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Original Article

Matched-pair analysis of the outcome of two different neck dissection techniques for oral squamous cell carcinoma

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ABSTRACT

Background: This study aimed to compare two different neck dissection (ND) techniques, conventional ND (CND) and functional ND (FND), in terms of lymph node yield (LNY) and regional recurrence (RR). FND is a concept based on dissection along the cervical fascial planes with en bloc removal of cervical lymph node levels (LNLs) while preserving the neurovascular and muscular structures, as described by Osvaldo Suárez. In contrast, CND involves the separate division of LNLs in situ without targeting the fascial planes.

Methods: This retrospective cohort study included previously untreated patients who underwent surgery at our institution between January 2019 and December 2023. Of the 253 patients, 201 underwent CND, and 52 underwent FND. Propensity score matching selected 52 CND patients to be matched to the FND group based on the following variables: age, body mass index, tumor localization, tumor size, vascular invasion, lymphatic involvement, and perineural invasion. Although the nodal stage (UICC-pN) was not included in the matching process, it was assessed as a study endpoint.

Results: The mean LNY was significantly higher in the FND group (55 vs. 44 nodes; $p = 0.016$). After a mean follow-up of 42 months (range, 12–60), RR occurred in 3.8% ($n = 2$) of patients in the FND group and 10.4% ($n = 5$) in the CND group ($p = 0.198$).

Conclusions: In the present cohort, FND achieved a significantly higher LNY while maintaining comparable regional control, underscoring its potential as an oncologically sound approach, albeit within the constraints of a retrospective, underpowered study.

1. Introduction

Squamous cell carcinoma (SCC) is the most common histological type of oral cancer [1]. Oral squamous cell carcinoma (OSCC) is associated with alcohol consumption, smoking, human papillomavirus (HPV) infection, age (5th to 7th decade), genetic factors, and immunosuppression [2]. A significant prognostic factor is the presence or absence of cervical metastases; nodal involvement has been shown to have a substantial negative impact on survival rates [3,4]. Performing neck dissection (ND) requires comprehensive knowledge of the lymphogenous spread patterns of OSCC and the anatomy of cervical lymphatic vessels, the modern description and publication of which were first carried out in 1932 by Henri Rouvière [5]. ND has a long history; it was first described and performed in 1888 by Franciszek Jawdyński, a Polish surgeon, as an extended en bloc radical ND. The technique gained widespread adoption following George Crile's publication of the procedure in English in 1906 [6–8].

Radical ND remained the standard therapy until the early 1960s, when Osvaldo Suárez first described functional neck dissection (FND). This surgical technique involves removing the cervical lymphatic groups and fibrofatty tissue by splitting and removing the cervical fascial walls and their contents. The goal is to preserve major non-lymphatic

Abbreviations: BMI, body mass index; DCF, deep cervical fascia; CT, computed tomography; FND, functional neck dissection; CND, conventional neck dissection; HPV, human papillomavirus; IJV, internal jugular vein; LN, lymph node; LNs, lymph nodes; LNLs, cervical node levels; MRI, magnetic resonance imaging; ND, neck dissection; OHM, omohyoid muscle; OSCC, oral squamous cell carcinoma; SAN, spinal accessory nerve; SCC, squamous cell carcinoma; SCM, sternocleidomastoid muscle; SND, selective neck dissection; SLNB, sentinel lymph node biopsy; UICC, union for International Cancer Control; PFS, progression-free survival; OS, overall survival; RR, regional recurrence; ENE, extranodal extension; FFPE, formalin-fixed paraffin-embedded; PSM, propensity score matching; PS, propensity scores; SMDs, standardized mean differences

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structures, such as the spinal accessory nerve (SAN), internal jugular vein (IJV), and sternocleidomastoid muscle (SCM). FND can be performed to excise certain lymph node levels (LNLs) as selective ND (SND) or to excise LNLs I−V as a comprehensive ND [9].

Selective neck dissection (SND) was developed in the early 1980s to provide equivalent cervical oncological control as comprehensive ND while reducing morbidity. SND is recommended for patients without cervical lymphadenopathy [10,11]. In recent years, sentinel lymph node biopsy (SLNB), which is the gold standard for breast cancer and melanoma therapy, has also been implemented for patients with OSCC with clinically and radiologically undetectable cervical lymph node (LN) involvement [12−14]. The FND technique used in this study was performed according to the method described by Osvaldo Suárez. Conventional neck dissection (CND) involves removing cervical fibrofatty tissue after separately dividing the LNLs in situ, preserving the main anatomical structures without targeting the anatomical fascial planes. To enable consistent clinical comparison between these two surgical techniques, outcomes were evaluated using a standardized methodology.

To this end, a matched-pair analysis was performed to establish a direct and balanced comparison between the FND and CND groups. This study aimed to minimize baseline bias and objectively evaluate surgical efficiency. Crucial confounding clinical and pathological variables were controlled using propensity score matching (PSM). To the best of our knowledge, this is the first study to perform a matched-pair analysis to investigate the possible advantages of FND over CND. To achieve this objective, a comparison was made between the LN yield (LNY) − the internationally recognized term for the number of excised lymph nodes (LNs) − in previously untreated patients with OSCC using both ND techniques.

2. Material and methods

2.1. Study design and patient eligibility

This study analyzed a cohort of patients diagnosed with OSCC who underwent surgery between January 2019 and December 2023 at our institution. Preoperative therapeutic decisions and indications for adjuvant treatment were established by the interdisciplinary Head and Neck Tumor Board. The study was approved by the Institutional Review Board (Ethics No 25−240) and conducted in accordance with the Declaration of Helsinki.

The inclusion criteria for this study were as follows: a confirmed diagnosis of OSCC, an indication for ND recommended by a multidisciplinary tumor board, and previously untreated patients. The exclusion criteria were non-SCC malignancies, extraoral tumor localizations, history of previous cervical surgery, prior radiotherapy or chemotherapy, and indications for radical ND. Of an initial cohort of approximately 900 patients, 645 were excluded for meeting the exclusion criteria. Of the remaining 255 patients with primary operable OSCC, two were excluded because of incomplete staging data. Of the remaining 253 patients, 52 underwent FND, and 201 underwent CND. A total of 52 cases from the CND group were matched to 52 FND cases based on the following variables: age, body mass index (BMI), tumor localization, tumor size (UICC-T), vascular invasion (UICC-V), lymphatic involvement (UICC-L), and perineural invasion status (UICC-Pn) (Fig. 1). LN status (UICC-pN) was not included in the matching process because it represented one of the study endpoints.

Clinical and demographic data, such as age, sex, BMI, alcohol and tobacco consumption, tumor localization, tumor-node-metastasis classification (TNM classification according to the 8th edition of the UICC), height, weight, radiation, chemotherapy, RR, type of ND, and distribution of LNs by level, were collected and entered into a patient-specific database.

2.2. Surgical technique

FND involved removing the LNLs en bloc while preserving the SAN, SCM, and IJV. After unwrapping the cervical fascia along the SCM, the SAN and IJV were identified (Fig. 2a, b). The fibrofatty tissue was removed by following the cleavage planes along the deep cervical fascia (DCF) in a lateral-to-medial direction, mainly using a No 10 blade scalpel (Video 1). For a comprehensive ND, LNLs Va, Vb, and IV were repositioned medially underneath the SCM and inferior to Erb's point, connecting with the upper part of the specimen containing LNLs I, II, and III (Fig. 2c). The IJV was exposed following an incision in the carotid sheath (Fig. 2d). This technique can be used for both SND and comprehensive ND. During the procedure, the boundaries of the LNLs were meticulously marked in situ with surgical sutures (3−0 Vicryl) to define their anatomical limits precisely. ND specimens were then removed en bloc to maintain structural integrity (Fig. 3a). Immediately following removal, the specimen was extracorporeally divided on the operating table by the surgeon according to suture markings, separating each LNL. Consequently, the specimens arrived at the pathology department in separately labeled containers, with each container housing a single specific level, establishing a highly precise protocol.

The second technique, CND, involved the removal of LNLs in a vertical and medial-to-lateral dissection, with division of the specimen in situ. Depending on the extent of lymphadenectomy required, the CND approach can be used as either SND or comprehensive ND. The technique did not target dissection along the DCF and was performed using scissors (Video 2). Similar to the FND technique, the harvested LNLs were submitted individually in separate containers. In accordance with our clinic's internal protocol and the German OSCC guidelines, excision of ipsilateral LNLs IV and V was performed simultaneously if cervical metastases were diagnosed on fresh frozen biopsy of LNLs II and III. This protocol was performed in both groups.

2.3. Histopathological examination

Histopathological examination was performed by the same five pathologists who were blinded to the surgical technique. For definitive evaluation, all submitted specimens were systematically processed by stepwise sectioning ("lamellation") at approximately 2−3 mm intervals. Each section was subsequently subjected to thorough macroscopic examination, including visual inspection and palpation, to identify LNs and any areas of firm, fibrotic, or otherwise non-adipose tissue. Suspected lymphatic structures and non-fatty tissues were carefully dissected and processed in their entirety using routine formalin-fixed paraffin-embedded (FFPE) workflows. The resulting histological slides were assessed for LNY, number of positive LNs specific to anatomical LNLs, tumor grade, metastatic deposit size, and extranodal extension (ENE).

2.4. Statistical analysis

All statistical analyses were performed using R (version 4.2.0). To reduce selection bias and improve comparability between treatment groups, PSM was conducted using the MatchIt package. Propensity scores (PS) were estimated using multivariable logistic regression, including tumor localization, age, BMI, and UICC T, V, L, and Pn stages as covariates. One-to-one nearest-neighbor matching was performed on the logit of the PS without replacement using a caliper width of 0.2 standard deviations of the propensity logit. Matching was performed prior to outcome analyses, and balance diagnostics were assessed to confirm an adequate covariate balance between groups. Covariate balance was evaluated using standardized mean differences (SMDs) before and after matching, with an absolute SMD of < 0.1 considered indicative of adequate balance. PS overlap was assessed graphically using histograms of PS distributions before and after matching (Fig. 4a). Covariate balance was visualized using a Love plot displaying absolute SMDs for all matched covariates (Fig. 4b).

Continuous variables, including age and LNY, were compared using the Wilcoxon signed-rank test, given the paired design and non-normal, approximately symmetric distribution of within-pair differences. Categorical/ordinal variables were analyzed using the chi-square test,

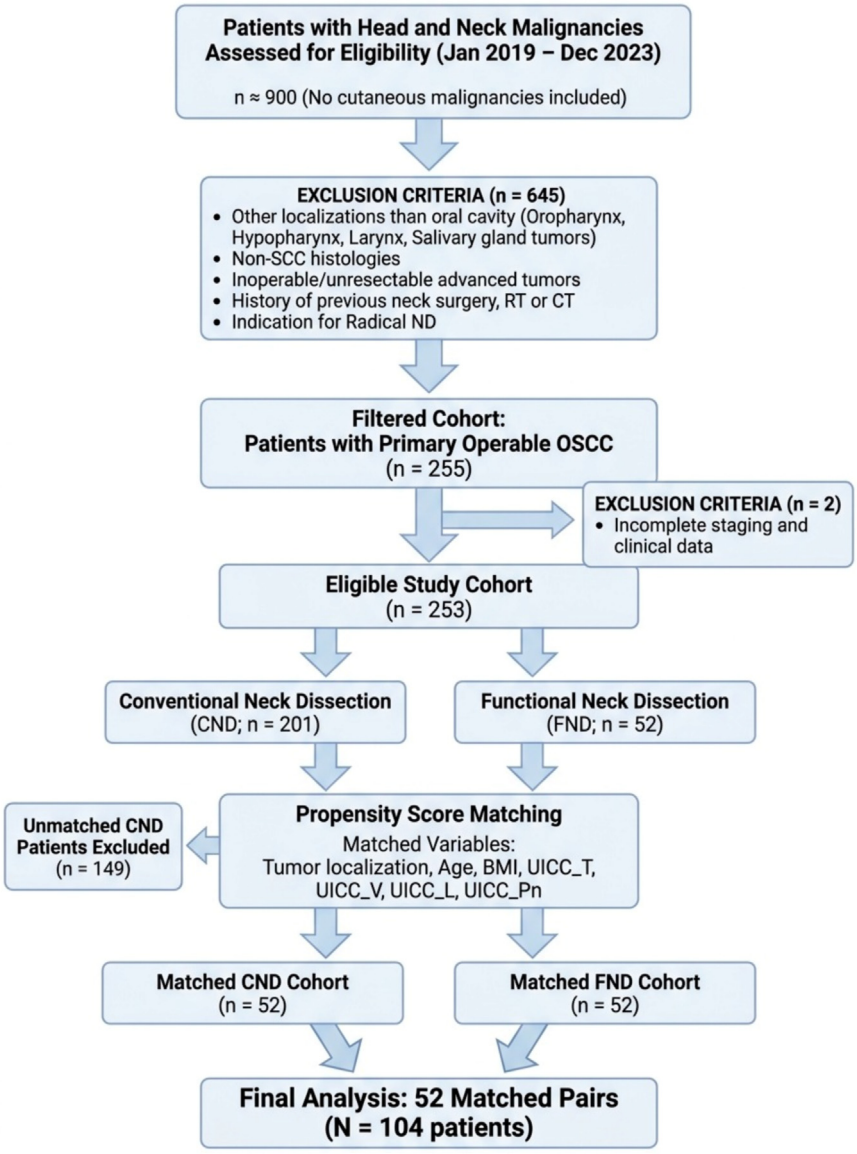


Fig. 1. Flowchart of patient selection and propensity score matching.

Fisher's exact test, or Cochran–Armitage Trend test, as appropriate, based on expected cell counts and data type. For each comparison, the corresponding statistical test is stated throughout the manuscript. The primary unit of analysis in this study was the patient. Accordingly, all demographic, clinical, and outcome variables were reported on a per-patient basis unless otherwise specified. For patients who underwent bilateral ND, LNY was calculated as the sum of LNs removed from both sides, resulting in a single value per patient for total LNY. For level-specific analyses (levels I–V), multiple measurements were available from the same patient. To account for the non-independence of these observations, we used a linear mixed-effects model fitted by restricted maximum likelihood (REML), including a random intercept for patient ID and a fixed effect for anatomical level. The degrees of freedom were estimated using Satterthwaite's approximation. The model assumptions were assessed by inspecting the residual distributions. Effect estimates are reported with corresponding standard errors and p-values. As a sensitivity analysis, a linear regression model was fitted to the PS-matched cohort with total LNY as the dependent variable and ND type and pathological nodal status (pN) as independent variables. This analysis was performed to assess whether the association between ND type and LNY remained robust after adjusting for pN status.

Survival analyses were performed in a PS–matched cohort restricted to patients who underwent CND or FND. Time-to-event outcomes were analyzed using the Kaplan–Meier method. Progression-free survival (PFS) and overall survival (OS) were defined as the time from surgery to the first occurrence of disease progression, death, or last follow-up, as appropriate. Survival time was calculated as a numeric variable, and the event status was defined as a binary indicator (1 = event, 0 = censored). Patients with missing survival time or status information were excluded from the analyses. Kaplan–Meier survival curves were generated stratified by ND type (CND vs. FND). Differences between the survival curves were assessed using the log-rank test. The results are presented graphically with the corresponding p-values (Fig. 5a, b). Risk tables were included to display the number of patients at risk over time. A two-sided p-value < 0.05 was considered statistically significant. Data manipulation and descriptive statistics were conducted using dplyr and DescTools packages.

3. Results

3.1. Cohort

A total of 253 previously untreated patients were included in this study. Following the PSM protocol, 104 patients were selected for the final analysis and divided into two equal groups of 52 patients each (Table 1). The total number of ND sides was 165, of which 84 belonged

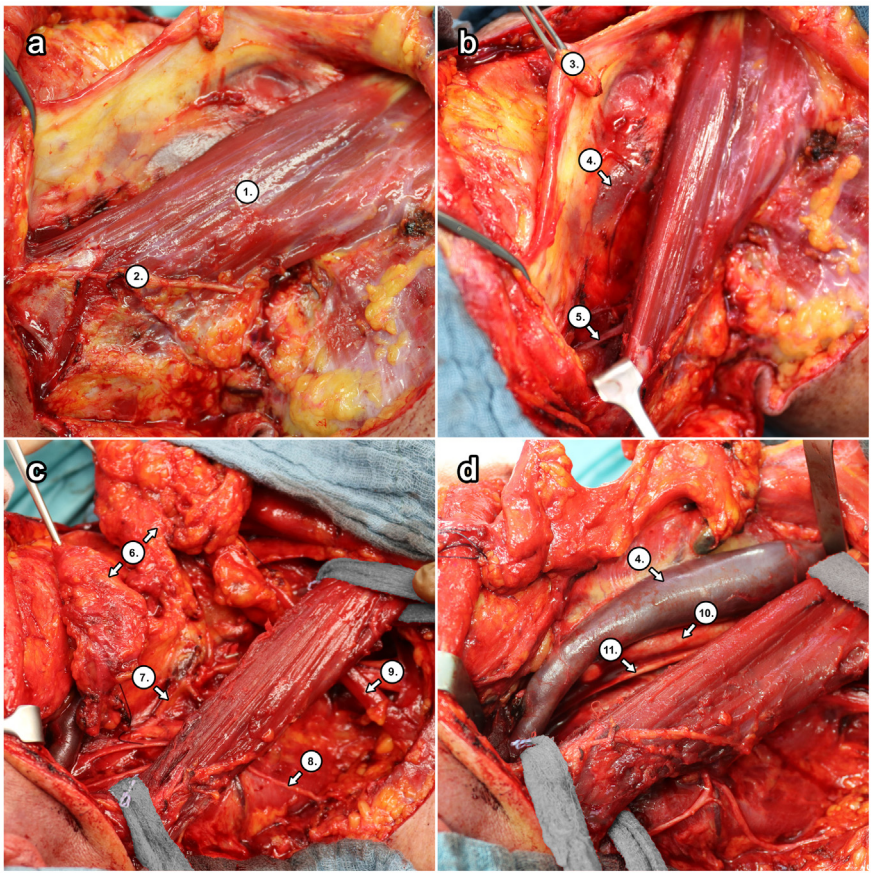


Fig. 2. Intraoperative views of a functional neck dissection. a) Exposure of the sternocleidomastoid muscle (1) and great auricular nerve (2) b) Unwrapping of the cervical fascia (3) to expose the underlying internal jugular vein (4), with visualization of the spinal accessory nerve (5) at its entry point into the sternocleidomastoid muscle c) Medial repositioning of the neck dissection specimen (6) containing levels IV, Va, and Vb underneath the sternocleidomastoid muscle and connection with the upper component containing levels I–III. Exposure of the cervical plexus (7), spinal accessory nerve in the posterior triangle (8), and omohyoid muscle (9) d) Visualization of the internal jugular vein (4), common carotid artery (10), and vagus nerve (11) after opening the carotid sheath.

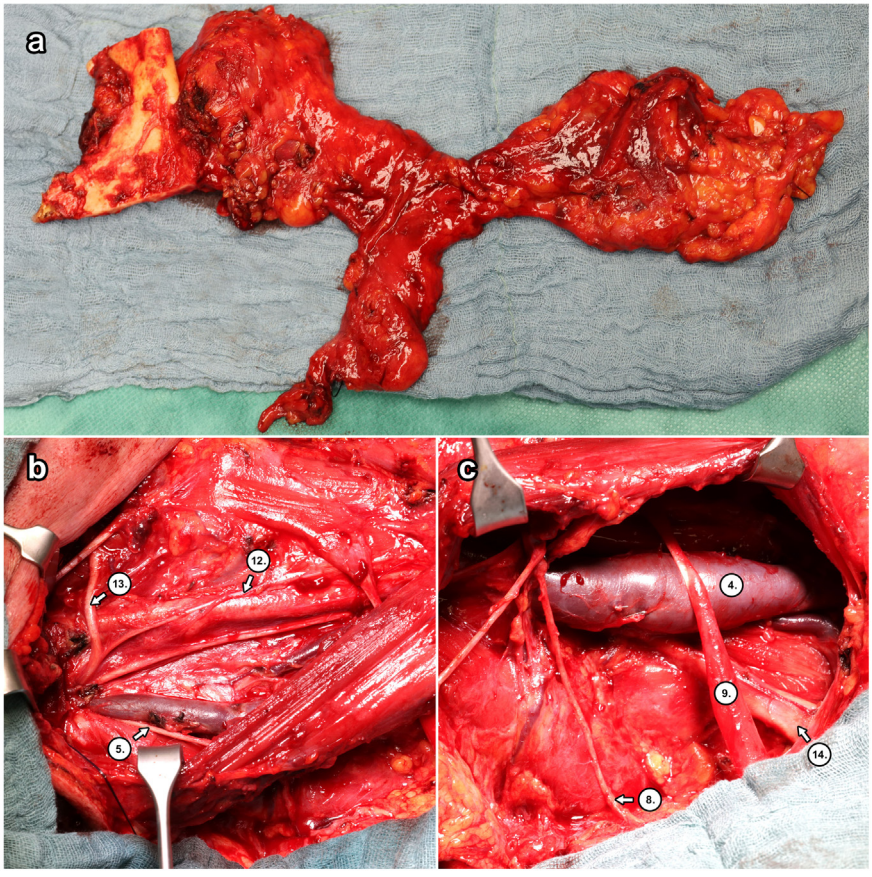


Fig. 3. Intraoperative view after functional neck dissection. a) En bloc segmental mandibulectomy and comprehensive functional neck dissection b) Exposure of the main anatomical structures: spinal accessory nerve (5), ansa cervicalis (12), hypoglossal nerve (13) c) Visualization of the posterior triangle of the neck and of the supraclavicular fossa, revealing the internal jugular vein (4), spinal accessory nerve in the posterior triangle (8), omohyoid muscle (9), and brachial plexus (14).

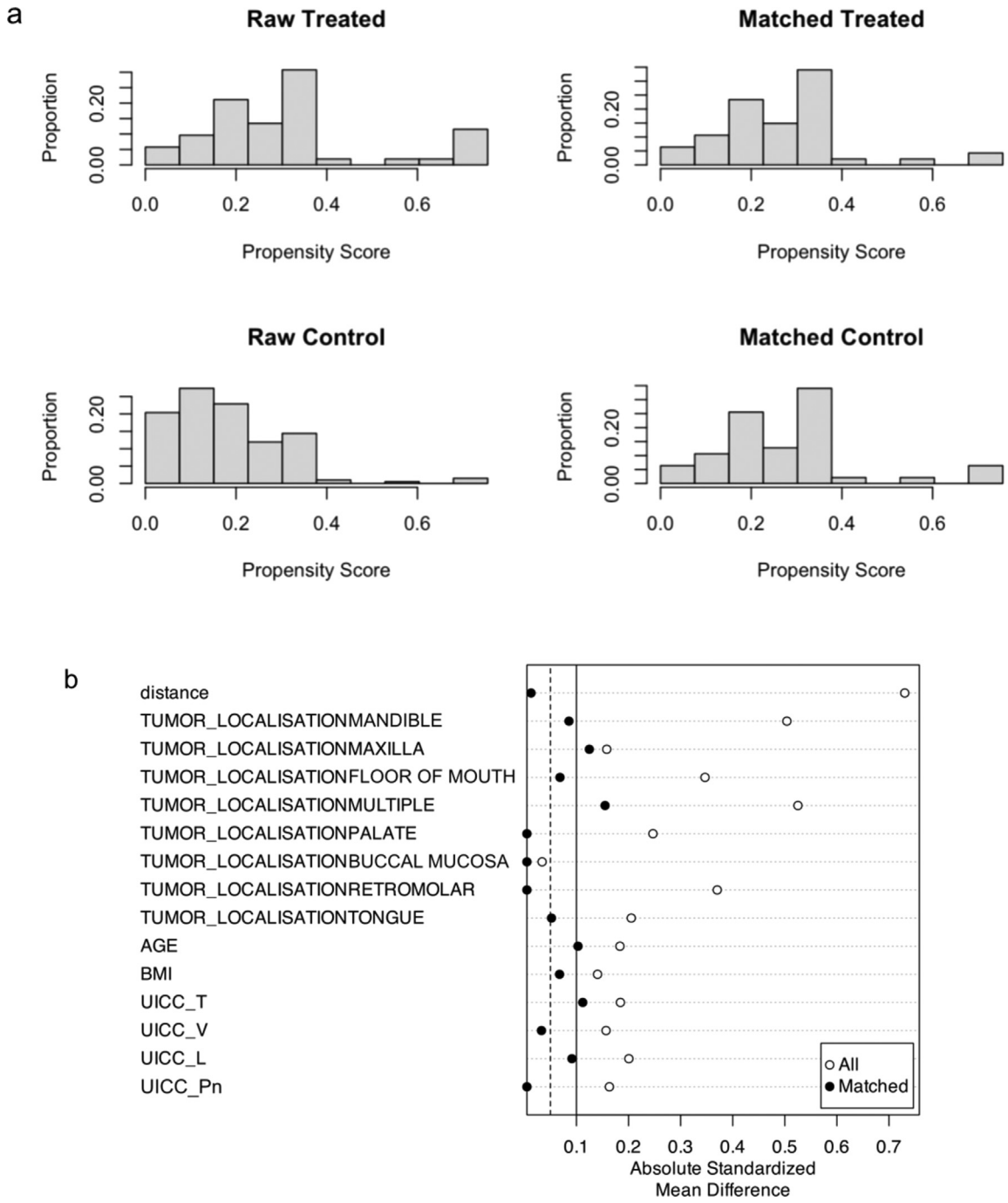


Fig. 4. The propensity score matching methodology. a) Distribution of estimated propensity scores by neck dissection type after 1:1 nearest-neighbor matching b) Love plot displaying absolute standardized mean differences for all covariates before (All) and after (Matched) the matching procedure.

to the FND group and 81 to the CND group. Ipsilateral ND was performed in 20 patients in the FND group and 23 in the CND group, whereas bilateral ND was performed in 32 and 29 patients, respectively (Table 2). A total of 300 LNLs were dissected in the CND group (mean: 5.76 per patient) compared with 276 LNLs in the FND group (mean: 5.30 per patient). The mean age was comparable between the cohorts: 62.5 ± 13.75 years (range, 34–92 years) for FND and 61.5 ± 10.75 years (range, 27–102 years) for CND.

3.2. LNY and RR rate

The mean LNY was significantly higher in the FND group than in the CND group (55 ± 28 vs. 44 ± 23 LNs; p = 0.016; Wilcoxon signed rank test) (Fig. 6a). For sensitivity analysis, a linear regression model adjusted for pathological nodal status (pN) was fitted in the matched cohort. Adjustment for pN did not alter the association between ND type and total LNY (β = 10.25 before adjustment vs. β = 10.25 after adjustment), indicating that the findings were robust to differences in nodal status. Topographic analysis demonstrated that FND achieved a superior yield in levels I–III both ipsilaterally (31 ± 9 vs. 26 ± 9; p = 0.005; Wilcoxon signed-rank) and contralaterally (30 ± 8 vs. 25 ± 10; p = 0.031; Wilcoxon signed-rank). Furthermore, in dissections involving LNLs IV and V, FND yielded a mean of 29 ± 20 LNs ipsilateral compared to 16 ± 6 LNs in the CND group (p = 0.225). Contralaterally, the mean number of LNs removed was 19 ± 10 in the FND group versus 11 ± 7 in the CND group (p = 0.295) (Table 2). Histopathological examination confirmed

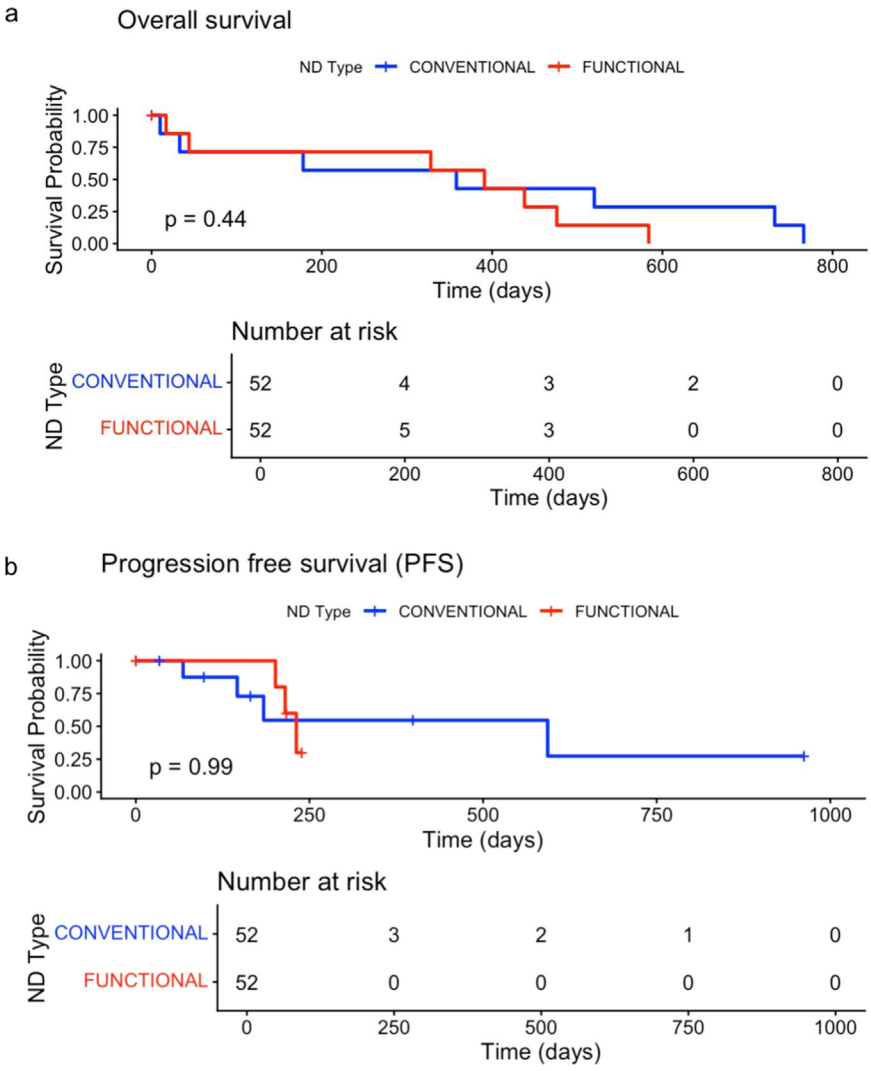


Fig. 5. Kaplan–Meier survival curves by neck dissection type in the matched cohort. P-values depict results from the log-rank test. a) Overall survival b) Progression-free survival.

cervical metastases (pN+) in 11 (20.8%) and 21 (40.4%) patients in the FND and CND groups, respectively (p = 0.019). RR was observed in two patients (3.8%) in the FND group and five patients (10,4%) in the CND group (Fig. 6b) (p = 0.198, Fisher's exact test).

3.3. Subgroup analysis

Across levels II–V (left and right sides), FND demonstrated significantly higher LNY than CND, with approximately 3.3 ± 0.6 nodes more per level on average (p < 0.001; Wilcoxon signed-rank test). The number of LNs localized at level I was similar in both groups (Fig. 6c).

3.4. Follow-up and oncologic characteristics

The median follow-up period was 42 months (range, 12–60). Follow-up consisted of monthly clinical examinations in the first year. Thereafter, clinical examinations were scheduled at three-month intervals. Radiological imaging, computed tomography (CT) or magnetic resonance imaging (MRI), was performed every 6-month interval. Patient compliance with the follow-up protocol was 100% (52/52) in the FND group and 92.3% (48/52) in the CND group.

The tumor characteristics were similar across the cohorts. High-grade (G3) poorly differentiated tumors were present in 19.2% (n = 10) of the FND and 17.3% (n = 9) of the CND groups. The most frequent primary tumor sites were the tongue and floor of the mouth, accounting for 53.9% (n = 28) and 57.7% (n = 30) of the cases, respectively. Approximately 60% of the patients in both cohorts presented with early-stage OSCC (pT1/pT2: 57.7% - FND vs. 58.5% - CND).

No significant differences were observed between the two cohorts in terms of histopathological features associated with tumor aggressiveness. Vascular invasion (V1) was identified in 3.8% (n = 2) of patients in each group. Lymphatic invasion (L1) was present in 5.8% (n = 3) of the FND group and 7.7% (n = 4) of the CND group, whereas perineural invasion (Pn1) was noted in 9.6% (n = 5) and 5.8% (n = 3) of patients, respectively.

The requirements for adjuvant treatment were comparable: radiotherapy was indicated for 44.2% (n = 23) of patients in the FND group and 50.0% (n = 26) in the CND group. Furthermore, adjuvant chemotherapy was administered to 9.6% (n = 5) of the FND cohort and 19.2% (n = 10) of the CND cohort. OS and PFS were analyzed as exploratory endpoints. No statistically significant differences were observed between the two ND techniques. Specifically, both OS (p = 0.44) and PFS (p = 0.99) were comparable between the groups, showing no statistically significant differences.

4. Discussion

ND remains a relevant therapeutic procedure and is routinely employed in complex multimodal treatment approaches for OSCC [15]. The cervical metastasis rate in this study was 20.8% (11 patients) in the

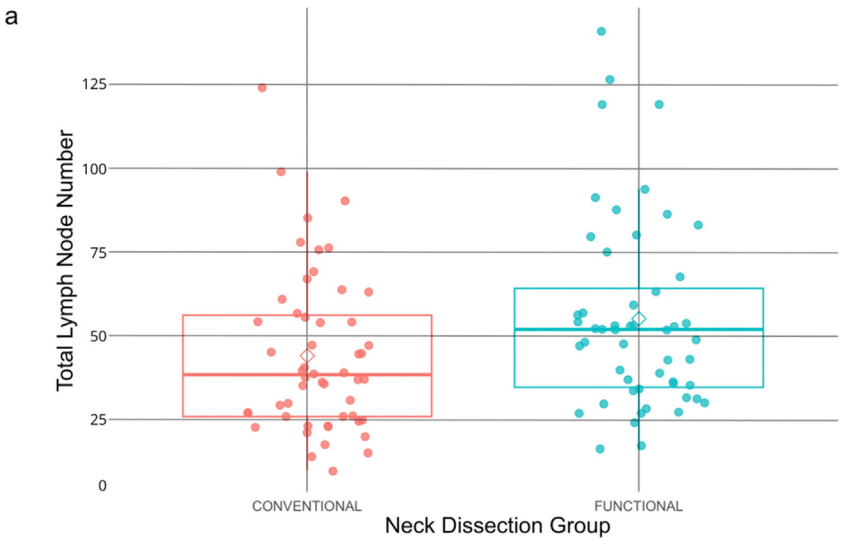
Table 1
Clinico-pathological characteristics of matched cohorts. FND = Functional Neck Dissection; CND = Conventional Neck Dissection. Significant values ($p < 0.05$) in bold. # Wilcoxon signed-rank test; § Chi-Square test; † Fisher exact test, Δ Cochran−Armitage Trend test. Values are mean (SD) in the first two rows and n (%) in subsequent rows.

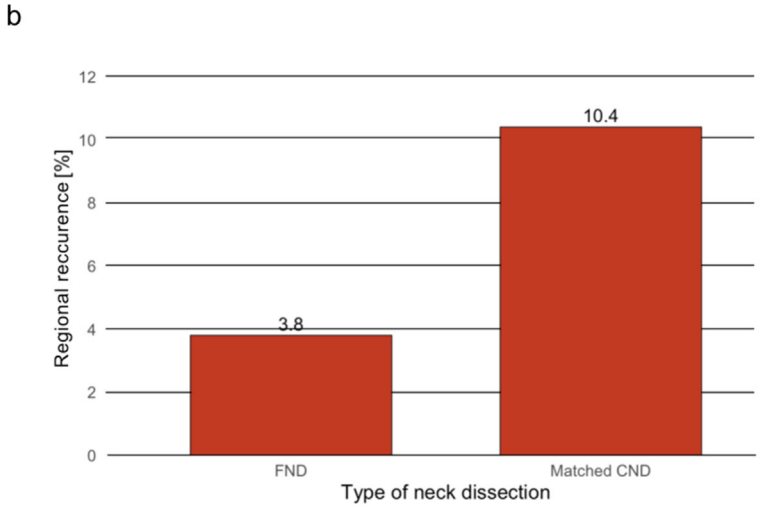
Variables		FND (n = 52)	Matched CND (n = 52)	P-value
Age (years)	Median	62.50 (13.75)	61.50 (10.75)	0.488#
BMI (kg/m^2)	Median	24.94 (7.14)	25.21 (6.70)	0.977#
History of tobacco use	No	30 (57.7%)	23 (51.1%)	0.657§
	Yes	22 (42.3%)	22 (48.9%)	
History of alcohol abuse	No	29 (55.8%)	26 (57.8%)	0.999§
	Yes	23 (44.2%)	19 (42.2%)	
Tumor localization	Mandibula	4 (7.7%)	3 (5.8%)	0.791†
	Maxilla	7 (13.5%)	8 (15.4%)	
	Mouth floor	17 (32.7%)	20 (38.5%)	
	Planum buccale	3 (5.8%)	5 (9.6%)	
	Retromolar	9 (17.3%)	4 (7.7%)	
	Tongue	11 (21.2%)	10 (19.2%)	
	Multiple	1 (1.9%)	2 (3.8%)	
Grading	G1	5 (9.6%)	2 (3.9%)	0.545Δ
	G2	37 (71.2%)	41 (78.8%)	
	G3	10 (19.2%)	9 (17.3%)	
Tumor stage	pT1	18 (34.6%)	18 (34.6%)	0.932Δ
	pT2	12 (23.1%)	14 (26.9%)	
	pT3	11 (21.2%)	8 (15.4%)	
	pT4	11 (21.2%)	12 (23.1%)	
Nodal stage	pN0	41 (78.9%)	31 (59.6%)	**0.019**Δ
	pN1	5 (9.6%)	7 (13.5%)	
	pN2	4 (7.7%)	6 (11.5%)	
	pN3	2 (3.8%)	8 (15.4%)	
Lymphatic invasion	L0	49 (94.2%)	48 (92.3%)	0.700§
	L1	3 (5.8%)	4 (7.7%)	
Venous invasion	V0	50 (96.2%)	50 (96.2%)	1.000§
	V1	2 (3.8%)	2 (3.8%)	
Perineural invasion	Pn0	47 (90.4%)	49 (94.2%)	0.462§
	Pn1	5 (9.6%)	3 (5.8%)	
Radiation	No	29 (55.8%)	26 (50.0%)	0.556§
	Yes	23 (44.2%)	26 (50.0%)	
Chemotherapy	No	47 (90.4%)	42 (80.8%)	0.163§
	Yes	5 (9.6%)	10 (19.2%)	
Regional recurrence	No	50 (96.2%)	43 (89.6%)	0.198§
	Yes	2 (3.8%)	5 (10.4%)	

FND group and 40.4% (21 patients) in the CND group. These results are consistent with data in the literature and are important for the prognosis [16–19]. The discrepancy in pN status between the groups is recognized as a potentially significant confounding factor that could affect long-term RR rates and patient survival outcomes. Nonetheless, the PSM model did not incorporate pN status as a matching covariate, and it was designated as an endpoint of the study. A sensitivity analysis with adjustments for pN status demonstrated that the association between ND technique and LNY remained unaltered ($\beta = 10.25$ before adjustment vs. $\beta = 10.25$ after adjustment). These findings indicated that the observed difference in LNY between ND techniques is robust to adjustment for pN status. However, RR rates remained statistically comparable between the cohorts, with 3.8% (two patients) in the FND group and 10.4% (five patients) in the CND group ($p = 0.198$). Subsequent to a median 42-month follow-up, no statistically significant differences in either OS ($p = 0.44$) or PFS ($p = 0.99$) were observed between the two groups. Despite this, follow-up compliance differed between groups; 100% of patients in the FND group participated in regular oncological follow-up compared to 92.3% in the CND group. The slightly lower follow-up rate in the CND group may represent a potential limitation, possibly leading to an underestimation of the RR in this cohort. It is noteworthy that FND resulted in a significantly higher LNY compared with CND (55 vs. 44 LNs; $p = 0.016$). When the total extent of the surgical procedures was analyzed, a total of 300 LNLs were dissected in the CND group, compared with 276 in the FND group. This resulted in an average of 5.76 and 5.30 LNLs per patient in the CND and FND groups, respectively. The present study corroborates the findings of a previous investigation by Lorenz et al., which involved 150 patients. The LNY was 22.53 in the FND group and 15 in the control group [20]. Nevertheless, the study design exhibited a risk of bias, as it compared two groups without considering potentially confounding factors. Moreover, this study did not evaluate patient outcomes. In the present study, FND was primarily carried out with a No 10-blade scalpel, followed by the cleavage plane of dissection along the DCF. This technique facilitates meticulous dissection between the branches of the cervical plexus. It ensures strict delimitation of the posterior boundary of LNLs II and III, defined by the posterior border of the SCM. This precision is particularly significant in SND, where demarcating this region after dissection with scissors can be challenging and arbitrary. This is attributable to the fact that SCM is not fully mobilized as it is in comprehensive ND. Conversely, CND is characterized by a vertical dissection technique using scissors, involving in situ sectioning of the specimen and separate removal of LNLs. Its disadvantages include less accurate delimitation of the posterior border of levels II and III, risking incomplete excision due to dissection through fibrofatty tissue. This is further supported by our findings on the number of LNs at each level. Although in situ sectioning could theoretically cause mechanical disruption and subsequent tumor cell dissemination, this risk remains highly debatable. To date, the demonstration of such an effect in clinical studies has been lacking, and its prognostic relevance remains uncertain. However, it is hypothesized that it could potentially impact regional control and long-term survival rates. Given the current trend toward minimizing the invasiveness of surgical interventions, it is imperative to acknowledge the increasing utilization of SLNB, even in OSCC management [21]. Therefore, SLNB has become a popular treatment for this form of cancer, particularly in the early stages of the disease [22]. Hasegawa et al. [23] conducted a randomized trial with 275 patients, demonstrating non-inferior three-year survival outcomes for SLNB versus ND in early OSCC. This technique has several advantages, including minimal invasiveness, reduced morbidity, improved quality of life, and cost-effectiveness [24]. Another advantage is the ability to accurately determine the patterns of cervical metastasis in individuals who have undergone ND. Disruption of the lymphatic channels is known to cause irregular drainage within the lymphatic vessels [25]. There are some limitations to this technique, especially in localization areas such as the floor of the mouth, due to the "shine-through effect" [26]. This phenomenon occurs because adjacent LNs are overshadowed by contrast material that accumulates in the primary tumor [27]. A further limitation of SLNB is evident in advanced cases and in the presence of cervical lymphadenopathy. A depth of invasion greater than 4 mm indicates the need for ND [28]. The surgical indication for ND remains a contentious issue, with the optimal approach being the subject of debate among surgeons. The choice between performing FND or CND is determined by several factors, such as the surgeon's preferences and skills. Regardless

Table 2
Lymph node parameters of matched cohorts. FND = Functional Neck Dissection; CND = Conventional Neck Dissection. Significant values ($p < 0.05$) in bold. § Fisher's exact test; # Wilcoxon signed-rank. Values are n (%) in the first row and mean (SD) in subsequent rows.

Variables		FND (n = 52)	Matched CND (n = 52)	P-value
Side of neck dissection	Ipsilateral	20 (38.5%)	23 (44.2%)	0.371§
	Both	32 (61.5%)	29 (55.8%)	
Total number of lymph nodes		55 (28)	44 (23)	**0.016**#
Lymph node number levels I–III	Ipsilateral	31 (9)	26 (9)	**0.005**#
	Contralateral	30 (8)	25 (10)	**0.031**#
Lymph node number levels IV–V	Ipsilateral	29 (20)	16 (6)	0.225#
	Contralateral	19 (10)	11 (7)	0.295#





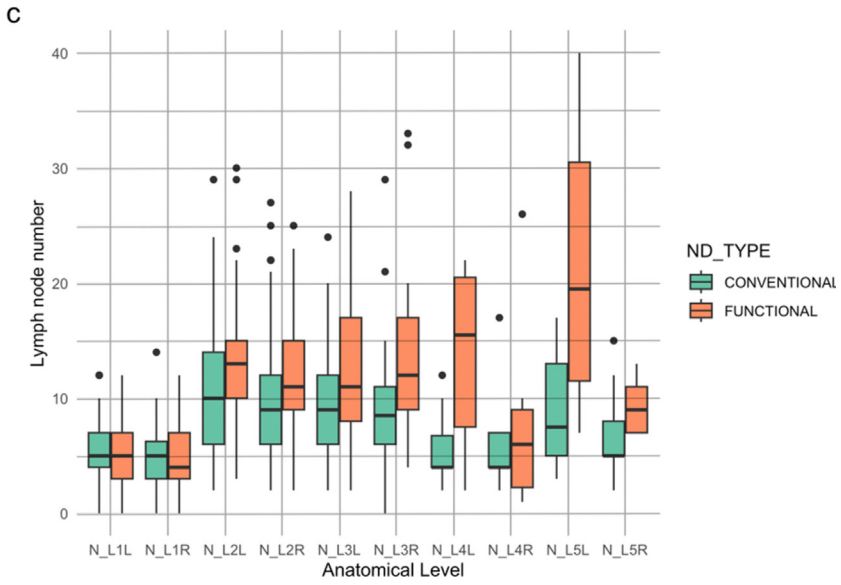


Fig. 6. Assessment of quantitative lymph node outcomes and regional control using two different neck dissection techniques. a) Comparison of lymph node yield (LNY) identified using functional neck dissection (FND) versus conventional neck dissection (CND). The LNY is shown for FND (teal) and CND (red) using the Wilcoxon signed-rank test ($p = 0.016$) b) Comparison of regional recurrence rates between both groups c) Distribution of lymph node counts by cervical anatomical level.

of the preferred technique, the most important aspect is the effective removal of cervical fibrofatty tissue and, implicitly, the LNs. This observation was corroborated by a study conducted by Cheng et al., who examined a cohort of 126 patients diagnosed with OSCC. The results showed that patients with an LNY below 37, nerve invasion, and low tumor differentiation had an unfavorable prognosis [29]. Cramer et al. evaluated LNY as a quality metric in 76,853 surgically treated patients and showed that an LNY ≥18 was associated with reduced mortality (HR 0.93, 95% CI 0.89−0.96) [30]. Gil et al. evaluated a cohort of 386 patients with OSCC who underwent ND, with a median follow-up of 67 months. The findings prove that LN density (LND)- defined as the ratio of positive LNs to the total number of excised LNs−is a strong, independent predictor of poor survival. Specifically, an LND greater than the 0.06 threshold reduces 5-year OS from 58% to 28% and disease-specific survival from 65% to 34% ($p < 0.001$) [31]. Nevertheless, LNY should be interpreted as a quality indicator and may be influenced by multiple factors, such as the level of surgical experience, treatment at an academic center, multi-pathologist examination, examination protocols, BMI, patient anatomy, and preoperative radiotherapy [32]. Furthermore, the significantly higher LNY observed in the FND group did not translate into a statistically significant reduction in RR rates within this cohort ($p = 0.198$). Consequently, this elevated nodal count should be interpreted primarily as a surgical quality indicator reflecting more thorough, anatomically guided clearance of the fascial planes rather than a definitive predictor of superior regional oncological control. This is further supported by our exploratory survival analyses, which demonstrated that both OS ($p = 0.44$) and PFS ($p = 0.99$) remained entirely comparable between the two ND techniques.

A notable limitation of this study is the multi-surgeon approach, which inherently introduces inter-surgeon variability regarding surgical preferences and individual technical skills. Such differences can directly contribute to heterogeneous surgical outcomes, potentially causing variations in LNY across both techniques. To ensure consistent technical standards and minimize variability, the surgeons involved in this study were all senior attending physicians with significant expertise in oncological surgery of the head and neck. Nevertheless, despite their shared expertise, subtle individual variations in procedural execution, anatomical dissection boundaries, and specimen handling cannot be entirely excluded.

Another limitation is the participation of multiple pathologists in specimen analysis. The histopathological evaluation was conducted in accordance with the standard institutional protocols. Although all pathologists were blinded to the surgical technique, inter-observer variability in LNs identification and counting may have introduced non-differential measurement variability. However, standardized specimen processing protocols within a single pathology department were applied throughout the study period, which likely reduced the variability in the pathological assessment. A third limitation of the study is the 42-month follow-up period, which is acceptable for an oncology study of this kind but has limitations when evaluating long-term oncological outcomes.

Another limitation stems from the retrospective nature of this cohort study, which introduces an inherent vulnerability to selection bias in the analysis. Furthermore, the use of PSM, an approach designed to minimize unintended differences between the groups analyzed, is not without potential error. This may result in residual confounding. The final limitation concerns the reduced cohort size, which may potentially result in inadequate statistical power to discern subtle variations between the study groups.

In conclusion, ND has evolved over the past century to address the issue of cervical lymphatic metastasis in head and neck tumors. In the present cohort, FND achieved a significantly higher LNY while maintaining comparable regional control, underscoring its potential as an oncologically sound approach, albeit within the constraints of a retrospective, underpowered study.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Oliver Vladu: Writing − original draft, Validation, Investigation, Formal analysis, Conceptualization. **Janik Riese:** Writing − review & editing, Formal analysis. **Maurice Klein:** Project administration, Methodology. **Danny Jonigk:** Writing − review & editing, Methodology, Formal analysis. **Jeff Berens:** Writing − review & editing, Methodology, Investigation. **Frank Hölzle:** Writing − review & editing, Supervision, Methodology. **Ashkan Rashad:** Writing − original draft, Supervision, Methodology, Conceptualization.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jormas.2026.102937.

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