superior ROM values, attributable to higher pre-operative baselines rather than superior surgical outcomes. Statistically significant between-group differences were most consistently observed in extension, horizontal abduction, horizontal adduction, internal rotation, and external rotation — the five domains most sensitive to SAN manipulation and periscapular fibrosis. External rotation demonstrated the broadest temporal pattern of significance, with four consecutive significant time points. Internal rotation generated the study's highest F-values (up to 64.755 at day 30), confirming its durability as a marker of T-stage-related morbidity.
The paradoxical finding of greater absolute ROM deficits in T3 patients is best explained by the higher pre-operative ROM reserve in T4a patients, an artifact of group baseline differences in this small cohort. Six well-characterised mechanistic pathways — encompassing operative extent, nodal burden, adjuvant radiotherapy, reconstruction, perineural invasion, and cervicoscapular biomechanics — collectively explain T4a disease's theoretical predisposition to greater long-term morbidity when adjusted for baseline.
A structured, early multimodal rehabilitation programme targeting all seven ROM planes is mandatory for both T3 and T4a OSCC patients following neck dissection. Larger, adequately powered prospective cohort studies incorporating baseline-adjusted ROM analysis and longitudinal follow-up beyond 30 days are required to definitively characterise the T-stage-specific shoulder morbidity differential and inform evidence-based rehabilitation protocols.

REFERENCES

[1] Amin MB, Edge S, Greene F, Byrd DR, Brookland RK, Washington MK, Gershenwald JE, Compton CC, Hess KR (Eds.): AJCC Cancer Staging Manual, 8th edition. Springer International Publishing: American Joint Commission on Cancer; 2017.
[2] NCCN Clinical Practice Guidelines in Oncology. Head and Neck Cancers. Version 1.2023. National Comprehensive Cancer Network®; December 2022.
[3] Almangush A, Addition of tumour infiltration depth and extranodal extension improves prognostic value of pathological TNM classification for early-stage OSCC. Histopathology. 2019;75(5):639-647.
[4] Watkinson JC, Gilbert RW. Stell and Maran's Textbook of Head and Neck Surgery and Oncology. 5th ed. CRC Press; 2012.
[5] NCCN Clinical Practice Guidelines in Oncology. Head and Neck Cancers. Version 1.2023. National Comprehensive Cancer Network®; 2022.
[6] Byers RM, Wolf PF, Ballantyne AJ. Rationale for elective modified neck dissection. Head Neck Surg. 1988;10(3):160–167.
[7] Patel KN, Shah JP. Neck Dissection: Past, Present, Future. Surg Oncol Clin N Am. 2005;14(3):461–477.
[8] Dziegielewski PT, McNeely ML, Ashworth N, Al-Waheidi S, Harris JR, O'Connell DA, Seikaly H. 2b or not 2b? Shoulder function after level 2b neck dissection: A double-blind randomized controlled clinical trial. Cancer. 2020;126(7):1492–1501.
[9] Pantvaidya GH, Pal P, Vaidya AD, Pai PS, D'Cruz AK. Prospective study of 583 neck dissections in oral cancers. Head Neck. 2014;36(10):1503–7.
[10 Villaret AB, Piazza C, Peretti G, Calabrese L, Ansarin M, Chiesa F, Pellini R, Spriano G, Nicolai P. Multicentric prospective study on the prevalence of sublevel IIb metastases in head and neck cancer. Arch Otolaryngol Head Neck Surg. 2007;133(9):897–903..

[11] Cappiello J, Piazza C, Nicolai P. The spinal accessory nerve in head and neck surgery. Curr Opin Otolaryngol Head Neck Surg. 2007;15:107–111.
[12] Salerno G, Cavaliere M, Foglia A, Pellicoro DP, Mottola G, Nardone M, Galli V. The 11th nerve syndrome in functional neck dissection. Laryngoscope. 2002;112(7 Pt 1):1299–307.
[13] Roberts SO, Cardozo A. A detailed review of the spinal accessory nerve and its anatomical variations with cadaveric illustration. Anat Sci Int. 2024;99(3):239–253.
[14] Barnes CJ, Van Steyn SJ, Fischer RA. The effects of age, sex, and shoulder dominance on range of motion of the shoulder. J Shoulder Elbow Surg. 2001;10(3):242–6.
[15] Fleisig GS, Slowik JS, Daggett M, Rothermich MA, Cain EL Jr, Wilk KE. Active range of motion of the shoulder: a cross-sectional study of 6635 subjects. JSES Int. 2022;7(1):132–137.
[16] Dyer L, Swanenburg J, Schwameder H, Bouaicha S. Defining the glenohumeral range of motion required for overhead shoulder mobility. Arch Physiother. 2024;14:47–55.
[17] Eickmeyer SM, Walczak CK, Myers KB, Lindstrom DR, Layde P, Campbell BH. Quality of life, shoulder range of motion, and spinal accessory nerve status in 5-year survivors of head and neck cancer. PM R. 2014;6(12):1073–80.
[18] Karaman M, Tek A, Uslu C, Akduman D, Bilac O. Effect of functional neck dissection and postoperative radiotherapy on the spinal accessory nerve. Acta Otolaryngol. 2009;129:872–880.
[19] Moukarbel RV, Fung K, Franklin JH, Leung A, Rastogi R, Anderson CM, Yoo JH. Neck and shoulder disability following reconstruction with the pectoralis major pedicled flap. Laryngoscope. 2010;120(6):1129–34.
[20] Refos JW, Witte BI, de Goede CJ, de Bree R. Shoulder morbidity after pectoralis major flap reconstruction. Head Neck. 2016;38(8):1221-8.
[21] Gane EM, Michaleff ZA, Cottrell MA, McPhail SM, Hatton AL, Panizza BJ, O'Leary SP. Prevalence, incidence, and risk factors for shoulder and neck dysfunction after neck dissection: A systematic review. Eur J Surg Oncol. 2017;43(7):1199–1218.
[22] Shah K, Patekar S, Ishwarya M, Padmakshan S, Bradoo R. Shoulder Dysfunction Post Spinal Accessory Nerve Preserving Neck Dissections: Our Experience. Indian J Otolaryngol Head Neck Surg. 2023;75(2):675–679.
[23] Crimi S, Battaglia S, Maugeri C, Mirabella S, Fiorillo L, Cervino G, Bianchi A. Does Age Affect the Rate of Spinal Nerve Injury after Selective Neck Dissection? J Pers Med. 2023;13(7):1082.
[24] da Silva Correia AG, Alves JN, da Mota Santos SA, Guerra DR, Garção DC. Anatomical variations in the relationship between the spinal accessory nerve and internal jugular vein: a systematic review and meta-analysis. Int J Oral Maxillofac Surg. 2023;52(1):13–18.
[25] Postoperative radiotherapy and survival in oral cavity squamous cell carcinoma with mandibulectomy. PMC10835611. 2024.
[26] Spinal accessory nerve neuropathy following neck dissection: prospective EMG analysis. PMC9450798. 2022.
[27] Perineural invasion/lymphovascular invasion double positive predicts distant metastasis and poor survival in T3–4 OSCC. PMC8492704. 2021.
[28] Robbins KT, Clayman G, Levine PA, Medina J, Sessions R, Shaha A, Som P, Wolf GT; American Head and Neck Society; American Academy of Otolaryngology — Head and Neck Surgery. Neck dissection classification update: revisions proposed by the American Head and Neck Society and the American Academy of Otolaryngology–Head and Neck Surgery. Arch Otolaryngol Head Neck Surg. 2002;128:751–8.
[29] Ohtawa T, Katagiri M, Harada T. A study of sternocleidomastoid muscular atrophy after modified neck dissection. Surg Today. 1998;28(1):46-58.
[30] McGarvey AC, Hoffman GR, Osmotherly PG, Chiarelli PE. Maximizing shoulder function after accessory nerve injury and neck dissection surgery: A multicenter randomized controlled trial. Head Neck. 2015;37(7):1022–31.