

Clinical Impact of Surgical Margin Status on Local Control and Survival Following Oral Cancer Surgery

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ABSTRACT:

Background:

Surgical margin status is one of the most important prognostic determinants in oral squamous cell carcinoma (OSCC), influencing local tumor control and long-term survival. Despite advances in surgical techniques, close and positive margins remain associated with unfavorable oncological outcomes. This study evaluated the impact of surgical margin status on recurrence and survival in patients undergoing curative surgery for oral cancer.

Materials & Methods:

A retrospective observational study was conducted on 180 patients with histopathologically confirmed OSCC who underwent primary curative surgical resection. Patients were categorized into three groups according to final histopathological surgical margin status: negative margin (n = 60), close margin (n = 60), and positive margin (n = 60). Baseline demographic characteristics, tumor stage, nodal status, local recurrence, disease-free survival (DFS), overall survival (OS), and overall oncological outcomes were compared among the three groups. Continuous variables were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's Honestly Significant Difference (HSD) post hoc test, whereas categorical variables were analyzed using the Chi-square test. Univariate Cox proportional hazards regression analysis was performed to identify prognostic factors associated with adverse oncological outcomes. A p-value <0.05 was considered statistically significant.

Results:

Baseline demographic characteristics were comparable among the three groups (age, $p = 0.721$; gender, $p = 0.842$). Advanced tumor stage ($p = 0.018$) and nodal involvement ($p = 0.024$) were significantly associated with close and positive surgical margins. Local recurrence increased progressively from 13.3% in the negative margin group to 26.7% in the close margin group and 45.0% in the positive margin group ($p < 0.001$). Mean DFS was significantly higher in patients with negative margins (48.20 ± 10.60 months) than in those with close (38.90 ± 11.40 months) and positive margins (28.50 ± 12.20 months) ($F = 43.281$, $p < 0.001$). Similarly, mean OS was significantly greater in the negative margin group (56.40 ± 8.90 months) compared with the close (47.80 ± 10.10 months) and positive margin groups (36.20 ± 12.80 months) ($F = 52.014$, $p < 0.001$). Tukey's HSD analysis demonstrated significant differences between all pairwise comparisons ($p < 0.001$). Univariate Cox regression identified positive surgical margins (HR = 3.18, 95% CI: 2.01–5.02), advanced tumor stage (HR = 2.64), positive nodal status (HR = 2.31), perineural invasion (HR = 2.05), close margins (HR = 1.91), poor differentiation (HR = 1.82), and lymphovascular invasion (HR = 1.74) as significant predictors of poor oncological outcomes (all $p < 0.05$). Patients with positive margins exhibited the highest recurrence and mortality rates and the lowest disease-free and overall survival.

Conclusion:

Surgical margin status is a strong independent prognostic indicator in OSCC. Histologically negative surgical margins are associated with significantly lower recurrence rates and superior DFS and OS, whereas close and positive margins adversely affect long-term oncological outcomes. Achieving adequate margin clearance during primary surgical resection remains essential for optimizing prognosis in patients with oral cancer.

Keywords: Disease-free survival, Local recurrence, Oncologic prognosis, Oral cancer surgery, Surgical margin status.

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Introduction

Oral cancer represents a significant global health burden, with oral squamous cell carcinoma (OSCC) accounting for the majority of malignant tumors arising in the oral cavity. Despite advances in diagnostic modalities, surgical techniques, and adjuvant therapies, surgical resection remains the cornerstone of curative-intent treatment for oral malignancies. Long-term oncologic outcomes are largely determined by the adequacy of tumor excision, among which surgical margin status is regarded

as one of the most critical prognostic factors [1, 2].

The primary objective of oral oncologic surgery is the complete removal of the tumor with histologically negative margins while preserving essential oral functions such as speech, mastication, and swallowing. However, achieving adequate margins in the oral cavity is inherently challenging due to complex anatomy, proximity to vital structures, limited surgical access, and the infiltrative growth patterns characteristic of oral cancers [3]. These factors frequently result in close or positive surgical

margins, which are associated with an increased risk of residual disease and local recurrence.

Numerous studies have demonstrated that positive surgical margins are strongly correlated with poorer local control, reduced disease-free survival (DFS), and diminished overall survival (OS) in patients with oral cancer [4, 5]. Close margins, although not uniformly defined across institutions, have also been shown to confer an intermediate but clinically meaningful risk of recurrence, leading to controversy regarding the need for re-resection or adjuvant therapy [6]. In addition, interobserver variability in pathological margin assessment and differences in specimen handling further complicate outcome interpretation.

Given the prognostic importance of margin status, accurate histopathological evaluation and standardized classification of surgical margins are essential components of oral cancer management [7]. Understanding the independent impact of margin status in conjunction with other clinicopathologic factors—such as tumor stage, histological grade, nodal involvement, and adjuvant therapy—is crucial for refining risk stratification and guiding postoperative treatment decisions [8].

In this context, the present study aims to evaluate the influence of surgical margin status on local recurrence, DFS, and OS in patients undergoing curative-intent surgery for oral malignancies. By elucidating the prognostic significance of negative, close, and positive margins, this study seeks to contribute to evidence-based surgical planning and optimization of oncologic outcomes in oral cancer patients.

Materials & Methods

Study Design

This retrospective observational study was conducted to evaluate the prognostic significance of surgical margin status on oncological outcomes in patients with OSCC undergoing curative-intent surgical resection.

Study Setting

A total of 180 consecutive patients with histopathologically confirmed OSCC who underwent primary surgical treatment were included in the study. This retrospective study included patient data collected from a tertiary care center between 2020 and 2024. Based on the final histopathological assessment of surgical margins, patients were equally categorized into three groups:

Negative surgical margin group (n = 60)

Close surgical margin group (n = 60)

Positive surgical margin group (n = 60)

Inclusion Criteria

Patients aged 18 years or older

Histopathologically confirmed primary OSCC

Patients treated with curative-intent surgical resection

Availability of complete clinicopathological records and histopathological reports

Documented surgical margin status

Availability of follow-up data for recurrence and survival analysis

Exclusion Criteria

Patients with recurrent oral cancer

Patients with distant metastasis at initial presentation

Previous treatment with surgery, chemotherapy, or radiotherapy for oral cancer

Incomplete clinical, pathological, or follow-up records

Patients lost to follow-up before outcome assessment

Data Collection

Clinical records and histopathological reports were reviewed to obtain demographic and clinicopathological information, including age, sex, primary tumor stage (T stage), cervical nodal status (N stage), histological differentiation, perineural invasion, lymphovascular invasion, and final surgical

margin status. Patients were followed for the occurrence of local recurrence, DFS, OS, disease status at the last follow-up, and mortality.

Outcome Measures

The primary outcome was the association between surgical margin status and local recurrence.

Secondary outcomes included:

DFS

OS

Overall oncological outcomes (disease-free status, survival status, and mortality)

Prognostic factors associated with recurrence and survival

Statistical Analysis

The collected data were entered into a Microsoft Excel spreadsheet and analyzed using IBM SPSS Statistics. Continuous variables were summarized as mean $\pm$ standard deviations (SD) along with standard error (SE) and 95% confidence intervals (95% CI), whereas categorical variables were expressed as frequency (n) and percentage (%). Prior to inferential analysis, the distribution of continuous variables was assessed for normality using the Shapiro–Wilk test, and homogeneity of variance was evaluated using Levene's test.

Baseline demographic variables, including age, were compared among the three surgical margin groups (Negative Margin, Close Margin, and Positive Margin) using one-way Analysis of Variance (ANOVA), while gender distribution was compared using the Chi-square test. Clinicopathological characteristics such as tumor stage and nodal status, as well as the association between surgical margin status and local recurrence, were analyzed using the Chi-square test of independence. When expected cell frequencies were less than five, Fisher's exact test was considered appropriate.

The comparison of DFS and OS among the three surgical margin groups was performed

using one-way ANOVA. Following a statistically significant ANOVA result, Tukey's Honestly Significant Difference (HSD) post hoc test was applied to determine pairwise differences between the study groups while controlling for multiple comparisons. Mean differences, 95% CI, and adjusted p-values were reported for all significant comparisons.

To identify prognostic factors associated with recurrence and survival, univariate Cox proportional hazards regression analysis was performed. The results were expressed as Hazard Ratios (HRs) with corresponding 95% CI and p-values. Variables demonstrating statistical significance in the univariate analysis ($p < 0.05$) were considered potential predictors of oncological outcomes and candidates for inclusion in a multivariable Cox proportional hazards model where appropriate.

Overall oncologic outcomes, including local recurrence, disease-free status at the last follow-up, OS, and mortality, were compared among the three surgical margin groups using the Chi-square test. All statistical analyses were two-tailed, and a p-value less than 0.05 were considered statistically significant. The results were presented using appropriate descriptive and inferential statistical measures, including means, SDs, SEs, 95% CI, F values, HRs, Chi-square statistics, and p-values, to comprehensively evaluate the prognostic impact of surgical margin status on recurrence and survival outcomes in patients undergoing oral cancer surgery.

Results

Table 1 & Figure 1 present the baseline demographic characteristics of the study population were comparable among the three surgical margin groups. The mean age of patients was 54.8 ± 9.7 years in the negative margin group, 56.1 ± 10.2 years in the close margin group, and 55.6 ± 9.4 years in the positive margin group. Although the close margin group had a marginally higher mean age, the difference among the three groups was not

statistically significant ($p = 0.721$), indicating a comparable age distribution at baseline.

With respect to gender distribution, male participants constituted the majority in all three groups, accounting for 42 (70.0%) patients in the negative margin group, 40 (66.7%) in the close margin group, and 43 (71.7%) in the positive margin group. Female participants comprised 18 (30.0%), 20 (33.3%), and 17 (28.3%) patients in the negative margin, close margin, and positive margin groups,

respectively. The gender distribution did not differ significantly among the groups ($p = 0.842$), demonstrating that the study groups were well matched with respect to sex.

Overall, the absence of statistically significant differences in age and gender indicates that the three surgical margin groups were demographically comparable at baseline, thereby minimizing the likelihood of demographic characteristics acting as confounding factors in the assessment of oncological outcomes

Table 1: Baseline Demographic Characteristics of the Study Population

Variable	Negative Margin (n=60)	Close Margin (n=60)	Positive Margin (n=60)	P value
Age (years), Mean $\pm$ SD	54.8 $\pm$ 9.7	56.1 $\pm$ 10.2	55.6 $\pm$ 9.4	0.721
Male, n (%)	42 (70.0)	40 (66.7)	43 (71.7)	0.842
Female, n (%)	18 (30.0)	20 (33.3)	17 (28.3)	

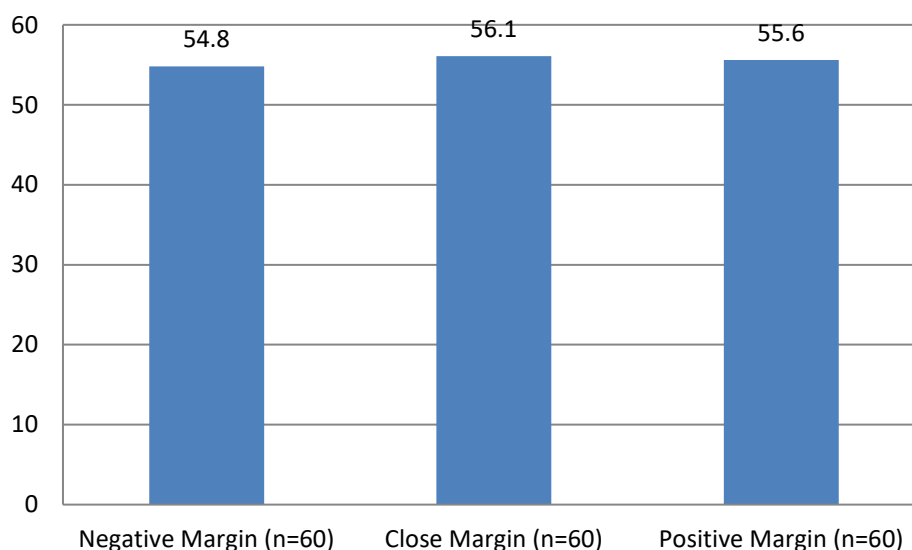


Figure 1: Distribution of Age and Gender Across Surgical Margin Groups

Table 2 & Figure 2 present the distribution of tumor characteristics varied significantly according to surgical margin status. With respect to tumor stage, T2 lesions were the most common across all three groups, accounting for 41.7% of patients in the negative margin group, 40.0% in the close margin group, and 30.0% in the positive margin group. Early-stage tumors (T1) were observed more frequently in the

negative margin group (30.0%) compared with the close margin (16.7%) and positive margin (8.3%) groups. In contrast, advanced-stage tumors were more prevalent among patients with positive margins, with T3 tumors comprising 40.0% and T4 tumors 21.7% of cases, compared with 20.0% and 8.3%, respectively, in the negative margin group. The association between tumor stage and surgical

margin status was statistically significant ($p = 0.018$), indicating that patients with advanced tumors were more likely to have close or positive surgical margins.

A similar trend was observed for nodal status. The majority of patients in the negative margin group had N0 disease (60.0%), whereas the proportion of node-negative patients progressively decreased in the close margin (46.7%) and positive margin (33.3%) groups. Conversely, the frequency of nodal metastasis increased with worsening margin status. N1 disease was observed in 28.3%, 33.3%, and 38.3% of patients in the negative, close, and positive margin groups, respectively, while N2 disease was present in 11.7%, 20.0%, and

28.3%, respectively. The association between nodal status and surgical margin status was also statistically significant ($p = 0.024$), suggesting that patients with nodal involvement were more likely to have close or positive surgical margins.

Overall, these findings indicate that advanced tumor stage and higher nodal burden were significantly associated with unfavorable surgical margin status, emphasizing that patients with more advanced disease have a greater likelihood of achieving close or positive margins following surgical resection. Such clinicopathological characteristics may contribute to poorer oncological outcomes and highlight the importance of meticulous surgical planning in advanced oral malignancies.

Table 2: Distribution of Tumor Characteristics According to Surgical Margin Status

Variable	Negative N (%)	Close N (%)	Positive N (%)	P value
Tumor Stage				
T1	18 (30.0)	10 (16.7)	5 (8.3)	0.018
T2	25 (41.7)	24 (40.0)	18 (30.0)	
T3	12 (20.0)	18 (30.0)	24 (40.0)	
T4	5 (8.3)	8 (13.3)	13 (21.7)	
Nodal Status				
N0	36 (60.0)	28 (46.7)	20 (33.3)	0.024
N1	17 (28.3)	20 (33.3)	23 (38.3)	
N2	7 (11.7)	12 (20.0)	17 (28.3)	

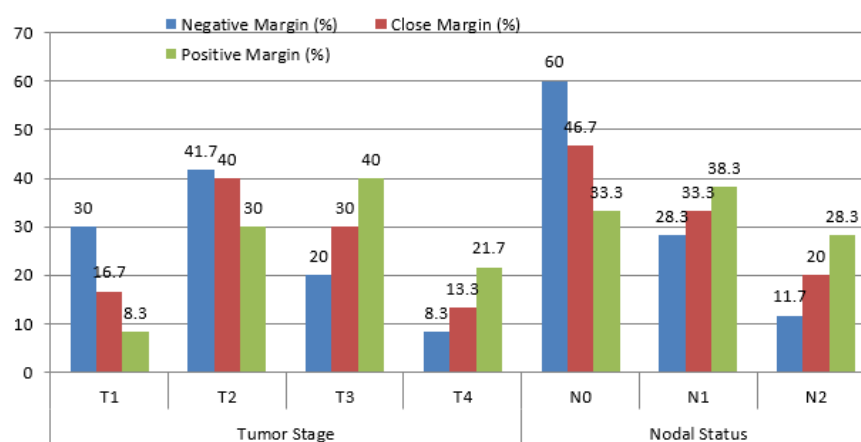


Figure 2: Distribution of Tumor Stage (T) and Nodal Status (N) Across Surgical Margin Groups

Table 3 & Figure 3 present the association between surgical margin status and local recurrence demonstrated a highly statistically significant relationship ($p < 0.001$). Among patients with negative surgical margins, only 8 patients (13.3%) developed local recurrence, whereas the majority (52 patients; 86.7%) remained free of recurrence during the follow-up period. In comparison, patients with close surgical margins exhibited a higher recurrence rate, with 16 patients (26.7%) experiencing local recurrence and 44 patients (73.3%) showing no evidence of recurrence.

The highest rate of local recurrence was observed among patients with positive surgical margins, where 27 patients (45.0%) developed recurrence, while only 33 patients (55.0%)

remained disease-free. Overall, of the 180 patients included in the study, 51 patients (28.3%) experienced local recurrence, whereas 129 patients (71.7%) had no recurrence during the study period.

These findings indicate a progressive increase in the risk of local recurrence with worsening surgical margin status. Patients with negative margins demonstrated the best local disease control, whereas those with positive margins had the highest likelihood of recurrence. The statistically significant association underscores the importance of achieving histologically negative surgical margins during oral cancer surgery to minimize local recurrence and improve oncological outcomes.

Table 3: Surgical Margin Status and Local Recurrence

Margin Status	Local Recurrence Present n (%)	No Recurrence n (%)	Total	P value
Negative	8 (13.3)	52 (86.7)	60	
Close	16 (26.7)	44 (73.3)	60	
Positive	27 (45.0)	33 (55.0)	60	
Total	51 (28.3)	129 (71.7)	180	<0.001

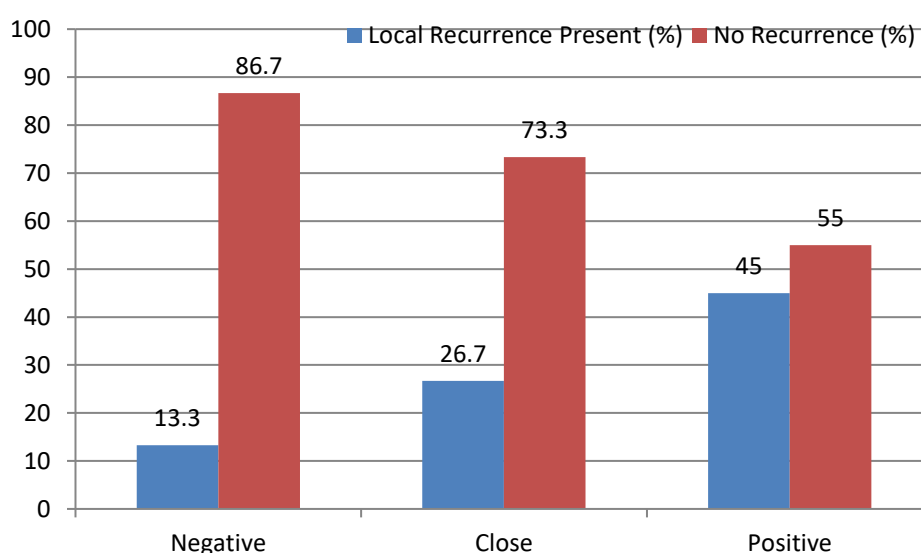


Figure 3: Comparison of Local Recurrence Rates Across Surgical Margin Groups

Table 4 & Figure 4 present the comparison of DFS among the three surgical margin groups demonstrated a highly statistically significant

difference ($F = 43.281$, $p < 0.001$). Patients with negative surgical margins exhibited the longest mean DFS (48.20 ± 10.60 months), followed by

those with close surgical margins (38.90 ± 11.40 months), while patients with positive surgical margins had the shortest mean DFS (28.50 ± 12.20 months). The corresponding 95% CI further confirmed the distinct separation between the three groups, indicating progressively poorer DFS with worsening margin status.

Table 5 presents the results of Tukey's HSD post hoc analysis, which revealed statistically significant differences among all pairwise comparisons. Patients with negative margins had significantly longer DFS than those with close margins (mean difference = 9.30 months, $p < 0.001$) and positive margins (mean difference = 19.70 months, $p < 0.001$). Likewise, patients

with close margins demonstrated significantly better DFS than those with positive margins (mean difference = 10.40 months, $p < 0.001$).

Overall, these findings indicate that DFS decreased progressively as surgical margin status worsened. Patients with negative margins experienced the most favorable DFS, whereas those with positive margins had the poorest outcomes, highlighting surgical margin status as a strong prognostic determinant of recurrence-free survival following oral cancer surgery. The statistically significant differences observed across all pairwise comparisons emphasize the critical importance of achieving histologically negative surgical margins to improve long-term oncological outcomes.

Table 4: Comparison of DFS Among Study Subjects

Margin Status	N	Mean (Months)	SD	SE	95% CI	F value	P value
Negative	60	48.20	10.60	1.37	45.46–50.94	43.281	<0.001
Close	60	38.90	11.40	1.47	35.96–41.84		
Positive	60	28.50	12.20	1.58	25.34–31.66		

Table 5: Tukey HSD Post Hoc Comparison of DFS

Comparison	Mean Difference	P value	95% CI	Significance
Negative vs Close	9.30	<0.001	5.48–13.12	Significant
Negative vs Positive	19.70	<0.001	15.88–23.52	Significant
Close vs Positive	10.40	<0.001	6.58–14.22	Significant

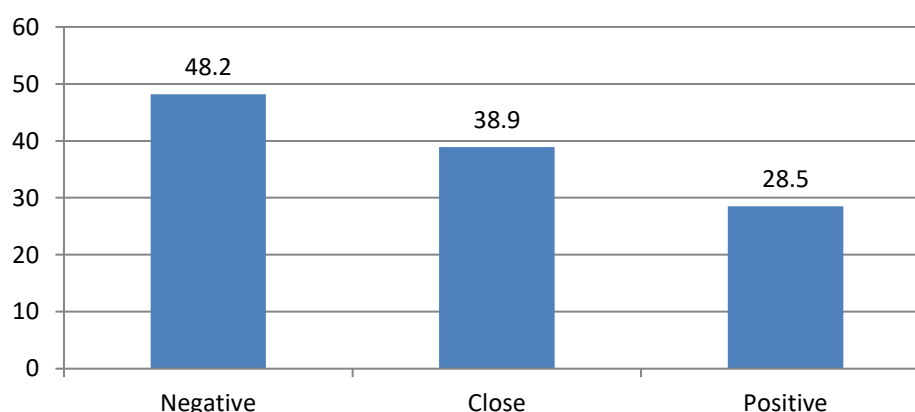


Figure 4: Comparative Analysis of DFS by Surgical Margin Status

Table 6 presents the univariate Cox proportional hazards regression analysis demonstrated that several clinicopathological variables were significantly associated with an increased risk of adverse oncological outcomes. Positive surgical margin status emerged as the strongest predictor of poor prognosis, with patients having positive margins exhibiting a 3.18-fold higher risk of recurrence or death compared with those having negative margins (HR = 3.18, 95% CI: 2.01–5.02, $p < 0.001$). Similarly, patients with close surgical margins had a 1.91-fold increased risk of adverse outcomes (HR = 1.91, 95% CI: 1.18–3.10, $p = 0.008$) compared with those with negative margins.

Advanced tumor stage (T3–T4) was also identified as a significant prognostic factor, increasing the risk of recurrence or mortality by 2.64 times (HR = 2.64, 95% CI: 1.73–4.03, $p < 0.001$). Likewise, positive nodal status was associated with a 2.31-fold higher risk of adverse outcomes (HR = 2.31, 95% CI: 1.51–3.54, $p < 0.001$), indicating the important prognostic impact of cervical lymph node involvement.

Histopathological features also significantly influenced patient prognosis. Poorly differentiated tumors were associated with a 1.82-fold increased risk of recurrence or death (HR = 1.82, 95% CI: 1.14–2.91, $p = 0.012$). Similarly, the presence of perineural invasion significantly increased the risk by 2.05 times (HR = 2.05, 95% CI: 1.34–3.14, $p = 0.001$), while lymphovascular invasion was associated with a 1.74-fold higher risk of adverse oncological outcomes (HR = 1.74, 95% CI: 1.11–2.73, $p = 0.016$).

Overall, the univariate Cox regression analysis identified positive surgical margins, close surgical margins, advanced tumor stage, positive nodal status, poor histological differentiation, perineural invasion, and lymphovascular invasion as significant predictors of poorer oncological outcomes. Among these variables, positive surgical margin status exhibited the highest hazard ratio, emphasizing its critical prognostic importance in patients undergoing surgery for oral cancer.

Table 6: Univariate Cox Regression Analysis

Variable	Hazard Ratio	95% CI	P value
Positive Margin	3.18	2.01–5.02	<0.001
Close Margin	1.91	1.18–3.10	0.008
T3–T4 Stage	2.64	1.73–4.03	<0.001
Positive Node	2.31	1.51–3.54	<0.001
Poor Differentiation	1.82	1.14–2.91	0.012
Perineural Invasion	2.05	1.34–3.14	0.001
Lymphovascular Invasion	1.74	1.11–2.73	0.016

Table 7 presents the comparison of overall oncologic outcomes according to surgical margin status demonstrated highly statistically significant differences across all evaluated parameters (all $p < 0.001$). Patients with negative surgical margins exhibited the most favorable oncological outcomes, with only 8 patients (13.3%) developing local recurrence,

while 52 patients (86.7%) remained disease-free at the final follow-up. Furthermore, 53 patients (88.3%) were alive at the last follow-up, and only 7 patients (11.7%) had died during the study period.

Patients with close surgical margins showed intermediate oncological outcomes. Local recurrence occurred in 16 patients (26.7%),

whereas 44 patients (73.3%) remained disease-free. At the end of follow-up, 45 patients (75.0%) were alive and 15 patients (25.0%) had died, indicating poorer outcomes compared with the negative margin group.

The positive surgical margin group demonstrated the least favorable prognosis. Nearly half of the patients (27; 45.0%) experienced local recurrence, while only 33 patients (55.0%) remained disease-free throughout the follow-up period. Similarly, 35 patients (58.3%) were alive at the last follow-up, whereas 25 patients (41.7%) had died, representing the highest mortality rate among the three groups.

Overall, the findings indicate a progressive deterioration in oncological outcomes with worsening surgical margin status. Patients with negative margins achieved the lowest recurrence rate, the highest disease-free survival, the greatest overall survival, and the lowest mortality, whereas positive margins were associated with the highest recurrence rate, poorest disease-free status, lowest survival, and highest mortality. The highly significant differences observed among the three groups underscore the critical prognostic importance of achieving histologically negative surgical margins during oral cancer surgery, as adequate margin clearance is strongly associated with improved local control and long-term survival outcomes.

Table 7: Overall Oncologic Outcomes

Outcome	Negative Margin	Close Margin	Positive Margin	P value
Local Recurrence	8 (13.3%)	16 (26.7%)	27 (45.0%)	<0.001
Disease-Free at Last Follow-up	52 (86.7%)	44 (73.3%)	33 (55.0%)	<0.001
Alive at Last Follow-up	53 (88.3%)	45 (75.0%)	35 (58.3%)	<0.001
Deaths	7 (11.7%)	15 (25.0%)	25 (41.7%)	<0.001

Discussion

The findings of the present study demonstrate that surgical margin status is a major determinant of oncological outcomes in patients with OSCC. Patients with histologically negative surgical margins experienced the lowest rates of local recurrence and significantly superior DFS and OS, whereas positive surgical margins were associated with the highest recurrence rates and the poorest survival outcomes. Furthermore, advanced tumor stage and nodal involvement were significantly associated with close and positive surgical margins, indicating that unfavorable clinicopathological characteristics contribute to the difficulty of achieving adequate surgical clearance.

The prognostic importance of surgical margin status in OSCC has been consistently demonstrated across multiple studies. Early

evidence by Loree and Strong (1990) [9] established that positive surgical margins are strongly associated with increased local recurrence and reduced survival in OSCC, emphasizing the need for complete tumor excision as a primary surgical objective. The present study supports these observations, as patients with positive margins demonstrated significantly higher local recurrence and markedly reduced DFS and OS compared with those who achieved negative margins.

Subsequently, Binahmed et al. (2007) [10] reinforced the clinical significance of positive margins in oral cancer, reporting significantly poorer local control and survival outcomes in patients with involved margins compared with those having clear margins. Their findings also suggested that adjuvant radiotherapy cannot fully compensate for inadequate surgical clearance. Similarly, in the present study,

patients with positive margins exhibited the highest recurrence rate (45.0%) together with the lowest survival outcomes, highlighting the persistent adverse prognostic impact of involved surgical margins.

The influence of margin condition—clear, close, or involved—was further clarified by McMahon et al. (2003) [11], who demonstrated that both positive and close margins adversely affect local recurrence and disease-specific survival in oral and oropharyngeal cancers. The results of the present study are in close agreement, demonstrating a progressive deterioration in oncological outcomes from negative to close and finally positive surgical margins. Patients with close margins showed intermediate recurrence rates and survival outcomes, supporting the concept that close margins represent an intermediate-risk category rather than being equivalent to clear margins.

In a comprehensive analysis of predictive factors for local tumor control, Liao et al. (2008) [12] identified surgical margin status as one of the strongest predictors of local control in oral cavity cancer. Their multivariable analysis demonstrated that inadequate margins significantly increased the risk of local failure independent of other clinicopathological variables. Consistent with these findings, the present study observed significantly reduced DFS and OS among patients with close and positive margins. Furthermore, univariate Cox regression analysis identified positive surgical margins as the strongest predictor of adverse oncological outcomes (HR = 3.18), emphasizing the prognostic importance of achieving complete tumor clearance.

More recently, Solomon et al. (2021) [13] specifically examined the prognostic significance of close surgical margins and reported higher recurrence rates in patients with close margins than in those with clear margins. The present findings corroborate this observation, with patients in the close margin group demonstrating significantly higher local recurrence and shorter DFS and OS than patients with negative margins, thereby

supporting the growing consensus that close margins should be considered a high-risk pathological feature requiring careful postoperative management.

Beyond margin status alone, tumor biology and invasion patterns also influence margin adequacy. Brown et al. (2002) [14] demonstrated that patterns of invasion and routes of tumor spread into the mandible can result in occult microscopic disease extending beyond clinically apparent tumor boundaries, contributing to close or positive margins despite apparently adequate resections. In agreement with this concept, the present study found that advanced primary tumor stage and cervical nodal metastasis were significantly associated with unfavorable surgical margins, suggesting that increasing tumor burden and invasive growth patterns make complete surgical excision more challenging.

Finally, Almangush et al. (2017) [15] reported in a systematic review and meta-analysis that several adverse histopathological biomarkers are associated with poor prognosis in tongue OSCC. Their findings suggest that unfavorable surgical margins frequently coexist with biologically aggressive tumor characteristics. The present study further supports this relationship, as univariate Cox regression analysis identified advanced tumor stage, nodal metastasis, poor histological differentiation, perineural invasion, and lymphovascular invasion as significant predictors of adverse oncological outcomes alongside surgical margin status.

Collectively, the present findings are consistent with previous evidence demonstrating that surgical margin status remains one of the most important prognostic indicators in OSCC. The progressive increase in local recurrence and decline in DFS and OS observed with worsening margin status underscore the importance of achieving histologically negative margins during primary surgery. Careful preoperative planning, meticulous surgical technique, and appropriate multidisciplinary management, including risk-adapted adjuvant therapy and close postoperative surveillance for

patients with close or positive margins, are essential to optimize long-term oncological outcomes.

Limitations

The present study has several limitations that should be considered while interpreting the findings. First, its retrospective observational design may have introduced selection and information bias due to reliance on previously recorded clinical and pathological data. Second, the study was conducted at a single center with a relatively modest sample size, which may limit the generalizability of the findings to broader populations. Third, although surgical margin status was the primary variable of interest, other factors that could influence oncological outcomes, such as variations in adjuvant therapy, surgeon experience, tumor subsite, depth of invasion, and molecular biomarkers, were not evaluated in detail. Fourth, multivariable Cox regression analysis was not performed to determine the independent prognostic significance of surgical margin status after adjustment for potential confounding variables. Finally, the duration of follow-up may not have been sufficient to capture very late recurrences or long-term survival outcomes in all patients. Future multicenter prospective studies with larger cohorts, longer follow-up periods, and comprehensive multivariable

analyses are warranted to validate these findings and further refine prognostic risk assessment.

Conclusion

The findings of this study demonstrate that surgical margin status is a critical determinant of oncological outcomes in patients undergoing curative surgery for OSCC. Patients with histologically negative surgical margins experienced significantly lower rates of local recurrence and superior DFS and OS compared with those having close or positive margins. Advanced tumor stage and nodal involvement were more frequently associated with unfavorable margin status, indicating the increased technical challenges of achieving adequate surgical clearance in advanced disease. Furthermore, positive surgical margins, advanced tumor stage, nodal metastasis, poor histological differentiation, perineural invasion, and lymphovascular invasion were identified as significant predictors of adverse outcomes. These findings emphasize that achieving histologically negative surgical margins should remain a primary objective of surgical management to optimize local tumor control and improve long-term survival. Careful preoperative planning, meticulous surgical technique, and appropriate multidisciplinary management are essential to maximize oncological outcomes and reduce the risk of recurrence in patients with oral cancer.

References

- Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin.* 2018 Nov; 68(6):394-424. doi: 10.3322/caac.21492. Epub 2018 Sep 12. Erratum in: *CA Cancer J Clin.* 2020 Jul; 70(4):313. doi: 10.3322/caac.21609. PMID: 30207593.
- Hinni ML, Ferlito A, Brandwein-Gensler MS, Takes RP, Silver CE, Westra WH, Seethala RR, Rodrigo JP, Corry J, Bradford CR, Hunt JL, Stojan P, Devaney KO, Gnepp DR, Hartl DM, Kowalski LP, Rinaldo A, Barnes L. Surgical margins in head and neck cancer: a contemporary review. *Head Neck.* 2013 Sep; 35(9):1362-70. doi: 10.1002/hed.23110. Epub 2012 Sep 3. PMID: 22941934.
- Woolgar JA. Histopathological prognosticators in oral and oropharyngeal squamous cell carcinoma. *Oral Oncol.* 2006 Mar; 42(3):229-39. doi: 10.1016/j.oraloncology.2005.05.008. Epub 2005 Sep 16. PMID: 16150633.
- Sutton DN, Brown JS, Rogers SN, Vaughan ED, Woolgar JA. The prognostic implications of the surgical margin in oral squamous cell carcinoma. *Int J Oral Maxillofac Surg.* 2003 Feb;32(1):30-4. doi: 10.1054/ijom.2002.0313. PMID: 12653229.
- Smits RW, Koljenović S, Hardillo JA, Ten Hove I, Meeuwis CA, Sewnaik A, Dronkers EA, Bakker Schut TC, Langeveld TP, Molenaar J, Hegt VN, Puppels GJ, Baatenburg de Jong RJ. Resection margins in oral

-
- cancer surgery: Room for improvement. *Head Neck*. 2016 Apr;38 Suppl 1:E2197-203. doi: 10.1002/hed.24075. Epub 2015 Jun 15. PMID: 25899524.
- Ch'ng S, Corbett-Burns S, Stanton N, Gao K, Shannon K, Clifford A, Gupta R, Clark JR. Close margin alone does not warrant postoperative adjuvant radiotherapy in oral squamous cell carcinoma. *Cancer*. 2013 Jul 1; 119(13):2427-37. doi: 10.1002/cncr.28081. Epub 2013 Apr 10. PMID: 23576156.
- Meier JD, Oliver DA, Varvares MA. Surgical margin determination in head and neck oncology: current clinical practice. The results of an International American Head and Neck Society Member Survey. *Head Neck*. 2005 Nov; 27(11):952-8. doi: 10.1002/hed.20269. PMID: 16127669.
- Brandwein-Gensler M, Smith RV, Wang B, Penner C, Theilken A, Broughel D, Schiff B, Owen RP, Smith J, Sarta C, Hebert T, Nason R, Ramer M, DeLacure M, Hirsch D, Myssiorek D, Heller K, Prystowsky M, Schlecht NF, Negassa A. Validation of the histologic risk model in a new cohort of patients with head and neck squamous cell carcinoma. *Am J Surg Pathol*. 2010 May; 34(5):676-88. doi: 10.1097/PAS.0b013e3181d95c37. PMID: 20414102.
- Loree TR, Strong EW. Significance of positive margins in oral cavity squamous carcinoma. *Am J Surg*. 1990 Oct; 160(4):410-4. doi: 10.1016/s0002-9610(05)80555-0. PMID: 2221245.
- Binahmed A, Nason RW, Abdoh AA. The clinical significance of the positive surgical margin in oral cancer. *Oral Oncol*. 2007 Sep; 43(8):780-4. doi: 10.1016/j.oraloncology.2006.10.001. Epub 2006 Dec 14. PMID: 17174145.
- McMahon J, O'Brien CJ, Pathak I, Hamill R, McNeil E, Hammersley N, Gardiner S, Junor E. Influence of condition of surgical margins on local recurrence and disease-specific survival in oral and oropharyngeal cancer. *Br J Oral Maxillofac Surg*. 2003 Aug; 41(4):224-31. doi: 10.1016/s0266-4356(03)00119-0. PMID: 12946663.
- Liao CT, Chang JT, Wang HM, Ng SH, Hsueh C, Lee LY, Lin CH, Chen IH, Huang SF, Cheng AJ, Yen TC. Analysis of risk factors of predictive local tumor control in oral cavity cancer. *Ann Surg Oncol*. 2008 Mar; 15(3):915-22. doi: 10.1245/s10434-007-9761-5. Epub 2007 Dec 29. PMID: 18165878.
- Solomon J, Hinthner A, Matthews TW, Nakoneshny SC, Hart R, Dort JC, Chandarana SP. The impact of close surgical margins on recurrence in oral squamous cell carcinoma. *J Otolaryngol Head Neck Surg*. 2021 Feb 12; 50(1):9. doi: 10.1186/s40463-020-00483-w. PMID: 33579388; PMCID: PMC7881652.
- Brown JS, Lowe D, Kalavrezos N, et al. Patterns of invasion and routes of tumor entry into the mandible by oral squamous cell carcinoma. *Head & Neck*. 2002 Apr; 24(4):370-383. DOI: 10.1002/hed.10062. PMID: 11933179.
- Almangush A, Heikkinen I, Mäkitie AA, Coletta RD, Läärä E, Leivo I, Salo T. Prognostic biomarkers for oral tongue squamous cell carcinoma: a systematic review and meta-analysis. *Br J Cancer*. 2017 Sep 5; 117(6):856-866. doi: 10.1038/bjc.2017.244. Epub 2017 Jul 27. PMID: 28751758; PMCID: PMC5589992.
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