Received: 13 May 2021 | Revised: 15 July 2021 | Accepted: 22 July 2021

DOI: 10.1002/JPER.21-0296

JOURNAL OF Periodontology

ORIGINAL ARTICLE

# Prognostic performance of the 2017 World Workshop classification on staging and grading of periodontitis compared with the British Society of Periodontology's implementation

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## Abstract

**Background:** The British Society of Periodontology (BSP) implemented a simplified version of the 2017 World Workshop Classification (WWC) on staging and grading of periodontitis, for use in UK clinical practice. The aim of this study was to assess the long-term (>10 years) prognostic capability of BSP's implementation (BSP-i) compared with the 2017 WWC, using periodontal-related tooth loss (TLP) as a disease outcome.

**Methods:** Data on medical history, smoking status, and clinical periodontal parameters were retrieved from 270 patients who received non-surgical and surgical periodontal therapy from 1966 to 2007. Each patient received a baseline diagnosis according to the 2017 WWC and the BSP-i guidelines for implementation. Univariate multilevel Cox regression frailty models were performed to analyze the association between variables with TLP. A post-hoc comparison with Bonferroni correction was performed to analyze interclass comparisons. The prognostic performance of both systems was analyzed using Harrell C index.

**Results:** The prognostic performance of both systems was very similar (0.922 for the 2017 WWC and 0.925 for the BSP-i). The singular prognostic performance of BSP stage was slightly higher than that of 2017 WWC stage (0.9212 versus 0.9188), while the 2017 WWC grade showed a slightly better performance than BSP grade (0.9175 versus 0.9155). BSP-i's extent performed better than the 2017 WWC extent (0.9203 versus 0.9098); however, in the 2017 WWC extent, the class "localized" was associated with a better prognosis than "generalized."

**Conclusion:** The overall prognostic performance of the two systems was excellent, with both systems having a Harrell C index score of >0.92.

KEYWORDS
attachment loss, periodontitis, risk factor assessment, tooth loss, validation study

  

## 1 | INTRODUCTION

Periodontitis is a plaque-induced multifactorial disease that is chronic in nature. It is initiated by the emergence of a dysbiosis within the dental plaque biofilm[1] and ultimately bone and attachment loss (AL) results from a disproportionate host immune-inflammatory response to the dysbiosis.[2,3] The host response is determined by genetic, epigenetic, lifestyle, environmental and behavioral risk factors[4] which makes risk prediction for disease progression challenging. Like many other chronic diseases, there is no cure for periodontitis and supportive periodontal therapy (SPT), also known as "periodontal maintenance," is paramount to prevent future deterioration.[5] Periodontal therapy should not only involve eliminating and/or controlling the associated symptoms but also include controlling the predisposing and modifying factors (local and systemic risk factors) that impact disease progression.[6] For this reason, patient-risk assessment needs to be performed at multiple levels namely, the patient/systemic level, mouth level, tooth, and site level.[7]

The European Federation of Periodontology (EFP) and American Academy of Periodontology (AAP) jointly implemented the concept of risk assessment in the 2017 International Classification system for periodontal diseases.[8] The new classification system uses a protocol for disease staging and grading, which has long been used in the diagnosis and treatment of malignant tumors, where the stage is a measure of the size of the lesion (tumor) at the point of diagnosis and the grade measures rate of cancer progression, based upon histological and/or molecular features of the lesion.[9,10] The 2017 classification also includes an in-built prognostication system, reinforcing the significance of risk assessment in comprehensive patient evaluation, and provides the necessary framework for inclusion of biomarker-based diagnostics for enhanced prognostication and risk stratification when future validated biomarker panels become available.[11] This prognostic capability of staging and grading was validated in a recent study, associating increased class severity (higher stage or grade) with increased tooth loss due to periodontitis (TLP).[12]

In the United Kingdom (UK), the British Society of Periodontology (BSP) also convened an implementation group to develop guidance on how the new classification system could be simply implemented in clinical practice within the public "national health service" (NHS). The BSP adopted a reductionist approach, as they felt the proposed system needed to be simplified if it was to be adopted in the UK's general practice environment.[13] Additionally, for the classification to be accepted within the NHS system, it needed to integrate established screening tools in the UK like the "Basic Periodontal Examination" (BPE) and clinical periodontal parameters like probing depth (PD) and bleeding on probing (BOP). The BSP identified several challenges in implementing the 2017 classification in general dental practice and hence made minimal but key adaptations to the classification as described by Tonetti et al.[11,13] Staging was implemented using a singular factor, radiographic bone loss for determining severity (or AL where contemporary radiographs are not available), excluding all other complexity factors, and changing the Stage IV threshold to bone loss within the apical one-third of the root. For grade, changes were made to Grade B threshold, and systemic complexity factors were not considered within the grading approach but documented separately noting them as risk factors as a part of the "diagnostic statement"[13] (Table 1).

The BSP-i was rapidly integrated into national NHS policy and protocols[14,15]; however, to the best of our knowledge, there are currently no published studies that have evaluated the reliability of BSP-version of the 2017 classification of periodontitis. Hence, the aim of this study was to assess the long-term (>10 years) prognostic capability of the BSP's implementation compared with the original 2017 World Workshop Classification (WWC) on staging and grading of periodontitis, using TLP as a definite outcome.

## 2 | MATERIALS AND METHODS

This study was conducted in agreement with the 1975 Declaration of Helsinki (World Medical Association [WMA], 1975) as most recently revised in 2013 (WMA, 2013).[16] The study was approved by the University of Michigan Medical School Institutional Review Board (IRBMED) with study identifier HUM00157260/HUM00160933. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed during the preparation of the manuscript.[17]

### 2.1 | Study population

This study was conducted on a periodontitis patient population who received non-surgical and surgical periodontal therapy from January 1966 to January 2007 at the University of Michigan School of Dentistry. Physical and digital records of patients were screened and evaluated by three examiners (MQ, AR, and MS). The following eligibility criteria were established:

- Patients met the case definition of periodontitis as defined by Tonetti et al.[11]

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**TABLE 1** Comparison of the parameters used in the staging and grading of periodontitis by 2017 WWC (the 2017 World Workshop classification) and BSP-i (The British Society of Periodontology implementation of the 2017 World Workshop classification)

| | | | 2017 WWC | BSP-i |
|---|---|---|---|---|
| **Staging of Periodontitis** | **Stage I** | **CAL**[1] | 1-2 mm | <2 mm from CEJ[4] if only bite wings available |
| | | **RBL**[2] | <15% | <15% or < 2 mm [*] (see above) |
| | | **TLP**[3] | N/A | |
| | **Stage II** | **CAL** | 3-4 mm | |
| | | **RBL** | Coronal third of root | Coronal third of root |
| | | **TLP** | N/A | |
| | **Stage III** | **CAL** | ≥5 mm | |
| | | **RBL** | Mid third of root or beyond | Mid third of root |
| | | **TLP** | ≤4 teeth | |
| | | **Complexity factors** | Probing depth ≥6 mm<br>Vertical bone loss ≥3 mm<br>Furcation involvement Class II or III<br>Moderate ridge defect | |
| | **Stage IV** | **CAL** | ≥5 mm | |
| | | **RBL** | Mid third of root or beyond | Apical third of root |
| | | **TLP** | ≥5 teeth | |
| | | **Complexity factors** | Need for complex rehabilitation due to:<br>Masticatory dysfunction<br>Secondary occlusal trauma (tooth mobility degree ≥2)<br>Severe ridge defect<br>Bite collapse, drifting, flaring<br>Less than 20 remaining teeth (10 opposing pairs) | |
| **Extent of Periodontitis** | **Localized** | ≤30% of teeth are at the stage-defining severity level | | ≤30% of teeth involved |
| | **Generalized** | >30% of teeth are at the stage-defining severity level | | >30% of teeth involved |
| **Grading of Periodontitis** | **Grade A** | **Longitudinal CAL over 5 years** | Evidence of no loss | |
| | | **RBL/age** | <0.25 | <0.5 |
| | | **Case phenotype** | Heavy biofilm deposits with low levels of destruction | |
| | | **Smoking** | Non-smoker | |
| | | **Diabetes** | Normoglycemic/no diagnosis of diabetes | |
| | | **CRP**[5] | <1 mg/L | |
| | **Grade B** | **Longitudinal CAL over 5 years** | <2 mm | |
| | | **RBL/age** | 0.25 to 1.0 | 0.5 to 1.0 |
| | | **Case phenotype** | Destruction commensurate with biofilm deposits | |
| | | **Smoking** | Smoker < 10 cigarettes/day | |
| | | **Diabetes** | HbA1c < 7.0% in patients with diabetes | |
| | | **CRP** | 1 to 3 mg/L | |

(Continues)

TABLE 1 (Continued)

| | | 2017 WWC | BSP-i |
|---|---|---|---|
| **Grade C** | **Longitudinal CAL over 5 years** | ≥2 mm | |
| | **RBL/age** | >1.0 | >1.0 |
| | **Case phenotype** | Destruction exceeds expectation given biofilm deposits | |
| | **Smoking** | Smoker ≥10 cigarettes/day | |
| | **Diabetes** | HbA1c ≥7.0% in patients with diabetes | |
| | **CRP** | >3 mg/L | |

*1, Clinical attachment loss; 2, Radiographic bone loss; 3, Periodontal-related tooth loss; 4, Cemento-enamel junction; 5 , C-reactive protein.

- Patients had at least one session of scaling and root planing (diseased area with or without additional surgery if needed) and maintained for ≥10 years after active therapy at the University of Michigan School of Dentistry.
- Complete patient charts with full-mouth radiographic series of diagnostic quality (taken within ≤12 months from the baseline/initial periodontal examination).
- Complete medical history recorded at baseline periodontal examination.
- Patients received at least one visit of supportive periodontal therapy (SPT)/year throughout the entire follow-up period.
- Patients whose teeth have been extracted at the University of Michigan School of Dentistry.

Patients who did not meet the a priori set criteria were excluded from the study. Demographic patient information, periodontal status, total number of SPT visits/year and relevant medical history (smoking and diabetes mellitus) were collected. Tooth loss (TL) data were analyzed in two stages. First, the overall tooth loss (OTL) was calculated by deducting the number of natural teeth present at the last follow-up visit (T1) from the number present at baseline periodontal examination (T0). Second, the cause of extraction of each tooth was identified as determined by patients' charts and calculating the time the tooth stayed in function until extraction. The reason for tooth loss should have been stated in patients' notes at the time of extraction, and charts that did mention the cause of tooth loss were excluded from the analysis. Only teeth extracted due to periodontal reasons (TLP) were considered in the current analysis. Teeth that were extracted due to reasons other than TLP were censored in the survival analysis.

Percentage of radiographic bone loss (RBL, in %) was primarily measured from periapical radiographs.[18] Probing depths (PD) and AL were evaluated at six sites per tooth. Information about tooth mobility, drifting or flaring (tooth migration), bite collapse, parafunctional habits, chewing difficulties, masticatory dysfunction, and plaque accumulation were collected from patient records when available. The number of teeth lost that was attributable to periodontitis as defined by Sanz et al. (0, ≤4 or ≥5) were reported.[19]

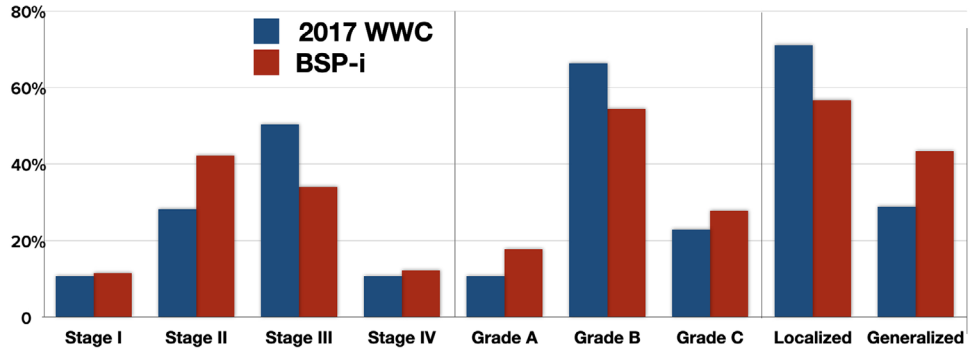
## 2.2 | Data collection and patient classification

Before classifying patients, the case definition for periodontitis as defined by the 2017 WWC[11] was confirmed. Then, each patient received a baseline diagnosis according to either the 2017 WWC[8] or BSP guidelines for implementation of the classification: for the 2017 WWC system, Stage: I, II, III, or IV; Grade A, B, or C were assigned to all patients by a single investigator (MS), after being calibrated by an expert author (HG). All teeth lost during active periodontal treatment such as teeth that were deemed hopeless at the patient screening were not considered when staging the patients and thus excluded from the study. The classification of staging and grading according to the BSP system was performed by two investigators (HD and MS). Table 1 shows a direct comparison of the parameters used in both classifications.

The 2017 WWC has clarified in a more recent publication that the extent of periodontitis involvement is to be considered localized if ≤30% of teeth are found to be at the stage-defining severity level. Whereas the extent would be generalized if >30% of teeth were at the stage-defining severity level.[19] All extent allocation in the present study was made based on this clarification.

## 2.3 | Statistical analysis

The following patient-level variables were included in the analysis: patient demographics, age, sex; stage, grade, and extent according to the 2017 WWC system; stage, grade,




| | Stage | | | | Grade | | | Extent | |
|---|---|---|---|---|---|---|---|---|---|
| | I | II | III | IV | A | B | C | Loc | Gen |
| 2017 WWC | 29 (10.74%) | 76 (28.15%) | 136 (50.37%) | 29 (10.74%) | 29 (10.74%) | 179 (66.30%) | 62 (22.96%) | 192 (71.11%) | 78 (28.89%) |
| BSP-i | 31 (11.48%) | 114 (42.22%) | 92 (34.07%) | 33 (12.22%) | 48 (17.78%) | 147 (54.44%) | 75 (27.78%) | 117 (56.67%) | 153 (43.33%) |
| *p-value* | 0.839 | *0.002** | *0.0006** | 0.627 | *0.035** | *0.011** | 0.246 | *0.0016** | |

**FIGURE 1** A frequency analysis portraying the frequency of occurrence of each class of stage, grade, or extent in both the 2017 WWC and the BSP-i

and extent according to the BSP implementation system. In addition, the following tooth-level variables were included: time occurring from baseline to the last follow-up, status at the last follow-up (teeth present, teeth lost to periodontitis, teeth lost for reasons other than periodontitis). In addition, the number of SPT sessions undertaken by the patient during follow-up was extracted from records and included as a variable in this study. Univariate multilevel Cox regression frailty models were performed to analyze the association of variables with periodontitis-related tooth loss. Hence, the influence of confounding factors on the prognostic performance of variables from the classification systems, multilevel multivariable Cox regression frailty models (including age, sex, and number of maintenance sessions undertaken by the patients during follow-up as confounding factors), addressing the clustering of teeth within subjects, were built. A post-hoc comparison with Bonferroni test was performed to analyze interclass comparison after the Cox regression. The prognostic performance of both BSP and 2017 WWC variables was analyzed by calculating Harrell C index, Akaike, and Bayesian Information Criterion (AIC and BIC) from the multivariable multilevel models. An internal validation of the prognostic measurements calculated in the univariate analysis was also undertaken by means of k-fold cross-validation (cross-fold command in STATA).

## 3 | RESULTS

### 3.1 | Difference in parameters used in both classification systems

The difference in parameters used for determining either the stage or grade of periodontitis between the 2017 WWC and BSP-i are all shown in Table 1.

### 3.2 | Demographic data of the cohort and allocation according to the two classification systems

Sufficient information for a total of 270 patients fulfilled the eligibility criteria and as included in this analysis, making up a total of 6,833 teeth. The average age in the cohort was 42.9 ± 11.8 years, of these 143 (53.0%) were male and 127 (47.0%) were female. The total number of teeth lost due to periodontal disease (TLP) over the follow-up period was 318 teeth (4.6%). Patients were allocated into categories according to both 2017 WWC and BSP-i (Fig. 1). The BSP-i allocated significantly more patients in Stage II (42.2%) and also had more Grade B patients (66.3%). The most significant differences were found for extent, with BSP-i system classifying more patients (43.3%) as generalized.

**TABLE 2** Multilevel univariate and multivariate Cox regression frailty models for the two classification systems

| Variables | Multilevel Univariate Analysis | | Multilevel Multivariate Analysis | |
|---|---|---|---|---|
| | HR 95%(CI) | *P value* | HR 95%(CI) | *P value* |
| 2017 WWC Stage I (ref) | 1.00 | – | 1.00 | – |
| Stage II | 1.81 (0.74–4.44) | 0.196 | 2.43 (0.66–9.01) | 0.183 |
| Stage III | 3.41 (1.47–7.89) | *0.004** | 7.77 (2.28–26.54) | *0.001** |
| Stage IV | 9.41 (3.53–25.06) | *0.000** | 10.47 (2.58–42.5) | *0.001** |
| 2017 WWC Grade A (ref) | 1.00 | – | 1.00 | – |
| Grade B | 1.90 (0.84–4.29) | 0.120 | 1.24 (2.36–6.45) | 0.723 |
| Grade C | 117.46 (29.6–462) | *0.001** | 3.32 (0.90–12.2) | 0.070 |
| 2017 WWC Extent 1+ (ref) | 1.00 | – | 1.00 | – |
| Extent 2++ | 0.70 (0.50–0.99) | 0.045* | 0.71 (0.46–1.09) | 0.120 |
| BSP-i Stage I (ref) | 1.00 | – | 1.00 | – |
| Stage II | 2.88 (1.20–6.91) | *0.018** | 3.94 (1.07–14.48) | 0.039* |
| Stage III | 5.56 (2.32–13.36) | *0.000** | 8.33 (2.25–30.78) | *0.001** |
| Stage IV | 11.17 (4.21–29.67) | *0.000** | 16.58 (4.06–67.66) | *0.000** |
| BSP-i Grade A (ref) | 1.00 | – | 1.00 | – |
| Grade B | 3.35 (1.64–6.87) | *0.001** | 4.84 (1.75–13.37) | *0.002** |
| Grade C | 4.79 (2.22–10.33) | *0.000** | 9.49 (3.14–28.68) | *0.000** |
| BSP-i Extent 1 (ref) | 1.00 | – | 1.00 | |
| Extent 2 | 3.65 (2.29–5.80) | 0.000* | 3.84 (1.91–7.69) | *0.000** |

Multivariate models were built including variables of the classification systems in conjunction with other confounding factors (age, sex, and number of maintenance sessions).
*Statistically significant.
+Localized.
++Generalized.

The post-hoc inter-rater reliability for the BSP-i system was measured using kappa coefficient (K). The K-agreement result for the stage was 0.79; grade: 1.0; and extent: 0.57. Differences in allocation between the two systems were evident for both stage, grade, and extent. In particular, the BSP-i significantly allocated more patients in Stage II (114/220, 42.2%) and less in Stage III (92/220, 34.0%) compared with the 2017 WWC (28.2% and 50.3%). Difference in allocation between BSP-i and 2017 WWC were also evident for Grade A (10.7% versus 17.8%) and Grade B (66.3% versus 54.4%). Focusing on the extent of periodontitis, the BSP-i system classified more patients as generalized (43.3%) compared with the 2017 WWC system (28.9%).

## 3.3 | Prognostic analysis of variables according to BSP-i and WWC 2017 systems

The univariate survival analysis categories within 2017 WWC stage and grade were significantly correlated with TLP, while the extent did not (Table 2). Kaplan–Meier figures graphically showed the prognostic stratification at the univariate analysis (Fig. 2). After adjusting for the confounding effects of age, sex, and number of periodontal maintenance sessions, 2017 WWC Stage III and IV were correlated with a worse prognosis, a similar trend was observed for 2017 WWC Grade C ($P = 0.070$). 2017 WWC extent did not correlate with TLP even in the multivariate analysis. Focusing on the BSP-i system, all the analyzed variables (stage, grade, and extent) were significantly correlated with TLP both at univariate and multivariate analysis.

A direct comparison of the two systems was performed by analyzing the prognostic performance of the corresponding variables in the multivariate models. The general prognostic performance (including all variables together in the model) of the two systems was similar (0.922 for the 2017 WWC and 0.925 for BSP-i). Table 3 shows the impact of controlling each of the confounders on the prognostic performance. The singular prognostic performance of the BSP-i stage was slightly higher than that of 2017 WWC stage (0.9212 versus 0.9188), while the 2017 WWC grade showed a slightly better performance than the BSP-i grade (0.9175 versus 0.9155). Focusing on the extent of the disease the BSP-i extent performed better than the 2017 WWC extent (0.9203 versus 0.9098); however, it is important to note that in the 2017 WWC extent, the class "localized" was associated with a better prognosis than "generalized."

**TABLE 3** Comparison of model prognostic stratification performance for TLP using measurements of model fit (Akaike information criterion and Bayesian information criterion); and prognostic performance (Harrell C-index)

| Predictor | Prognostic performance from multilevel univariate Cox regression frailty models | | |
|---|---|---|---|
| | Harrell C-index | Akaike Information Criterion (AIC) | Bayesian Information Criterion (BIC) |
| Age | 0.567 | 5060 | 5067 |
| Sex | 0.513 | 5062 | 5067 |
| 2017 WWC_Stage | 0.640 | 5039 | 5059 |
| 2017 WWC_Grade | 0.608 | 5050 | 5064 |
| 2017 WWC _Extent | 0.520 | 5059 | 5066 |
| BSP-i_Stage | 0.659 | 5037 | 5057 |
| BSP-i_Grade | 0.597 | 5050 | 5063 |
| BSP-i_Extent | 0.617 | 5035 | 5042 |
| Maintenance Sessions | 0.910 | 3805 | 3812 |
| 2017 WWC (Stage + Grade + Extent)* | 0.680 | 5030 | 5070 |
| BSP-i (Stage + Grade + Extent)* | 0.691 | 5027 | 5068 |

Higher Harrell C-index and lower AIC and BIC indicate better prognostic performance. Also included are values which are controlled for the confounding effect of age, sex, and number of periodontal maintenance sessions.

*Multivariate analysis.

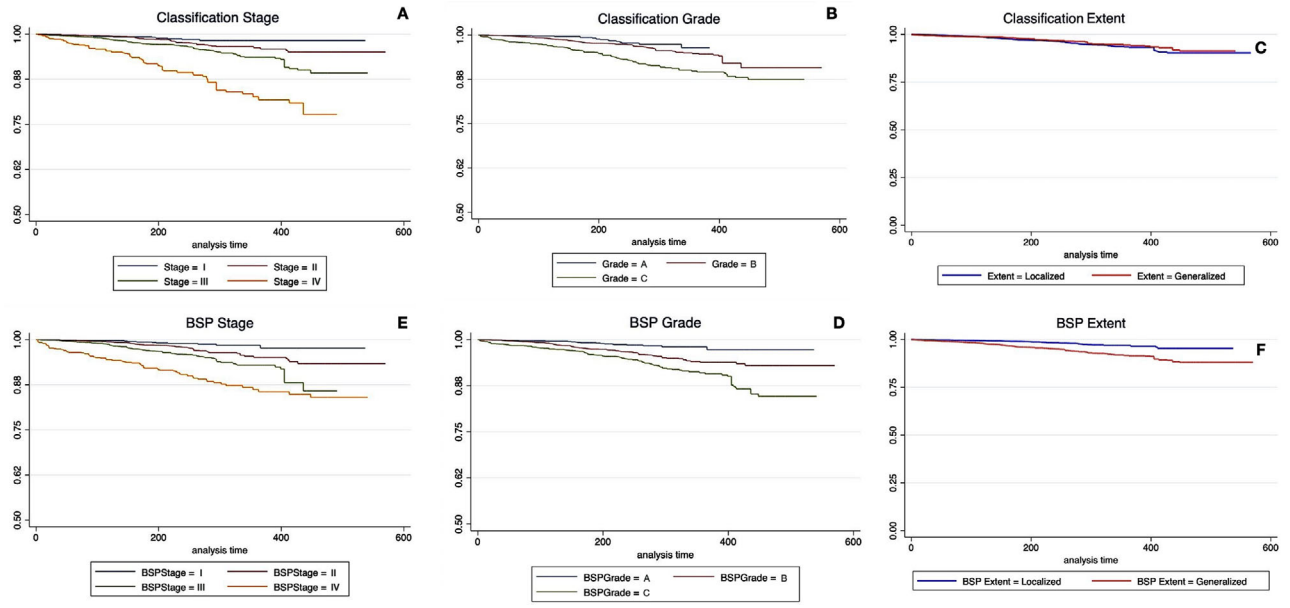



**FIGURE 2** Survival curves built for periodontal-related tooth loss (TLP) on multilevel multivariate Cox regression analysis adjusting for confounding factors such as: age, sex, and number of maintenance visits

## 4 | DISCUSSION

Our results revealed that the different risk categories of periodontitis as defined by both the 2017 WWC and the BSP-i were associated with different risk classes. Basically, the higher the stage or grade is, the greater the risk is for TLP. However, with small exceptions, different class severities of stage and grade had a stronger correlation with TLP in the BSP-i when compared with the original 2017 WWC (Table 2). Both models showed excellent overall prognostic performance (0.922 for the 2017 WWC and 0.925 for the BSP-i). Although the overall prognostic performance was very similar, the prognostic performance of the BSP-i stage and extent was slightly better than the 2017 WWC stage, while the 2017 WWC grade demonstrated a better performance than the BSP-i grade.

Patient allocation between the two systems was slightly different (Fig. 1). The most significant differences were found for extent. The BSP-i system classified 43.3% of the patients as generalized compared with the 2017 WWC system 28.9%. The approach by which the extent component of the 2017 WWC had to be used was clarified in a recent publication,[19] where the number of teeth at the stage-defining severity was considered with a cut-off percentage of 30% for a localized versus a generalized extent.[19] In the current analysis, the majority of Stage I or II cases (mild and moderate periodontitis) exhibited a generalized extent of disease. Interestingly, the 2017 WWC extent did not correlate with TLP in either the univariate or the multivariate analysis. Another important difference was that the 2017 WWC allocated more cases to Stage III. This may be due to the description of the complexity factors (vertical BL ≥3 mm; furcation II or III; PD ≥6 mm; or moderate ridge defects) in the 2017 WWC, which may have driven more readily the allocation to Stage III versus a singular factor of radiographic evaluation in the BSP-i.

It is worthy of note that the risk factors included in the 2017 WWC such as smoking and diabetes mellitus while in the BSP-I, both are considered as the separate risk entities in addition to the stage, grade, and extent, and not as a part of the classification process itself. The BSP-i system assumes that the percentage of radiographic bone loss/age ratio captures the historical disease susceptibility, with all patients' risk factors and indicators leading to it, such as smoking and poorly controlled diabetes. This, however, does not take into consideration future disease susceptibility. Nevertheless, disease susceptibility may change if a patient's smoking habit changes (from heavy to light and vice versa).[21] The same could be expected for patients with diabetes.[22]

The results of the multilevel-multivariate analysis demonstrated the number of SPT sessions attended by patients represented the best predictor for tooth survival. This agrees with the overwhelming body of evidence available.[23] Irregular compliance with SPT has been consistently associated with an increased risk of tooth loss.[24–26] Additionally, SPT frequency and patient compliance seemed to diminish the detrimental effects of residual PD and smoking, on maintenance therapy outcomes in terms of tooth loss.[27,28] This is demonstrated by the low rate of TLP (4.6%) encountered in the current study.

The present analysis has several strengths. Instead of using overall tooth loss (OTL) that is frequently employed in similar studies, only TLP was used. The key parameters that are usually used to gauge periodontitis severity (similar to those used for stage and grade) were not found to affect OTL.[20] A recent long-term investigation has demonstrated that the Staging and Grading systems are indeed prognostic for TLP, but not OTL.[12] Moreover, the current study only assessed teeth that were lost during SPT and did not include any teeth that were extracted during the cause-related phase of therapy.

One of the limitations of the present study was that the authors were unable to perform a classical external validation study of the two classification systems by calculating discrimination and calibration, as no prior model has been developed and the pre-requisite model parameters are not available to test.[30–32] Therefore, it was decided that a formal validation study would not be possible. The authors opted to evaluate the single prognostic performance of each variable in a univariate analysis and multivariate analysis was performed with the aim to adjust the results of the univariate analysis for confounding factors. The overall analysis was performed to evaluate the statistical significance of variables included and evaluate if they were independently associated with a higher risk of tooth loss, to allow comparison of similar parameters in the two classifications and analyze how they performed (e.g., stage in the BSP-i versus stage in the WWC). The authors recognize the limitations associated with this method and, to reduce the possibility of an over-optimistic performance, internal data validation techniques were applied by means of k-fold cross-validation (see Supplementary Table 1 in online *Journal of Periodontology*). Interestingly, the results of the internal validation confirmed the previously obtained findings, excluding the possibility of an overoptimistic performance of the initial models.

In addition, other limitations are related to the absence of an a priori calculation of the sample size and to the possibility of selection bias in the study cohort. As this study was not carried out using a prospective cohort of participants, the available sample size was pre-determined. However, our cohort respected the sample size requirements outlined by Collins et al. for the external validation of time-to-event data.[33] In particular, a total of 318 TLs events were present in our cohort, exceeding the ideal threshold of 200 events required to provide an adequate statistical power.[33]

The current study was conducted using dental school data records. A range of operators treated those patients, including undergraduate and graduate dental students, and their instructors. All those bring their own biases. This could lead to different criteria being applied clinically for the need for extractions, or how a "periodontally hopeless" tooth is defined. The inclusion of data from many years could also have led to some systematic bias caused by changing perspectives on the possibility of rescuing a tooth as compared with implant placement. This study set the limit of ≥10 years of regular SPT as a criterion for inclusion. This selectively excluded patients who either died or lost their entire dentition due to rapid periodontitis progression before they hit the 10-year mark. The ≥10 years SPT threshold ensured that an effect from TLP could be demonstrated, given the slow pattern of periodontitis progression.[29]

The ideal system for risk assessment in everyday practice should be quick, simple, reliable, and easy to understand for both the professional and the patient. The main rationale behind abridging the 2017 WWC by the BSP-i was to simplify the classification process for clinicians in practice, especially general practitioners and dental students. This could make treatment outcomes more predictable and improve our ability to share findings with our patients. A few examples of cases that demonstrate the practical implementation of the BPS-I were published recently.[34,35] More importantly, the results presented in this manuscript demonstrated that the BSP's pragmatic approach through implementing a reductionist model of the original 2017 WWC neither affected the class allocation nor the prognostic performance of the system. This should be considered as the most significant finding in terms of practicality of implementing this classification in general dental practice. Indeed, in July 2021 the NHS Business Services Authority embedded the BSP-I and associated stages of S3-Level guidelines for treatment within NHS statute for dental practices.[36]

## 5 | CONCLUSIONS

Different risk categories of periodontitis as defined by both the 2017 WWC and the BSP implementation of the classification were associated with different risk classes. The overall prognostic performance of the two systems was excellent, with both systems having a Harrell C index score of >0.92.

### ACKNOWLEDGMENT

Musa Qazi, Department of Periodontics and Oral Medicine, University of Michigan School of Dentistry, Ann Arbor, MI, assisted with data collection. The authors report no conflicts of interest related to this study.

### AUTHOR CONTRIBUTIONS

Study conception and design: Dr. Saleh, Dr. Troiano. Analysis and interpretation of the data: Dr. Dukka, Dr. Saleh, Dr. Troiano, Prof. Dietrich. Data collection: Dr. Saleh, Dr. Dukka, Dr. Ravida, Dr. Qazi. Drafting of the manuscript:

Dr. Saleh, Dr. Dukka, Prof. Greenwell. Critical revision of the manuscript: Prof. Greenwell, Dr. Wang, Miss Yonel, Prof. Dietrich, Prof. Chapple. All authors gave their final approval and agreed to be accountable for all aspects of the work.

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## SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**How to cite this article:** Dukka H, Dietrich T, Saleh MHA, et al. The prognostic performance of the 2017 World Workshop classification on staging and grading of periodontitis compared to the British Society of Periodontology's implementation. *J Periodontol*. 2022;93:537–547. https://doi.org/10.1002/JPER.21-0296