Received: 13 April 2023 | Accepted: 13 May 2023

DOI: 10.1111/jop.13454

ORIGINAL ARTICLE

Journal of Oral Pathology & Medicine WILEY

Predicting oral cancer survival—Development and validation of an Asia-Pacific nomogram

Weilan Wang[1] | Qingpeng Zhang[1] | Peter Thomson[2] | Dileep Sharma[3] | Poornima Ramamurthy[2] | Siu-Wai Choi[4]

[1]School of Data Science, The City University of Hong Kong, Hong Kong, China

[2]College of Medicine and Dentistry, James Cook University, Cairns, Queensland, Australia

[3]Oral Health, School of Health Sciences, University of Newcastle, Callaghan, New South Wales, Australia

[4]Department of Orthopaedics and Traumatology, University of Hong Kong, Hong Kong, China

Correspondence
Peter Thomson, College of Medicine and Dentistry, James Cook University, Cairns, QLD, Australia.
Email: peter.thomson1@jcu.edu.au

Abstract

Background: Nomograms are graphical calculating devices that predict response to treatment during cancer management. Oral squamous cell carcinoma (OSCC) is a lethal and deforming disease of rising incidence and global significance. The aim of this study was to develop a nomogram to predict individualized OSCC survival using a population-based dataset obtained from Queensland, Australia and externally validated using a cohort of OSCC patients treated in Hong Kong.

Methods: Clinico-pathological data for newly diagnosed OSCC patients, including age, sex, tumour site and grading, were accessed retrospectively from the Queensland Cancer Registry (QCR) in Australia and the Clinical Data Analysis and Reporting System (CDARS) in Hong Kong. Multivariate Cox proportional hazard regression was used to construct overall survival (OS) and cancer-specific survival (CSS) prediction models. Nomograms were internally validated using 10-fold cross validation, and externally validated against the Hong Kong dataset.

Results: Data from 9885 OSCC patients in Queensland and 465 patients from Hong Kong were analysed. All clinico-pathological variables significantly influenced survival outcomes. Nomogram calibration curves demonstrated excellent agreement between predicted and actual probability for Queensland patients. External validation in the Hong Kong population demonstrated slightly poorer nomogram performance, but predictive power remained strong.

Conclusion: Based upon readily available data documenting patient demographic and clinico-pathological variables, predictive nomograms offer pragmatic aid to clinicians in individualized treatment planning and prognosis assessment in contemporary OSCC management.

KEYWORDS
nomogram, oral squamous cell carcinoma, prediction, survival

1 | INTRODUCTION

Oral squamous cell carcinoma (OSCC) remains a lethal and deforming disease of rising incidence and growing global significance. We have recently documented a concerning rise in new case presentation within the populations of both Hong Kong and Australia.[1,2] Despite advances in diagnosis and management, and improved quality of life outcomes following contemporary treatment interventions, around 50% of patients still die from uncontrolled loco-regional disease or the development of widespread, blood-borne metastases. Our ability to accurately predict clinical outcomes and survival for newly presenting patients remains frustratingly elusive in clinical practice.[3–5]

Nomograms are graphical calculators that aid clinicians with limited statistical acumen to assess pre-prepared two-dimensional diagrammatical figures to calculate outcome predictions based upon risk factor analysis. Consisting of a set of scales, and constructed using pertinent clinico-pathological variables, the 'unknown' outcome variable is determined by plotting the point of intersection of an index line drawn across the scales. Nomograms have been trialled to aid outcome prediction for several cancers including lung, prostate, breast, colon, bladder and renal.[6–10]

We recently piloted the use of nomogram prediction to assist in the diagnosis and management of precursor potentially malignant oral lesions and consider that nomograms may have a similar, pragmatic potential to predict the prognosis of newly presenting, invasive OSCC.[10]

The aim of this study, therefore, was to utilise population-based retrospective, clinico-pathological data from a cohort of Australian OSCC patients with known clinical outcomes to develop a predictive nomogram for oral cancer prediction and then to externally validate the nomogram using data from OSCC patients treated in Hong Kong.

2 | METHODS

2.1 | Study populations and data extraction

In Australia, the Queensland Cancer Registry (QCR) was accessed for the period 1982 (when data were first compiled) to 2018 (most recent available data). Utilising the International Classification of Diseases, 10th Revision (ICD-10), primary tumours confirmed histopathologically as OSCC in patients aged 18 years and older and arising at labial commissure, floor of mouth, cheek and vestibule, tongue, retromolar, mouth (unspecified), gingiva, tonsil, palate, oropharynx and ill-defined lip, oral cavity and pharynx sites were identified. Clinico-pathological data including tumour grading, patient age at diagnosis, sex and mortality outcomes (death related to cancer or non-cancer death) were collated.

In Hong Kong, the Clinical Data Analysis and Reporting System (CDARS), a computerised database of patient records managed and maintained by the Hong Kong Hospital Authority, was accessed to determine similar details for OSCC patients diagnosed and treated at the Queen Mary Hospital in Hong Kong between 1st October 2000 and 1st October 2019.

2.2 | Statistical methods

Continuous variables are presented as mean and standard deviations (SD), whilst categorical variables are listed as numbers and percentages. Patient follow-up was defined as the period from date of diagnosis to study census date or date of death (as appropriate), with survival measured as the time from diagnosis to death. Cox proportional hazard regression was used to analyse the impact of each clinico-pathological variable on overall survival (OS) and cancer-specific survival (CSS), and included age at diagnosis, sex, primary tumour site and tumour grading. OS was defined as time from OSCC diagnosis until death caused by anything other than malignant disease, whilst CSS was time from diagnosis until death due to malignancy.

Nomograms for OS and CSS prediction were based upon the Cox proportional hazard regression model with best predictive power. Harrell's concordance index (C-index), quantifying the level of concordance between predicted probabilities and actual event outcomes, was used to assess predictive performance of the nomogram; C-index ranged from 0.5 (completely random prediction) to 1.0 (perfect prediction).[11] To further improve model performance, age at diagnosis (a continuous, but not normally distributed variable) was transformed using a restricted cubic spline, to adjust for possible non-linear relationships between age at diagnosis and disease prognosis; age categories were defined as under 40, 40–50, 51–60, 61–70, 71–80 and over 80. To assess performance, internal validation (using 10-fold cross validation) and nomogram calibration at four time points (1-year, 3-year, 5-year and 10-year survival) were carried out. Bootstrapping methodology was applied to the dataset, with 1000 resampling and replacement performed.

The C-index was then utilized to assess model performance using external data. The differences between the training dataset (collected from the Queensland population) and the external validation dataset (collected from Hong Kong patients) were investigated using Student's *t*-test for continuous variables and Chi-square test for categorical variables.

A scoring system was established from the nomogram to provide a simplified estimate of survival. The influence of each variable with the highest coefficient in the Cox proportional hazard regression was assigned 100 in the nomogram, whilst scoring of other features were calculated from their regression coefficients accordingly. Total points from the scoring formula were converted to mortality probabilities.[12]

All analyses were performed on R version 4.1.0, Cox regression was performed using the 'survival' package, with nomogram development, calibration and validation all performed using the 'rms' (regression modelling strategies) package. A two-sided p value <0.05 or a 95% confident interval (CI) of Hazard ratio (HR) not including 1 were considered statistically significant.[13]

TABLE 1 Comparison of patient demographics and tumour characterization between Australian and Hong Kong populations.

	Queensland patients ($n = 9885$)	Hong Kong patients ($n = 465$)	*p*-value
Mean patient age at diagnosis (years + SD)	61.9 (12.1)	61.4 (14.1)	0.444
No. of male patients	7070 (71.5%)	273 (58.7%)	***<0.001***
Mean patient follow-up (months + SD)	67.3 (74.8)	53.5 (54)	***<0.001***
All-cause mortality	5859 (52.27%)	182 (39.14%)	***<0.001***
Cancer-specific mortality	4381 (44.3%)	110 (23.7%)	***<0.001***
Tumour grading			***<0.001***
Well differentiated	1140 (11.53)	132 (28.4%)	
Moderately differentiated	4888 (49.5%)	248 (53.3%)	
Poorly differentiated	2359 (23.9%)	54 (11.6%)	
Undifferentiated	33 (0.3%)	0 (0)	
Not stated/unknown	1465 (14.8%)	31 (6.67%)	
Tumour site			***<0.001***
Labial commissure	17 (0.2%)	3 (0.6%)	
Floor of mouth	1173 (11.9%)	26 (5.6%)	
Cheek and vestibule	379 (3.8%)	144 (31.0%)	
Tongue	4076 (41.2%)	227 (48.8%)	
Retromolar region	353 (3.6%)	12 (2.6%)	
Mouth	102 (1.0%)	0 (0)	
Gingiva	547 (5.5%)	0 (0)	
Tonsil	2152 (21.8%)	36 (7.7%)	
Hard and soft palate	639 (6.5%)	16 (3.4%)	
Overlapping lesion lip, oral cavity, pharynx	54 (0.6%)	0 (0)	
Oropharynx	393 (4.0%)	1 (0.2%)	

Note: The *p* value <0.001, regarded as highly significant.

2.3 | ETHICAL APPROVAL

Approval to conduct this study in Australia was obtained from the James Cook University Human Research Ethics Committee (Reference number H8609) and the Public Health Act 2005 provided by Queensland Health. The QCR dataset was received as a de-identified, password protected spreadsheet and managed under the Australian Code for the Responsible Conduct of Research.

In Hong Kong, ethical approval to collect data was granted by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (Reference Number UW-19-704).

3 | RESULTS

3.1 | Patient demographics, tumour characterization and Survival

In total, demographic and tumour data from 9885 OSCC patients in Queensland and 465 patients from Hong Kong were collated and are presented for comparative analysis in Table 1. There was no significant difference between patients' mean age at diagnosis but, although most patients were male in both Queensland and Hong Kong populations, an increased number of female patients were treated in Hong Kong. The mean follow-up period was longer for Queensland patients, and both all-cause and cancer-specific mortalities were noted to be higher in Australia compared to Hong Kong. Review of both tumour grading and site confirmed significant differences between the two populations, with an increased incidence of well differentiated tumours and a larger percentage of cheek and vestibule tumours seen in Hong Kong patients. Poorly differentiated tumours and tonsillar and floor of mouth sites were observed more commonly within the Queensland population.

Univariable and multivariable Cox proportional hazard regression analysis was carried out using data from the Queensland population and results presented in Table 2 for OS and Table 3 for CSS. Tonsil was used as the primary tumour site reference and well differentiated tumours as the grading reference for the analyses due to their better OS and CSS rates. Univariable regression showed that all input variables, except for sex, significantly affected both OS and CSS. In the multivariable Cox proportional hazard regression analyses, however, all variables impacted OS and CSS.

3.2 | Nomogram for survival probability prediction

The C-index of the OS Cox proportional hazard regression model was 0.6451 (95% CI: 0.6371, 0.6508), while that for CSS was 0.6309 (95%

TABLE 2 Clinico-pathological variables and overall survival (univariable and multivariable Cox analyses).

	Univariable Cox regression		Multivariable Cox regression	
Variable	**Hazard ratio (95% CI)**	***p*-value**	**Hazard ratio (95% CI)**	***p*-value**
Age at diagnosis	1.043 (1.041–1.046)	<0.001	1.045 (1.043–1.048)	<0.001
Male sex	1.018 (0.962–1.077)	0.5327	1.198 (1.130–1.269)	<0.001
Tumour grading		***<0.001***		***<0.001***
Well differentiated	1.000 (reference)	-	1.000 (reference)	-
Moderately differentiated	1.201 (1.102–1.310)	<0.001	1.288 (1.181–1.405)	<0.001
Poorly differentiated	1.141 (1.037–1.256)	0.007	1.353 (1.227–1.492)	<0.001
Undifferentiated	1.155 (0.762–1.752)	0.497	1.611 (1.061–2.446)	0.025
Not stated/Unknown	1.420 (1.279–1.575)	<0.001	1.487 (1.339–1.651)	<0.001
Tumour site		***<0.001***		***<0.001***
Tonsil	1.000 (reference)	-	1.000 (reference)	-
Gingiva	1.349 (1.190–1.529)	<0.001	1.066 (0.937–1.212)	0.333
Labial commissure	1.223 (0.692–2.161)	0.489	1.110 (0.628–1.964)	0.719
Tongue	1.224 (1.136–1.319)	<0.001	1.145 (1.061–1.235)	<0.001
Cheek and vestibule	1.535 (1.336–1.764)	<0.001	1.150 (0.997–1.327)	0.055
Floor of mouth	1.390 (1.267–1.525)	<0.001	1.315 (1.197–1.445)	<0.001
Retromolar region	1.610 (1.399–1.852)	<0.001	1.404 (1.219–1.617)	<0.001
Overlapping lesion lip, oral cavity, pharynx	1.726 (1.226–2.430)	0.002	1.420 (1.009–2.000)	0.044
Mouth	1.888 (1.505–2.368)	<0.001	1.464 (1.165–1.839)	0.001
Hard and soft palate	1.820 (1.633–2.027)	<0.001	1.609 (1.442–1.796)	<0.001
Oropharynx	2.530 (2.219–2.885)	<0.001	2.329 (2.042–2.657)	<0.0001

Note: The *p* value <0.001, regarded as highly significant.

TABLE 3 Clinico-pathological variables and cancer-specific survival (univariable and multivariable analyses).

	Univariable Cox regression		Multivariable Cox regression	
Variable	**Hazard ratio (95% CI)**	***p*-value**	**Hazard ratio (95% CI)**	***p*-value**
Age at diagnosis	1.033 (1.030–1.035)	<0.001	1.034 (1.032–1.037)	<0.001
Male sex	1.058 (0.991–1.130)	0.092	1.182 (1.105–1.265)	<0.001
Tumour grading		<0.001		<0.001
Well differentiated	1.000 (reference)	-	1.000 (reference)	-
Moderately differentiated	1.321 (1.190–1.466)	<0.001	1.385 (1.247–1.539)	<0.001
Poorly differentiated	1.336 (1.192–1.497)	<0.001	1.523 (1.356–1.711)	<0.001
Undifferentiated	1.501 (0.948–2.378)	0.084	1.925 (1.214–3.053)	0.005
Not stated/unknown	1.549 (1.368–1.754)	<0.001	1.594 (1.406–1.807)	<0.001
Tumour site		<0.001		<0.001
Tonsil	1.000 (reference)	-	1.000 (reference)	-
Gingiva	1.246 (1.076–1.444)	0.003	1.076 (0.926–1.251)	0.340
Labial commissure	1.144 (0.570–2.296)	0.706	1.093 (0.544–2.195)	0.804
Tongue	1.211 (1.113–1.319)	<0.001	1.183 (1.084–1.290)	<0.001
Cheek and vestibule	1.375 (1.165–1.624)	<0.001	1.150 (0.970–1.365)	0.108
Floor of mouth	1.336 (1.200–1.487)	<0.001	1.312 (1.176–1.463)	<0.001
Retromolar region	1.551 (1.320–1.823)	<0.001	1.422 (1.209–1.673)	<0.001
Overlapping lesion lip, oral cavity, pharynx	1.635 (1.106–2.418)	0.014	1.405 (0.950–2.077)	0.089
Mouth	1.759 (1.344–2.302)	<0.001	1.475 (1.125–1.934)	0.005
Hard and soft palate	1.700 (1.499–1.927)	<0.001	1.582 (1.393–1.797)	<0.001
Oropharynx	2.681 (2.321–3.097)	<0.001	2.506 (2.168–2.896)	<0.001

TABLE 4 The C-indices (95% CIs) of Cox regression models using different transformation methods of age at diagnosis.

	No transformation	Restricted cubic spline	Grouping
Overall Survival	0.6451 (0.6371, 0.6531)	0.6451 (0.6371, 0.6531)	0.6427 (0.6344, 0.6504)
Cancer-specific survival	0.6309 (0.6219, 0.6399)	0.6309 (0.6218, 0.6400)	0.6293 (0.6202, 0.6384)

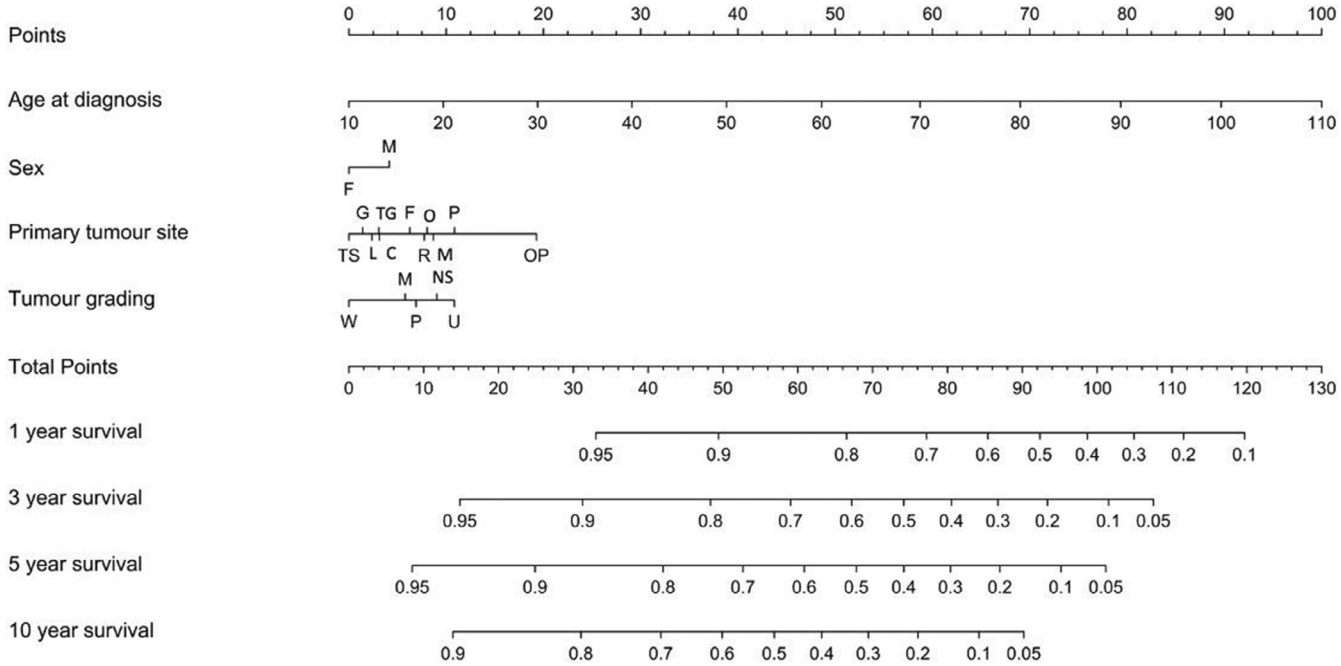

FIGURE 1 Nomogram to predict overall survival probability. *Sex*: F, female; M, male. *Tumour site*: TS, tonsil; G, gingiva; L, labial commissure; C, cheek and vestibule; F, floor of mouth; R, retromolar region; O, overlapping lesion of lip, oral cavity, pharynx; M, mouth; P, hard and soft palate; OP, oropharynx. *Tumour grading*: W, well differentiated; M, moderately differentiated; P, poorly differentiated; U, undifferentiated; NS, not stated/unknown.

CI: 0.6219, 0.6399). To further assess the association between age at diagnosis and probability of survival, the restricted cubic spline of age at diagnosis and age categorization were used in the regression model to replace exact age, but no significant improvement in C-index was seen (Table 4), suggesting the association between age at diagnosis and survival approaches a linear relationship. For ease of incorporation into the clinical practice setting, age at diagnosis without modification was used to plot the nomogram.

Nomograms to predict 1-, 3-, 5- and 10-year overall and cancer-free survival probabilities were established using data collected from Queensland (Figures 1 and 2). The nomograms map predicted survival probabilities into points on a scale from 0 to 100, with the total points accumulated by the various factors corresponding to the predicted survival probability for a patient. For example, when looking at the nomogram for overall survival (Figure 1), if the patient was 40 years old at the age of diagnosis, that corresponds to 30 points, and the patient is male (4 points), primary tumour site oropharynx (19 points), tumour graded as undifferentiated (11 points), making a total of 64 points which translates to a 1-year survival probability of around 0.82, or 82%, around 65% survival at 3 years, 55% survival at 5 years and 45% survival at 10 years.

The nomogram can be simplified using the following formulas:

$$\begin{aligned}&\textit{Overall mortality score}\\&=(Age-10)+4.1*Male+(5.8*M+6.9*P+9.0*NS\\&\quad+10.8*U)differentiated+(1.4*G+2.4*L+3.1*TG+3.2*C\\&\quad+6.2*F+7.7*R+7.9*O+8.7*M+10.8*P+19.2*OR)site\end{aligned}$$

$$\begin{aligned}&\textit{Cancer specific survival score}\\&=(Age-10)+4.9*Male+(9.6*M+12.4*P+13.7*NS\\&\quad+19.3*U)differentiated+(2.2*G+2.6*L+4.9*TG+4.1*C\\&\quad+8.0*F+10.4*R+10.0*O+11.5*M+13.5*P+27.1*OP)site\end{aligned}$$

An OS score larger than 70 is associated with high mortality risk, with less than 80% of survival at one-year and less than 50% chance of survival at 5-years. A CSS score larger than 80 is associated with a less than 80% chance of survival at 1-year and around a 50% chance of survival at 5-years.

The C-indexes of the 10-fold cross validation of the OS and CSS were 0.6437 and 0.6289, respectively. Calibration graphs of observed

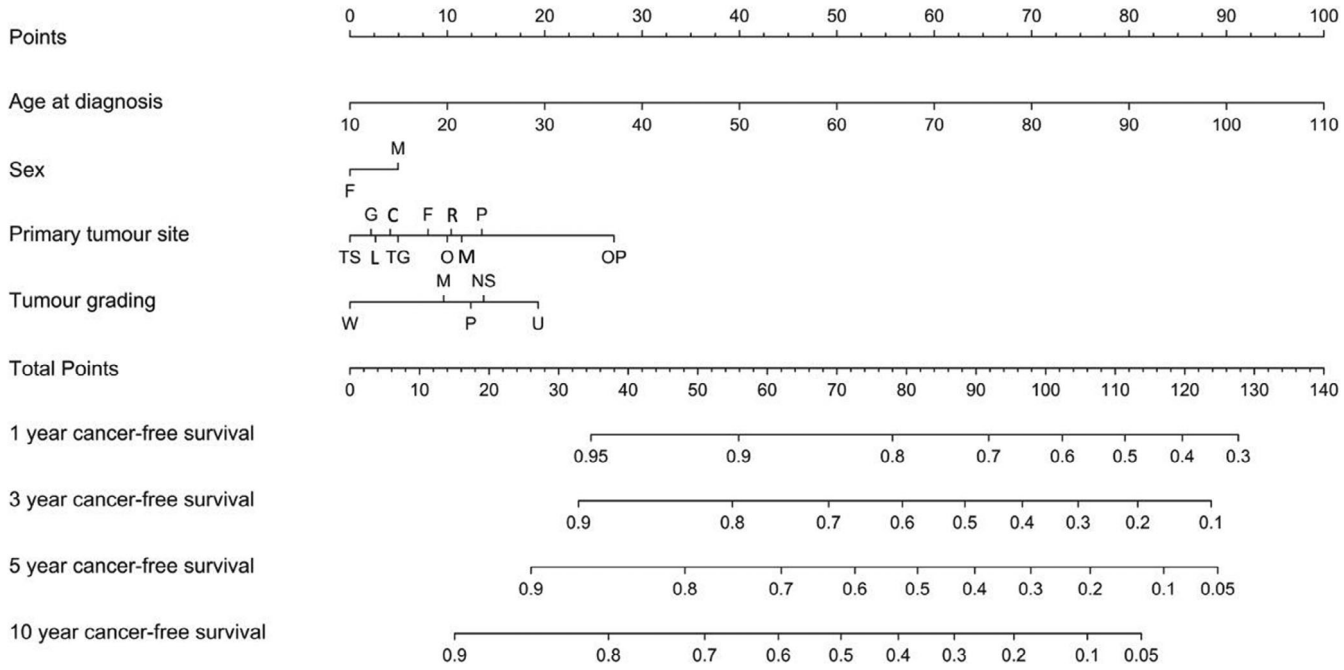

FIGURE 2 Nomogram to predict cancer-specific survival probability. *Sex*: F, female; M, male. *Tumour site*: TS, tonsil; G, gingiva; L, labial commissure; C, Cheek and vestibule; F, floor of mouth; R, retromolar region; O, overlapping lesion of lip, oral cavity, pharynx; M, mouth; P, hard and soft palate; OP, oropharynx. *Tumour grading*: W, well differentiated; M, moderately differentiated; P, poorly differentiated; U, undifferentiated; NS, not stated/unknown.

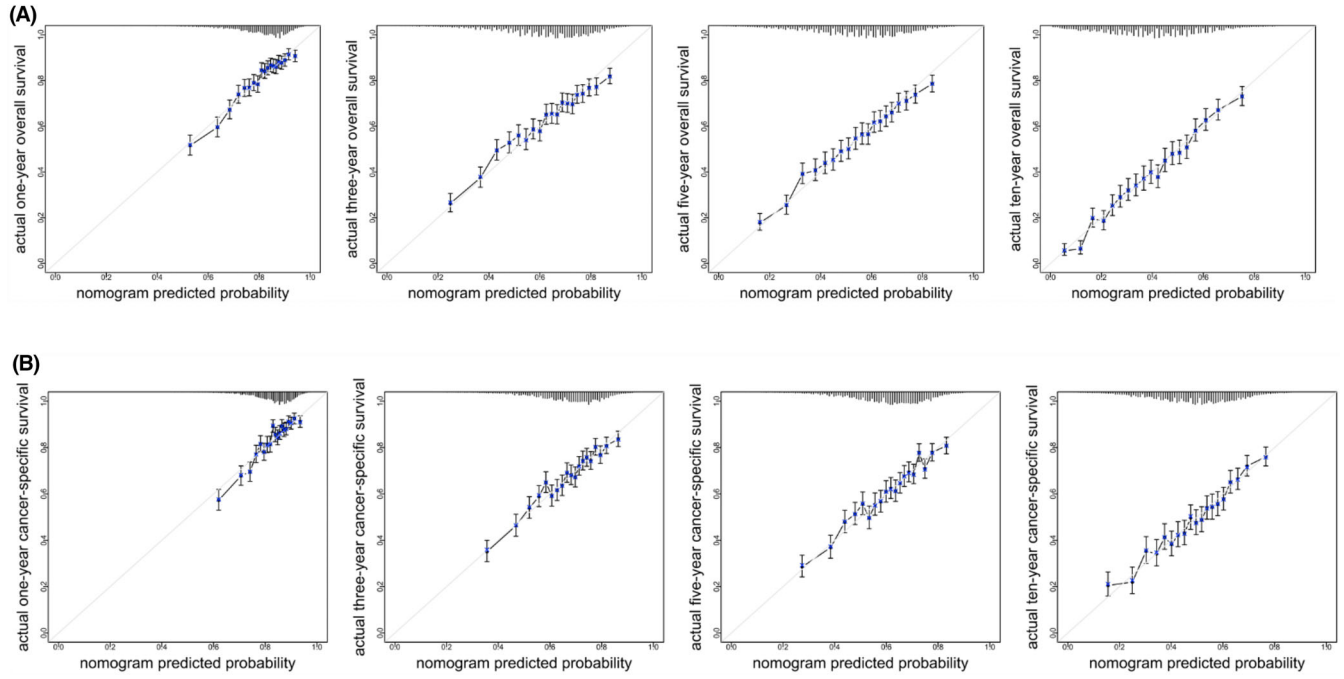

FIGURE 3 Calibration of Overall Survival (A) and Cancer-Specific Survival (B) at 1-, 3-, 5 and 10-years.

and predicted OS and CSS at time points 1, 3, 5 and 10 years are shown in Figure 3. The grey, 45-degree lines represent a perfect match of predicted and actual survival probability, while the black lines illustrate the actual relationships between predicted and actual survival probability together with 95% confidence intervals, confirming good fit.

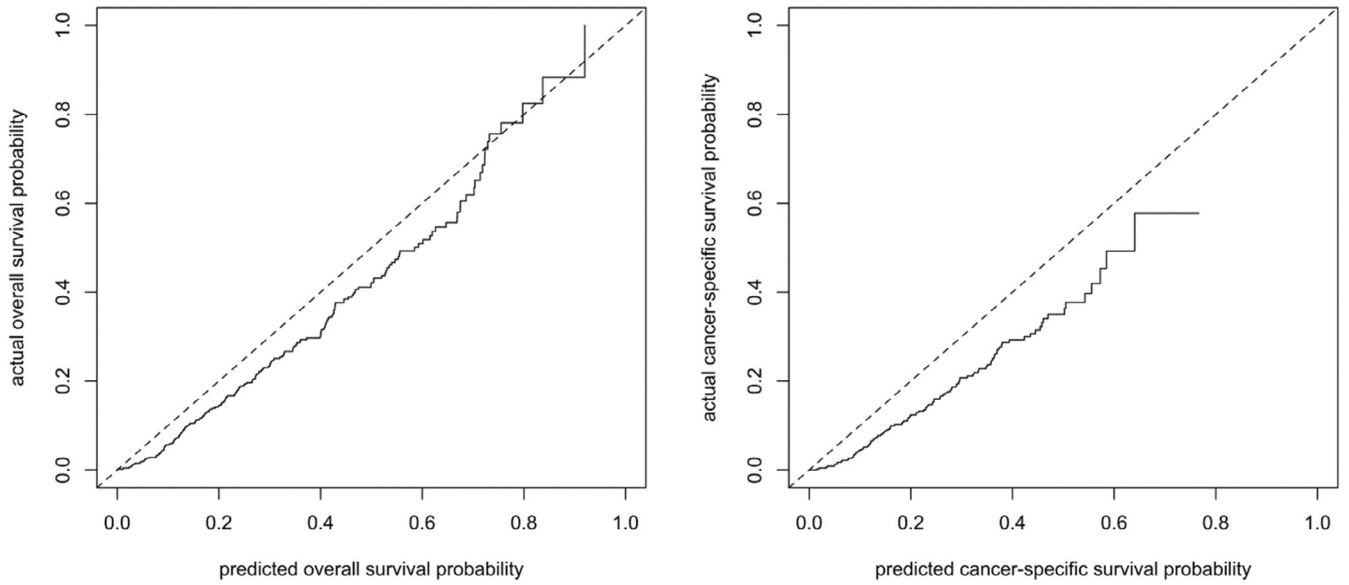

FIGURE 4 External Validation of Overall Survival and Cancer-Specific Survival.

3.3 | External validation of the nomograms

External validation using data from Hong Kong patients confirmed C-indices for OS and CSS of 0.6250 and 0.5687, respectively. OS and CSS probability nomogram calibration plots are shown in Figure 4, with the calibration curves demonstrating how far nomogram predicted probabilities are from actual outcomes. Actual survival in Hong Kong is generally lower than nomogram predicted survival probabilities, especially for CSS.

4 | DISCUSSION

4.1 | Clinical application of the nomogram

As practical statistical instruments, nomograms have considerable potential to analyse and graphically present multiple demographics and clinico-pathological variables facilitating individualized predictive outcome assessment for patients. In this study, a nomogram was developed to predict the probability of OS and CSS in a cohort of Queensland OSCC patients presenting over a 36-year period. The large, 9885 patient cohort in this study is advantageous in helping to reduce potential biases inherent in smaller study samples. In addition, the variables assessed, patient age, sex, primary tumour site and tumour grading, are readily available for most patients at the time of diagnosis and are considered reliable predictors of outcome, allowing the nomogram to give an immediate insight into patient prognosis and facilitate a more personalized approach to clinical management.[14]

4.2 | Survival Prediction

Univariable and multivariable Cox proportional regression confirmed that most clinico-pathological variables examined in this study influenced both OS and CSS; Tables 2 and 3. In terms of sex, whilst being male did not significantly influence survival in univariable analyses this was likely a 'suppressor' effect due to the older age of females at diagnosis and resultant shorter survival times.[15] In multivariable analysis, for patients of the same age, males displayed a higher hazard ratio for OS and CSS. Using well differentiated tumours as the reference, poorer survival was confirmed for other all tumour grades including those for which detailed grading was unavailable. Site-specific differences were also noted, with tumours arising in the oropharynx exhibiting poorest OS and CSS.

As illustrated by the calibration plots in Figure 3, predictive accuracy of the nomogram for 1-, 3-, 5- and 10-year OS and CSS in the Queensland population was excellent.

4.3 | External Validation

The nomogram was externally validated using independent data from Hong Kong. Whilst significant demographic and clinico-pathological differences were seen in this population compared to the Australian cohort, this is probably to be expected due to racial and geographic variation. Uncertainties in a predictive instrument increase for patients who exhibit dissimilar characteristics to those used in model generation. It is thus unsurprising that nomogram performance was slightly poorer for the Hong Kong population, which showed lower C-indices and less calibration curve fit for both OS and CSS analyses. Nonetheless, a reliable reference of survival estimation for OSCC patients was shown in a population other than that in which the nomogram was established.[14,16–18]

4.4 | Study limitations

The use of retrospective data during nomogram development does risk the introduction of study bias, due to varying approaches to

patient management or treatment decision making by different clinicians over time. The potential for missing or incomplete data to restrict analysis may also be relevant. As shown in Table 1, details of tumour grading, a fundamental oncological characteristic, was not available for 14.8% of Queensland and 6.67% of Hong Kong patients. Although the nomogram demonstrated reliability in survival prediction at the time of patient diagnosis, increased accuracy and better applicability throughout the treatment regime may be facilitated by including patients' socio-economic status, risk factor behaviour, human papillomavirus activity, tumour staging and a detailed review of applied therapeutic modalities.[14,19–22]

4.5 | Conclusions

The nomogram is a practical diagrammatic instrument allowing clinicians to objectively predict outcome and assist personalized clinical decision-making for individual patients. A prediction nomogram for OSCC management was developed using readily available clinicopathological data from a large population of Queensland patients, demonstrating good calibration for OS and CSS prediction. The model was externally validated using a smaller cohort of Hong Kong patients, although appeared to perform less well in this population who exhibited dissimilar characteristics. The authors are developing a web-based version of the nomogram to encourage access for more widespread application and testing.

AUTHOR CONTRIBUTIONS

Conceptualization: Weilan Wang, Siu-Wai Choi. *Data curation*: Peter Thomson. *Investigation and resources*: Siu-Wai Choi, Peter Thomson, D Sharma and Poornima Ramamurthy. *Methodology*: Weilan Wang and Qingpeng Zhang. *Project administration*: Siu-Wai Choi. *Supervision*: Siu-Wai Choi. *Writing*: Weilan Wang, Poornima Ramamurthy, Peter Thomson and Siu-Wai Choi.

ACKNOWLEDGEMENTS

This study was carried out as a collaborative project between members of the Asia-Pacific Research in Oral Oncology Network (APRON), whose focus is to improve knowledge and understanding of the aetiology, population-based risk, clinical presentation, interventional management and prognosis of oral cancer. The authors also appreciate the generous help from Mr. Yitao Lu in data analysis. Open access publishing facilitated by James Cook University, as part of the Wiley - James Cook University agreement via the Council of Australian University Librarians.

FUNDING INFORMATION

No funding was received.

CONFLICT OF INTEREST STATEMENT

The authors have no conflict of interest to declare.

PEER REVIEW

The peer review history for this article is available at https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/jop.13454.

DATA AVAILABILITY STATEMENT

The datasets generated and/or analysed during the current study are not publicly available due to confidentiality issues but are available from the corresponding authors on reasonable request.

ORCID

Peter Thomson https://orcid.org/0000-0002-2007-7975
Siu-Wai Choi https://orcid.org/0000-0002-8189-790X

REFERENCES

1. Choi S-W, Thomson P. Increasing incidence of oral cancer in Hong Kong—who, where…and why? *J Oral Pathol Med*. 2019;48:483-490.
2. Sun A, Sharma D, Choi S-W, Ramamurthy P, Thomson P. Oral cancer in Australia—rising incidence and worsening mortality. *J Oral Pathol Med*. 2023;52:328-334. doi:10.1111/jop.13421
3. Chamoli A, Gosavi AS, Shirwadkar UP, et al. Overview of oral cavity squamous cell carcinoma: risk factors, mechanisms, and diagnostics. *Oral Oncol*. 2021;121:105451.
4. Thomson P. *Oral Cancer: From Prevention to Intervention*. Cambridge Scholars Publishing; 2019.
5. Adeoye J, Hui L, Koohi-Moghadam M, Tan JY, Choi S-W, Thomson PJ. Comparison of time-to-event machine learning models in predicting oral cavity cancer prognosis. *Int J Med Inform*. 2022;157:104635.
6. Balachandran VP, Gonen M, Smith JJ, DeMatteo RP. Nomograms in oncology – more than meets the eye. *Lancet Oncol*. 2015;16:e173-e180.
7. Sjoquist KM, Renfro LA, Simes RJ, et al. Personalizing survival predictions in advanced colorectal cancer: the ARCAD nomogram project. *J Natl Cancer Inst*. 2018;110:638-648.
8. Gittleman H, Sloan AE, Barnholtz-Sloan JS. An independently validated survival nomogram for lower-grade glioma. *Neuro Oncol*. 2020;22:665-674.
9. Cao X, Zheng Y-Z, Liao H-Y, et al. A clinical nomogram and heat map for assessing survival in patients with stage I non-small cell lung cancer after complete resection. *Ther Adv Med Oncol*. 2020;12:1758835920970063.
10. Goodson ML, Smith DR, Thomson PJ. The "Newcastle Nomogram"-statistical modelling predicts malignant transformation in potentially malignant disorders. *J Oral Pathol Med*. 2019;48:662-668.
11. Gönen M, Heller G. Concordance probability and discriminatory power in proportional hazards regression. *Biometrika*. 2005;92:965-970.
12. Iasonos A, Schrag D, Raj GV, Panageas KS. How to build and interpret a nomogram for cancer prognosis. *J Clin Oncol*. 2008;26:1364-1370.
13. R Core Team. R: A language and environment for statistical computing. 2021 https://www.R-project.org/
14. Montero PH, Yu C, Palmer FL, et al. Nomograms for preoperative prediction of prognosis in patients with oral cavity squamous cell carcinoma. *Cancer*. 2014;120:214-221.
15. MacKinnon DP, Krull JL, Lockwood CM. Equivalence of the mediation, confounding and suppression effect. *Prev Sci*. 2000;1:173-181.
16. Yu AJ, Choi JS, Swanson MS, et al. Association of race/ethnicity, stage, and survival in oral cavity squamous cell carcinoma: a SEER Study. *OTO Open*. 2019;3:2473974X19891126.
17. Zhang Y, Cui C, Wang Y, Wang L. Effects of stigma, hope and social support on quality of life among Chinese patients diagnosed with oral

cancer: a cross-sectional study. *Health Qual Life Outcomes*. 2020; 18:112.

18. Adeoye J, Thomson P, Choi SW. Prognostic significance of multi-positive invasive histopathology in oral cancer. *J Oral Pathol Med*. 2020;49:1004-1010.
19. Lafaurie GI, Perdomo SJ, Buenahora MR, Amaya S, Díaz-Báez D. Human papilloma virus: an etiological and prognostic factor for oral cancer? *J Investig Clin Dent*. 2018;9:e12313.
20. Zanoni DK, Montero PH, Migliacci JC, et al. Survival outcomes after treatment of cancer of the oral cavity (1985–2015). *Oral Oncol*. 2019; 90:115-121.
21. Almangush A, Mäkitie AA, Triantafyllou A, et al. Staging and grading of oral squamous cell carcinoma: an update. *Oral Oncol*. 2020;107: 104799.
22. Wang W, Adeoye J, Thomson P, Choi SW. Statistical profiling of oral cancer and the prediction of outcome. *J Oral Pathol Med*. 2021;50: 39-46.

How to cite this article: Wang W, Zhang Q, Thomson P, Sharma D, Ramamurthy P, Choi S-W. Predicting oral cancer survival—Development and validation of an Asia-Pacific nomogram. *J Oral Pathol Med*. 2023;1-9. doi:10.1111/jop.13454