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CASE REPORT OR CASE SERIES

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A comprehensive approach to assigning periodontal prognosis

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Abstract

Aim: The purpose of this retrospective case series study was to evaluate the usefulness and performance of a comprehensive approach to assigning periodontal prognosis by assessing the risk of tooth loss due to periodontal disease (TLPD) and estimate the survival time (ST) of periodontally compromised teeth (PCT).

Material and Methods: The Long-Term Outcome (LTO) index was utilized to assess the risk of TLPD, at baseline, in 100 patients following periodontal maintenance for a mean 24.7 year (±2.4). A TLPD prediction model was utilized to assign ST to PCT. The performance of the TLPD prediction based on both parameters was assessed.

Results: The mean TLPD rate increased as the LTO index increased (Kruskal–Wallis $p < .001$). The percentage of TLPD increased as the ST decreased, with significantly differences between the LTO categories <4 and ≥4 for all ST intervals (Mann–Whitney $p < .001$ to p .021).

Only 21% of PCT were lost. This percentage was 58% for teeth assigned the shortest ST and increased to 71% and 88% for these teeth in LTO ≥4 patients.

Conclusions: This approach might be useful to predict TLPD in patients with an initial higher risk of TLPD while it was not useful in patients with lower risk of TLPD.

KEYWORDS

periodontal disease, periodontal prognosis, tooth loss

1 | INTRODUCTION

Several studies have assessed the accuracy of conventional periodontal prognostic indexes in patients following periodontal maintenance (PM). For hopeless prognosis, tooth loss due to periodontal disease (TLPD) prediction failed, implying a False +, in between 19.6% and 38% of the cases (Becker, Berg, & Becker, 1984; Fardal, Johannessen, & Linden, 2004; McGuire & Nunn, 1996). These percentages were much higher for questionable prognosis: the TLPD prediction failed in between 37% and 74% of cases (Becker et al., 1984; McFall, 1982; McGuire & Nunn, 1996). Thus, this low sensitivity or capability of anticipating the TLPD event represents a major limitation of periodontal prognosis. On the contrary, the specificity or capability of ascertaining that TLPD will not occur has been shown to be much more accurate. This prediction only failed between 0.46% and 2% of times, implying a False—(Becker et al., 1984; McFall, 1982; McGuire & Nunn, 1996).

The rather low accuracy of conventional prognostic indexes for predicting TLPD might be partially due to the fact that these indexes are mainly based on tooth-related factors (TRFs), without considering the potential impact of patient-related factors (PRFs).

Two lines of research have explored the impact of PRFs in patients following PM, identifying patients that are more prone to lose their teeth. The first approach attempted to characterize the baseline status of patients that lose more teeth during PM (Fardal, Grytten, Martin, Houlihan, & Heasman, 2016; Martinez-Canut, 2015; Martinez-Canut, Llobell, & Romero, 2017; Tonetti, Muller-Campanile, & Lang, 1998; Wasserman & Hirschfeld, 1988); the second approach focused on assessing the risk of disease progression and the resulting tooth loss (Lang & Tonetti, 2003; Lindskog et al., 2010; Page et al., 2002; Page, Krall, Martin, Mancl, &

Garcia, 2002). The tools developed for this purpose have been assessed in longitudinal studies, their capability to identify patients with different levels of risk being demonstrated (Lang, Suvan, & Tonetti, 2015).

Despite the above-described efforts, we still lack on useful and accurate guidelines to assign the particular prognosis of each tooth when simultaneously implementing TRFs and PRFs. This was the purpose of a recently developed prediction model that calculates the probability of TLPD and the associated survival rate of periodontally compromised teeth (Martinez-Canut, Alcaraz, et al., 2017). Despite this model presenting high specificity and being useful to define survival time intervals associated with the probability of TLPD in different TLPD samples, its sensitivity was still low and did not enhance the accuracy of conventional periodontal prognostic indexes. This limitation might well be explained by the fact that we do not know how to interpret and implement the actual impact of certain PRFs.

TLPD is concentrated in a low percentage of patients following PM. Studies analysing prognostic factors using clearly defined samples of TLPD (Chambrone & Chambrone, 2006; Checchi, Montevecchi, Gatto, & Trombelli, 2002; Fardal et al., 2004; Lü et al., 2013; Martinez-Canut, 2015; Muzzi et al., 2006) have certainly found low percentages of patients that lose more than 3 teeth, ranging from 3% to 8.9%. Therefore, research efforts to improve the accuracy of periodontal prognosis should focus on these patients, attempting to improve the sensitivity of the TLPD prediction. Conversely, the specificity of the prediction that TLPD will not occur has been shown to be high, especially in the remaining percentage of patients that will not experience TLPD.

Looking further into the prognosis of patients that are more prone to experiencing TLPD, a research study was carried out to analyse predictors of long-term outcomes in patients following PM (Martinez-Canut, Llobell & Romero, 2017). The results enabled the development of a Long-Term Outcome (LTO) index to assess the proclivity of patients to lose their teeth. The use of this tool, coupled with the estimation of survival time of periodontally compromised teeth in patients more prone to experiencing TLPD, might enhance our knowledge of periodontal prognosis.

The purpose of this retrospective cases series study was to evaluate the performance of a comprehensive approach to assign periodontal prognosis by assessing, at baseline, the risk of TLPD with the LTO Index and estimate survival time of periodontally compromised teeth with the use of a prediction model.

Clinical Relevance

Scientific rationale for the study: Periodontal prognosis lacks clearly defined guidelines to identify patients with higher risk (PHR) of tooth loss due to periodontal disease (TLPD) and focuses on the dichotomous TLPD event, without considering survival time (ST). This retrospective study seeks to overcome these limitations.

Principal findings: PHR were identified at baseline with the use of an index. The ST of periodontally compromised teeth was estimated with a prediction model. The accuracy of the TLPD prediction increased for teeth with the shortest ST in PHR.

Practical implications: This combined approach might enhance the accuracy and usefulness of periodontal prognosis; however, in this study, it is limited to the few patients with an initial higher risk of TLPD.

2 | MATERIAL AND METHODS

2.1 | Patient population

The sample used in this study consisted of 100 PM patients who were followed from 20 to 28 years (24.7 ± 2.4). These patients were selected from the baseline sample of our previous study (Martinez-Canut, Llobell & Romero, 2017). The inclusion criteria were the diagnosis of moderate and severe chronic periodontitis (Armitage, 1999), the absence of previous periodontal treatment and complete records on periapical radiographs at baseline, periapical radiographs of TLPD during follow-up and intra-oral photographs at baseline and at the end of follow-up. The exclusion criteria were mild periodontitis, aggressive periodontitis (Lang et al., 1999), being less than 36 or more than 70 years of age, the presence of serious disease with an influence on the periodontium, more than six non-replaced missing teeth and extensive restorations with natural teeth and implants.

2.2 | Tooth sample

2.2.1 | Treatment rendered and periodontal maintenance programme

Treatment rendered and periodontal maintenance programme has been previously described (Martinez-Canut, 2015; Martinez-Canut, Llobell & Romero, 2017). In brief, these patients received similar treatment and complied with PM every 4 months. Soon after the intervals were shortened or lengthened by one or two months in accordance with changes in probing pocket depth and/or bleeding upon probing.

2.2.2 | Data collection

In March and May 2017, the baseline periodontal prognosis was retrospectively assigned to each patient with the LTO index and to each tooth, estimating the survival rate associated with the prediction model.

The LTO index

This predictive index assesses the proclivity of the patient to experience TLPD and includes five variables, assessed at baseline, that were found to be statistically associated with higher TLPD rates in patients following PM (Martinez-Canut, Llobell & Romero, 2017). The index consists of a simple addition of one score for each variable involved in the patient. Thus, the final

value ranges from the presence of 0 to 5 of the following variables: fewer subgingival calculus deposits, a Gingival Index (Löe & Silness, 1963) below 1.7, vertical and circumferential bone defects and/or furcation defects, mean gingival recession >1.5 mm and abfractions. The higher the value of the Index, especially with bruxism and smoking, the higher the resulting TLPD rate and the accuracy of the Index. Figures 1 and 2 show the clinical and radiological features defining the category of the LTO index, the estimated survival time and the actual TLPD taking place after 23 and 25 years.

The variable furcation involvement is considered positive in the index when grade II and III furcation involvement (Hamp, Nyman, & Lindhe, 1975) is present, while inter-proximal bone loss (mesial and distal surfaces) is minimal (<2 mm) or it is absent.

This index was assessed by two independent examiners/the authors, utilizing the baseline clinical and radiological records of each patient,

FIGURE 1 Twenty three year follow-up of a 36 year old female LTO 0 patient with moderate chronic periodontitis. The assigned survival time of periodontally compromised teeth, 12 (12 to 22 years), is shown in black. LTO index was 0 due to the presence of subgingival calculus (C+ 0) and gingival inflammation (IG 0), and the absence of vertical bone defects (VD 0), furcation involvement (FD 0), general gingival recession (GR 0) and abfractions (ABF 0). Several incisors presented bone loss of around 50% and grade 1 and 2 mobility. Several molars present 30% to 50% bone loss and grade I and II furcation involvement, associated with moderate to severe inter-proximal bone loss. The parameter furcation defect is considered positive only when there is minimal inter-proximal bone loss. TLPD was 0. Molar 27 was lost due to caries (C). TLPD rarely occurs with this index category

FIGURE 2 Twenty five year follow-up of a 36 year old female LTO 5 patient with severe chronic periodontitis, smoking and bruxism (clenching). Seventeen teeth were assigned different survival times. LTO index was 5 due to the presence of all variables: absence of subgingival calculus (C+ 1), reduced Gingival Index (IG 1), presence of vertical bone defects (VD 1), grade II furcation involvement (FD 1), general gingival recession (GR 1) and abfractions (ABF 1). Teeth lost (TLPD) were 17, 16, 15, 14, 24, 25, 37 and 36, after 8 to 26 years

as has been previously described (Martinez-Canut, Llobell & Romero, 2017). Inter-examiner agreement was verified (Kappa statistics).

Consensus between the examiners was required to identify each TLPD based on clinical and radiological records. The criteria to define TLPD were spontaneous exfoliation and bone loss >75% with grade III mobility (Lindhe & Nyman, 1977), which caused pain under function or spontaneously. For molars, bone loss >50% was associated with grade III furcation lesion and repeated abscesses. Teeth extracted for restorative purposes with bone loss >75 and grade III mobility, as well as endodontic complications with bone >75% without caries or root fracture, were considered TLPD and extracted.

The probability of TLPD and the associated survival time

The prediction model utilized for this purpose (www.perioproject.com) consists of a mathematical algorithm that calculates the probability of TLPD by introducing to the model 11 predictors of TLPD as they were at baseline (Martinez-Canut, Alcaraz, Alcraz Jr. et al., 2018). These variables were five patient-related factors (severe periodontitis, smoking, bruxism, fewer baseline teeth and younger age) and six tooth-related factors (type of tooth, probing pocket depth, bone loss, furcation involvement mobility and crown-to-root ratio). The probability of TLPD from 0 to 1 was associated with the following intervals of expected survival time of periodontally compromised teeth: 12–22 years; 9–20 years, 6–20 years, 5–18 years and 4–13 years.

A single examiner (MC) introduced the data to the model utilizing the baseline records of the patient.

Distribution of patients and TLPD according to LTO index and survival time

The patients' sample was categorized according to the LTO index. For each category, from 0 to 5, the number of teeth that were assigned a survival time interval, together with the number and percentage of teeth lost in the long-term was recorded.

2.3 | Statistical analysis

Data entry and descriptive and analytical statistical evaluations were performed by independent statisticians (ERATEMA, I.A & L.D.) utilizing the SSPS software program (IBM, SPSS Statistics, V.19, Armonk, NY, USA). Due to the small sample size and the zero-truncated nature of the data, non-parametric tests (Kruskal–Wallis and Mann–Whitney) were utilized to assess TLPD percentage differences among the LTO groups, for each survival rate.

3 | RESULTS

3.1 | Patients' sample

The mean age of the patients' sample was 42.3 years (±6.95), and the age ranged from 36 to 70 year. Sixty-six patients were females (66%) and 34 males (34%). The subjects were mostly Caucasian and of European origin. None of the patients had previously undergone periodontal treatment.

TABLE 1 Distribution of survival rates for each LTO index category (0–5). It is detailed the number, mean and percentage of TLPD occurring in teeth that are assigned the survival rates 12–22, 9–20, 6–20, 5–18 and 4–13

LTO index	*n*. pts.	*n*. (*m*. TLPD/pt.)	S.R 12–22			S.R. 9–20			S.R. 6–20			S.R. 5–18 and 4–13		
			n. teeth	*n*. (%) TLPD	*m*. S.R.	*n*. teeth	*n*. (%) TLPD	*m*. S.R.	*n*. teeth	*n*. (%) TLPD	*m*. S.R.	*n*. teeth	*n*. (%) TLPD	*m*. S.R.
0	11	2 (0.18)	35	0 (0%)		9	2 (22%)	20	0			0		
1	29	13 (0.44)	126	4 (3%)	15.7	61	2 (3%)	20	26	2 (7%)	17.5	13	5 (38%)	11
2	19	23 (1.2)	87	0 (0%)		47	8 (17%)	17.7	34	11 (32%)	17	24	5 (21%)	14
3	19	54 (2.8)	97	5 (5%)	13.6	57	7 (12%)	14.2	46	12 (26%)	16	51	30 (59%)	13
4	14	63 (4.5)	73	13 (17%)	16	61	17 (27%)	16.7	29	13 (45%)	13	28	20 (71%)	9
5	8	64 (8)	34	5 (15%)	15.4	28	12 (43%)	14.7	32	24 (75%)	14.7	26	23 (88%)	11
Total	100	219	452	27 (6%)	15.3	257	47 (18%)	15.75	167	62 (37%)	15.1	142	83 (58%)	12.5

LTO index, Long-Term Outcome index; TLPD, tooth loss due to periodontal disease; *n*. pts., number of patients; *n*. (*m*. TLPD/pt.) TLPD number and mean TLPD per patient; S.R., survival rates; *m*. S.R., mean survival rates.

3.2 | Inter- and intra-examiner agreement

Inter-examiner agreement was well above the level of chance at 0.89–0.94 (kappa statistic $p < .001$ for individual variables).

3.3 | Tooth sample and TLPD sample

Thirty-five patients maintained the whole dentition, excluding third molars, (980 teeth) and 65 patients presented 193 non-replaced missing teeth with a mean 2.9 per patient and a total of 1.820 teeth. In the 2.607 teeth sample, 1.024 teeth (39%) were assigned a certain survival time and 219 of these teeth (21.3%) were actually lost (Table 1).

3.4 | Characterization of teeth with certain probability of TLPD and the associated survival time

The use of the prediction model to estimate survival time intervals enabled a systematic characterization of teeth with certain probability of TLPD. This probability clearly differed depending on the type of tooth, as it was previously shown (Martinez-Canut, Alcaraz, Alcaraz Jr. et al., 2018).

Longer survival time intervals (12–22) were assigned, depending on the type of tooth, mainly to teeth with the intermediate category of TRFs (grade II furcation involvement; grade 2 mobility; probing pocket depth 5–6 mm, etc.) in the absence of PRFs (smoking, bruxism, severe periodontitis, etc.) or with the least affected category of TRFs in the presence of PRFs; only 6% of these teeth were lost.

Intermediate survival time intervals (mainly 9–20 and several 6–20 years, depending on the type of tooth) were assigned to teeth with the poorest category of TRFs in the absence of PRFs; only 18% of these teeth were lost. The survival time interval 6–20 was also assigned to teeth with the poorest category of PRFs in the presence of PRFs, except for upper molars and lower second molar; 37% of these teeth were lost.

The shortest survival rates (5–18 and 4–13 years) were assigned to teeth with the poorest category of TRFs in the presence of PRFs and also in the absence of PRF for teeth more prone to be lost (upper molars and second lower molar); 58% of these teeth were lost.

According to the above-described percentage of TLPD, teeth-assigned survival time intervals were lost in a rather low percentage of cases in the total sample. However, these percentages substantially increased as the LTO index increased and especially for the shortest survival time intervals, as it is addressed latter.

Only three teeth without estimated survival time of 1.648 teeth (good prognosis) were lost (False) revealing high accuracy of the TLPD prediction.

3.5 | Distribution of patients and TLPD according to the LTO index and the survival time

Table 1 depicts the main results of the study. Each patient was assigned a LTO category: 11 patients presented category 0; 29 patients presented category 1, etc. The number of periodontally compromised teeth that were assigned the corresponding survival time (12–22, 9–20, 6–20, 5–18 and 4–13) is detailed for each LTO category. For instance, for category LTO 0 (11 patients), 35 teeth were assigned a 12–22 survival time and nine teeth were assigned a 9–20 survival time.

The number and percentage of teeth that were actually lost were also recorded. For instance, in the LTO 0 group, 0 teeth of 35 teeth assigned a 12–22 survival time were lost and two teeth (22%) of nine teeth assigned a 9–20 survival time were lost.

The main findings were as follows:

Mean TLPD rate according to the LTO index: The mean TLPD rate per patient increased as the LTO index increased. This increase was approximately twofold for each increasing category of the index: 0.18, 0.44, 1.2, 2.8, 4.5 and 8 for LTO categories 0, 1, 2, 3, 4 and 5, respectively.

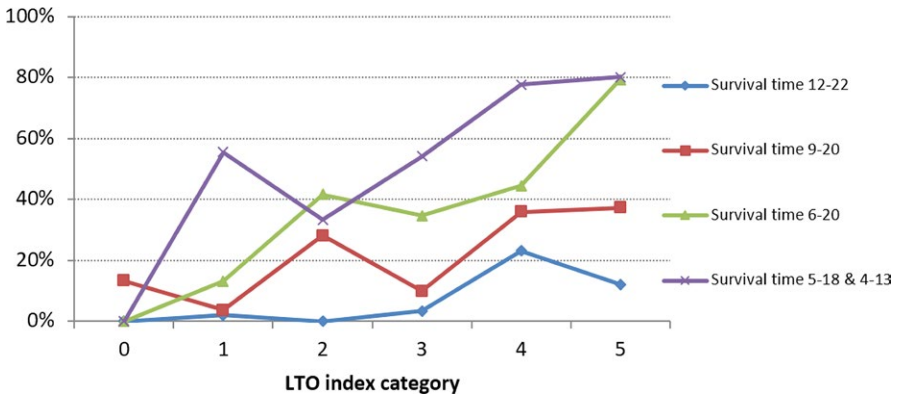

FIGURE 3 Mean percentage of TLPD according to the LTO index for each survival time interval. The mean percentage of TLPD significantly differed between some LTO categories, with post hoc mean comparison showing significant differences between categories 0 and 1 *versus* 3 (p.0.001 and p.0.003) and 0, 1 and 2 *versus* 4 and 5 (p.<0.001 to p.0.002). Several overlaps between LTO categories 0 and 1 could be partially explained by the small TLPD sample: for LTO 0, 2 teeth lost out of 9 for survival time 9 to 20; for LTO 1, 5 teeth lost out of 13 for survival time 5-18 and 4-13.

TABLE 2 Mean percentage of TLPD according to the LTO categories <4 and ≥4 for each survival time interval

	S.T. 12–22		S.T 9–20		S.T. 6–20		S.T. 5–18 and 4–13	
LTO index	*n*. pts.	Mean % (*SD*)	*n*. pts.	Mean % (*SD*)	*n*. pts.	Mean % (*SD*)	*n*. pts.	Mean % (*SD*)
LTO < 4	69	1.7 (16.7)	57	12.8 (24.8)	39	30.7 (38.1)	30	47.7 (42.3)
LTO ≥ 4	22	19.2 (28.9)	20	36.4 (32.8)	18	58 (39.6)	16	79 (31)
Total	91	5.9 (16.7)	77	18.9 (28.8)	57	39.4 (40.3)	46	58.6 (41.2)

TLPD, tooth loss due to periodontal disease; LTO index, Long-Term Outcome index; *n*. pts., number of patients; Mean % (*SD*), mean percentage of TLPD and standard deviation.

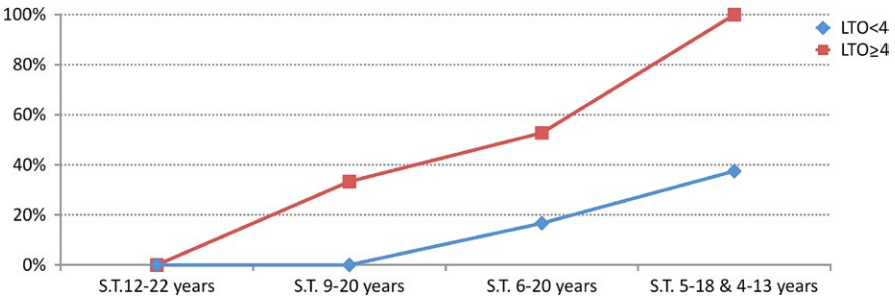

FIGURE 4 Percentage distribution of TLPD for LTO index <4 and ≥4, for each survival time interval. TLPD, Tooth loss due to periodontal disease; LTO index, Long-term outcome index; S.T., survival time intervals 12-22 years, 9-20 years, 6 to 20 years, and 5-18 & 4-13 years.

Percentage of TLPD according to the survival time: The mean percentage of TLPD increased as the survival time decreased: 6%, 18%, 37% and 58% for the survival time intervals 12–22 years, 9–20, 6–20 and 5–18 plus 4–13 years, respectively, with significant differences between the intervals (Kruskal–Wallis $p < .001$).

Percentage of TLPD according to each LTO index category for each survival time interval: When the percentage of TLPD was analysed for each LTO index category and each survival time interval, statistical significant differences were found (Kruskal–Wallis $p < .001$) between groups. However, no significant differences were found between all the LTO categories (Mann–Whitney with post hoc comparison of means), except for the LTO categories 0 and 1 versus 3 (p .001 and p .003) and 0 and 2 versus 4 and 5 ($p < .001$ and p .002). Figure 3 depicts several overlaps between the LTO categories 0, 1 and 2, with more reduced TLPD sample.

Due to these findings, the reduced sample size and the zero-truncated nature of the data, only two LTO categories were analysed: <4 and ≥4. Table 2 depicts the percentage of TLPD between the LTO categories <4 and ≥4 in each one of the survival time intervals.

Significant differences were found in the mean percentage of TLPD between these two categories (Figure 4) and significant differences were also found in the percentage of TLPD between the LTO categories <4 and ≥4 in each one of the survival time intervals (Mann–Whitney): 12–22 years ($p < .001$), 9–20 years (p .001), 6–20 years (p .016) and 5–18 and 4–13 years (p .021).

LTO ≥4 patients showed a two- to threefold increase in the TLPD rate for longer survival rates (12–22 and 9–20 years) and a two- to fourfold increase in the TLPD rate for shorter survival rates, in comparison with LTO < 4.

In 22 LTO ≥4 patients, between 71% and 88% of the teeth assigned the shortest survival time were lost. For the survival time 6–20, between 45% and 75% of teeth assigned the survival time 6–20 years were lost.

For the remaining LTO categories and survival time intervals, the percentage of TLPD varied within a wide range, from 0% to 59%.

3.6 | Occurrence of TLPD within the estimated survival time

When TLPD occurred, it matched the assigned survival time in a high percentage of cases: 82% for the survival time 12–22 years and close to 90% for the remaining survival time intervals.

For the survival time 12–22 years, five of 27 teeth (18%) were lost before 12 years and all of them presented an unfavourable crown-to-root (C/R) ratio 1/1.

For the survival time 9–20, two of 47 teeth (with an unfavourable C/R ratio 1/1) were lost before 9 years and 4 after 20 years (all of them with a favourable C/R ratio 2/1).

For the survival time 6–20, one of 62 teeth was lost (with an unfavourable C/R ratio 1/1) before 6 years and 6 after 20 years (five of them with a favourable C/R ratio 2/1)

For the shortest survival time (5–18 and 4–13), one of 83 teeth was lost before 4 years (with a deep vertical defect) and eight were lost after 18 years (seven of them with a favourable C/R ratio ½).

4 | DISCUSSION

This study represents an attempt to extend beyond conventional periodontal prognosis by simultaneously integrating the overall prognosis (LTO index) and individual tooth prognosis (survival time) of periodontally compromised teeth.

The accuracy of the TLPD prediction has been identified with the actual percentage of TLPD of teeth being assigned a certain prognostic category (Becker et al., 1984; Fardal et al., 2004; McFall, 1982; McGuire & Nunn, 1996). This percentage also represents the probability of TLPD. Under this perspective, it has generally been assumed that the mean probability of accurately predicting TLPD, excluding good prognosis, is close to being a chance occurrence or comparable to a coin toss (McGuire & Nunn, 1996). Therefore, any new tool designed to assign individual tooth prognosis is expected to accurately predict percentages of TLPD of periodontally compromised teeth well above 50%.

The results of the present study might suggest the need to reconsider the conventional interpretation of the accuracy of the TLPD prediction. It has reported accuracy ranging from 0% to 88%. Only 21.3% of teeth assigned survival times were lost. Furthermore, even in the worst scenario, characterized by the poorest TRFs category (grade III furcation involvement and grade 3 mobility) and the presence of PRFs, the percentage of TLPD for teeth with the shortest survival time was 58%. Thus, the assignment of survival time to periodontally compromised teeth would seem to be a fairly useless approach.

However, the assignation of survival time represents one side of the coin of the more complex issue of assigning overall and individual tooth prognosis simultaneously. This approach opens up the scope for periodontal prognosis and it is a language unto itself, based on probabilistic terms: the probability of TLPD calculated by a prediction model that is associated with a survival time; the probability of TLPD occurring; the probability of TLPD occurring within the estimated survival time; and the probability of TLPD of these events occurring in accordance with the LTO index categories.

This approach goes beyond ascertaining the dichotomous TLPD prediction. Although the term accuracy is the one utilized in relation to the TLPD prediction, the term probability might be more appropriate to describe the complex reality of the TLPD event in time and depending on the type of patient.

For instance, in LTO <4 patients, the probability of TLPD of teeth assigned a longer survival time was 0% to 5%. This does not mean that the approach utilized was useless to predict TLPD, it means that these teeth, in these patients, were retained in 95% to 100% of cases in the long-term.

The probabilistic language utilized simplifies the actual meaning of the above statement: the majority (from 95% to 100%) of teeth presenting grade II furcation involvement and/or grade 2 mobility in the absence of PRFs, in patients with no risk or low risk of TLPD, were retained in the long-term. This seems an accurate and useful prediction, as LTO <4 patients and teeth assigned longer survival rates were the most prevalent groups.

On the opposite extreme, in LTO ≥4 patients, the probability of TLPD of teeth assigned the shortest survival time was 71% to 88%. This also seems quite an accurate and especially useful prediction. Although these patients and these teeth are the less prevalent, these would be the target group in periodontal prognosis. In the present study, 22 patients (22%) at a higher risk of TLPD (LTO ≥ 4) concentrated 58% of total TLPD and these teeth were lost a mean 5 years before the remaining teeth were lost.

Thus, the baseline identification of these patients seems to be of paramount relevance and might help to assign a more accurate and useful prognosis. LTO ≥4 patients are uncommon, as the prevalence of patients with TLPD rates >3 teeth ranges from 3% to 8.9%, as already mentioned. The LTO index has been shown to be a useful approach to identifying these patients (Martinez-Canut, Llobell & Romero, 2017) although long-term prospective studies are needed for a definitive validation. Meanwhile, the retrospective use of the LTO index with patients that have experienced poorer outcomes might help clinicians to interpret routine clinical and radiological parameters from a prognostic scope.

In the remaining intermediate situations (shorter survival time intervals in patients with low risk of TLPD and longer survival time intervals in patients at risk of tooth loss), the probability of TLPD ranged from 15% to 60%, revealing the uncertainty of the TLPD prediction in these situations. A more precise probability can be defined by considering the survival time and the LTO category (Table 1). An interesting complementary datum is related with the length of the follow-up, as 50% of teeth were lost before and 50% were lost after 10 years. Therefore, under a simpler interpretation, the probability of TLPD before 10 years would be twice as low as compared to the one after 10 years.

The assignation of survival time to periodontally compromised teeth might seem a convoluted approach to assigning individual tooth prognosis. However, this approach attempts to respond to the fact that TLPD occurs progressively in time and perhaps most severely compromised teeth could be lost before the remaining compromised teeth or with higher probability. In the present study, the TLPD rates before and after 10 years were comparable. Despite the limitation of the survival time intervals, due to their long span and the overlap between the intervals, several findings deserve attention: first, the shorter the survival time, the higher the probability of TLPD and this finding seems more relevant than matching the estimated survival time. Second, the actual mean survival time was around 15 years for all survival time intervals except for teeth with the shortest survival time, which were lost a mean of around 3 years earlier. This mean was 5 years earlier for these teeth in LTO ≥4 patients. Third, the teeth lost matched the estimated survival time in a high percentage of cases, as was found in a previous publication (Martinez-Canut, Alcaraz, Alcaraz Jr. 2018). Searching for a plausible explanation for the rather low percentage of extreme deviations from the estimated survival time revealed an interesting finding. Crown-to-root ratio explained most of these situations, so that an 1/1 unfavourable ratio or a ½ favourable ratio was observed in shorter and longer survival rates, respectively. This observation was already pointed out by pioneering researchers on the subject (McGuire & Nunn, 1996).

The variable of crown-to-root ratio was already incorporated in the algorithm of the prediction model to calculate the probability of TLPD, with a certain increase in the probability of TLPD (Odds ratio 3.3 for non-molars) (Martinez-Canut, 2015). However, its actual role might be

much more relevant than was revealed with the statistical analysis and perhaps root length itself might be more relevant than crown-to-root ratio.

The main limitation of the present study is the patients′ sample size, especially for the subsamples with higher LTO index values. Despite all efforts to increase this subsample, the actual prevalence of patients concentrating higher rates of TLPD is certainly low. A baseline sample of 500 patients was required (Martinez-Canut, 2015) for a final sample of 22 LTO index 4 and 5. Interestingly, these 22 patients would represent 4.4% of our baseline sample of 500 patients, which is consistent with the actual percentage of patients experiencing higher TLPD rates reported in the literature, with the use of genuine TLPD samples instead of overall tooth loss samples (Chambrone & Chambrone, 2006; Checchi et al., 2002; Fardal et al., 2004; Lü et al., 2013; Muzzi et al., 2006).

We must stress the paucity of knowledge to satisfactorily explain why the presence of a baseline reduced Gingival Index and fewer subgingival calculus deposits predicted the retention of teeth rather than TLPD. These findings would suggest the following considerations: the outcome of periodontal treatment might depend, paradoxically, on the presence of these risk factors (subgingival calculus and gingival inflammation) and the capability of arresting or controlling them. The absence or lesser extent of these risk factors would not predict a better outcome and furthermore would mask the actual severity of the disease. This circumstance especially applies to patients at higher risk of TLPD.

Our previous research (Martinez-Canut, Llobell & Romero, 2017) noted the association of these two features with smoking, which would be the actual prognostic factor. However, according to our observations, heavy subgingival calculus deposits were clearly associated with good long-term outcomes. These deposits were frequently identified as being very close to the inter-proximal bone, without disruption or radiolucency of the cortical bone. This might suggest the possibility that factors other than smoking, such as systemic bone mineral influence the type of subgingival calculus (Brennan, Genco, Hovey, Trevisan, & Wactawski-Wende, 2007) and perhaps the metabolism of the supporting bone itself.

We should also stress that our findings, as well as the LTO index that was developed, are the result of the analysis of a particular sample, whose results depend on the peculiarities of the patients, the performance of previous periodontal treatment, the treatment philosophy, the criteria to indicate extraction, etc. Therefore, these results cannot be automatically extrapolated to other patient samples and further research is needed in order to comprehensively validate the LTO index and the TLPD prediction model.

The assigned periodontal prognosis would only be valid as long as the parameters on which the prognosis is based remain as such during follow-up. This applies especially to smoking. In our research, smokers who had quit for more than 5 years were considered non-smokers. Patients without reliable data on smoking and bruxism were excluded from the study.

The assignation of overall and individual tooth prognosis simultaneously represents a major challenge in periodontal prognosis. According to the mean percentage of TLPD of teeth assigned survival time intervals in the present study, from 0% to 88%, the authors have demonstrated the inaccuracy of this comprehensive approach to assign periodontal prognosis to the whole sample. From a different perspective, this approach has been demonstrated to be useful and quite accurate for predicting the retention of the most prevalent group of periodontally involved teeth (longest survival time) in the most prevalent group of patients (LTO <4), as well as for predicting the TLPD of teeth that are most severely compromised (shortest survival time) in the target group of patients at higher risk of TLPD (LTO ≥4).

5 | CONCLUSIONS

This study has introduced a comprehensive approach to assigning periodontal prognosis simultaneously utilizing two different tools: an index to assess the initial risk of TLPD and a prediction model to assign survival time to periodontally compromised teeth.

The TLPD rate increased as the risk of TLPD increased while the percentage of TLPD increased as the survival time decreased.

The percentage of TLPD of teeth assigned a survival time varied to a great extent, from 0% to 88%.

This approach might be useful to discharge the TLPD of teeth assigned longer survival times in patients at no risk or at low risk of TLPD. In parallel, it was useful to predict the TLPD of teeth assigned the shortest survival time in patients at higher risk of TLPD. These patients represented 22% of the total sample but accumulated 58% of the total TLPD sample.

This approach was not useful to predict TLPD in patients with no risk or low risk of TLPD.

CONFLICT OF INTEREST AND SOURCE OF FUNDING STATEMENT

Pedro Martinez-Canut has developed and owns Perioproject (patent pending), a web-based with an open access and free of charge tool to assigning periodontal prognosis. No external funding apart from the self-support of this author was available for this study. The second author declares no conflict of interest.

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