Prospective evaluation of periodontally diseased molars in smokers using the Miller–McEntire Periodontal Prognostic Index

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INTRODUCTION

A n important goal in clinical periodontics is the accurate assessment of periodontal prognosis, which can support effective therapeutic decisions. Among several established prognostic factors, only some factors can be altered by periodontal treatment and patient cooperation. These include probing depth, mobility, smoking, and plaque removal. On the other hand, age, molar type, and furcation involvement cannot be altered.1,2 Miller et al. developed a prognostic index specifically for periodontally diseased molars based on these prognostic factors2 except plaque removal, as at the time it was not possible to quantitatively assess this factor.2,3 McGuire and Nunn4 evaluated probing depth, bone loss, mobility, furcation, and smoking as prognostic factors and found these could predict tooth survival. A more recent study by Dannewitz et al.3 evaluated molar tooth loss and prognostic value of smoking, bone loss, furcation involvement, and number of molars left. The results of this study showed that periodontal therapy of molars improves their prognosis. Furthermore, furcation involvement, initial bone loss, and smoking were factors that significantly impacted the number of surviving molars. In the study by Miller et al.,3 scores were assigned for seven prognostic factors (age, smoking, diabetes, probing depth, molar type, mobility, and furcation) and a quantitative scoring system. The Miller–McEntire Periodontal Prognostic Index (MMPI) was devised, to determine the...
periodontal prognosis of molars. In addition to a quantitative scoring system, the timing of assessment is an important factor. Other studies have determined prognosis after patients were in maintenance, not at the initial examination as done by Miller et al.[3] This approach may have resulted in many molars with furcation involvement being extracted before their prognosis was determined because of the perception that they had a poor prognosis, resulting in the extraction of potentially salvageable molars. In contrast, Miller et al.[3] treated a high percentage of molars with furcation involvement which is likely to result in a more accurate prognostic score for teeth with furcation involvement. Together, these strengths support the validity and reliability of MMPPI. However, as the primary study evaluating the MMPPI was retrospective in nature, it was unable to determine the impact of smoking dose and duration on the prognostic outcome. At the same time, it evidenced that among the assessed prognostic factors, smoking had the highest impact. Considering the well-established dose–response relationship of smoking to periodontal disease risk, a similar relationship with prognosis is anticipated. In addition, its value as a part of a comprehensive prognostic index is yet to be established. Thus, the aim of the present prospective study was to determine and validate a more accurate score for smoking by incorporation of a more detailed, five-level smoking score in the MMPPI.

**MATERIALS AND METHODS**

**Study population and sampling**

A prospective cohort study was carried out at the Department of Periodontology, Dr. D.Y. Patil Dental College and Hospital, Dr. D.Y. Patil Vidyapeeth, Pune with a sample size of 25 patients and 200 teeth. The follow-up duration was 2 years. All study procedures were conducted after approval from the Dr. D.Y. Patil Vidyapeeth Ethics Committee. The sample size of 200 teeth was calculated using the data from the previous literature.[4] For this purpose, the reported hazard ratios with 95% confidence intervals were used.

**Inclusion and exclusion criteria**

Patients who were active smokers with moderate-to-severe chronic periodontitis were included in the study. Periodontitis was diagnosed based on clinical attachment loss according to the AAP 1999 classification and severity was determined as “moderate” when 3–4 mm of loss of attachment was present or “severe” when ≥5 mm of loss of attachment was present. Exclusion criteria were the presence of restorations in molars, the presence of dental prosthesis and prosthodontic abutments, endodontically treated molars, former smokers, and patients with diabetes mellitus or any other known systemic or infectious disease such as cardiovascular or renal disorders, thyroid disease, and hepatitis.

**Study procedures**

All study procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki, 2008. A total of 200 molar teeth in the 25 included patients were assigned MMPPI scores by scoring for age, smoking, molar type, probing depth, furcation involvement, and mobility. The scoring criteria were as follows:

1. **Age** was scored as 0 if age <40 years, and 1 if patient’s age was 40 years and above
2. **Probing depth (PD):** The deepest PD of six probing sites on a molar was used to determine the PD score: <5 mm = 0; 5–7 mm = 1; 8–10 mm = 2; and >10 mm = 3
3. **Mobility:** No mobility = 0; Class I mobility = 1; Class II = 2; and Class III = 3
4. **Furcation involvement:** The presence of a furcation involvement used for scoring irrespective of the severity of furcation involvement.[3] It was scored as follows: No furcation involvement = 0; one furcation involved = 1; two furcations involved = 2; and three furcations or through-and-through furcations on mandibular molars = 3
5. **Smoking:** was assessed as follows: Nonsmokers = 0; patients that smoked occasionally = 1; patients who smoked half a pack of cigarettes a day = 2; patients who smoked one pack of cigarettes a day = 3; and patients who smoked more than one pack of cigarettes a day = 4.[5]

The sum of these scores was used as the MMPPI score for that tooth at the initial examination and recomputed at 2-year posttreatment. Active periodontal treatment was begun at initial examination once the baseline scores were determined. The initial treatment included scaling and root planing with topical application of metronidazole gel (Metrogyl) and smoking cessation counseling. Open flap debridement and regenerative periodontal surgery were subsequently performed where indicated. Supportive periodontal therapy (SPT) was provided at 6 monthly intervals. Oral hygiene reinforcement, smoking cessation counseling, scaling, coronal polishing, and subgingival instrumentation of sites with persisting periodontal pockets and bleeding on probing was done during the SPT visits. At the exit examination, 2-year posttherapy, scoring for prognostic factors, molar survival, and their periodontal health was assessed. The criteria established by the American Academy of Periodontology were used to define the clinical health of the surviving molars as; “the absence of inflammation which may appear clinically as redness, suppuration, bleeding on probing.”[2]

**Data analysis**

Descriptive statistics and frequency distribution were determined for all variables. Chi-square tests were used to compare the frequency distribution of each scoring component of MMPPI. For molar survival analysis, Cox proportional hazard model was applied to calculate hazard ratios (HR). HR is a measure of the effect of a factor on an event over a period, in this case, the loss of a molar tooth. Univariate Cox proportional hazard models were applied for each of MMPPI component factors and for the total MMPPI score at baseline. Here, the molar survival outcome at the end of 2 years was considered as the event or censoring variable. All statistical analyses were...
done in R statistical environment (http://www.R-project.org/). The Cox proportional hazard analysis was done using the R package "survival."[13]

RESULTS

Two hundred teeth (25 participants) were assessed over 2 years. Descriptive statistics and Chi-square tests for all recorded variables at baseline and 2 years are presented in Table 1. At baseline, a total of 7 patients were above the age of 40 years (56 teeth) and the other 18 were younger than 40 (144 teeth). All the 25 patients enrolled in the study received Phase I therapy that included scaling and root planing. A total of 6 patients were treated with scaling and root planing with topical application of metronidazole gel, 15 patients underwent open-flap debridement (whenever indicated, conservative osseous reduction was done to reduce thick bone, facilitate flap adaptation, and before suturing, roots were conditioned with citric acid), and 4 patients underwent regenerative periodontal therapy (osseous graft material was placed in angular bone defects and craters and a resorbable collagen membrane was placed over the graft material beneath the flap in order to stabilize the clot and to prevent the loss of graft material to enhance regeneration).

Table 1: Distribution of prognostic variables and Miller Mc-Entire Periodontal Prognostic Index scores at baseline and 2 years

| Prognostic parameter: Score level (number of participants/teeth) | Baseline | 2 years | P (Chi-square test) |
|------------------------------------------------------------------|----------|---------|---------------------|
| **Age (years)**                                                   |          |         |                     |
| <40                                                              | 18       | 18      | 1                   |
| >40                                                              | 7        | 7       |                     |
| **PD (mm)**                                                      |          |         |                     |
| <5                                                               | 38       | 197     | <0.0001             |
| 5-7                                                              | 112      | 0       |                     |
| 8-10                                                             | 48       | 0       |                     |
| >10                                                              | 2        | 0       |                     |
| **Mobility**                                                     |          |         | <0.0001             |
| No mobility                                                      | 178      | 197     |                     |
| Class I                                                          | 20       | 0       |                     |
| Class II                                                         | 2        | 0       |                     |
| Class III                                                        | 0        | 0       |                     |
| **Smokers**                                                      |          |         |                     |
| Score 0                                                          | 0        | 21      | 0.001               |
| Score 1                                                          | 22       | 3       |                     |
| Score 2                                                          | 1        | 0       |                     |
| Score 3                                                          | 2        | 0       |                     |
| Score 4                                                          | 0        | 0       |                     |
| **Furcation involvement**                                        |          |         |                     |
| Score 0                                                          | 162      | 181     | 0.001               |
| Score 1                                                          | 9        | 9       |                     |
| Score 2                                                          | 28       | 9       |                     |
| Score 3                                                          | 1        | 1       |                     |
| **Molar type**                                                   |          |         |                     |
| Score 0                                                          | 100      | 100     | 1                   |
| Score 1                                                          | 51       | 51      |                     |
| Score 2                                                          | 49       | 49      |                     |
| **Total Miller-McEntire Score**                                  |          |         |                     |
| Score 0                                                          | 0        | 68      | 0.011               |
| Score 1                                                          | 22       | 58      |                     |
| Score 2                                                          | 26       | 50      |                     |
| Score 3                                                          | 54       | 17      |                     |
| Score 4                                                          | 45       | 6       |                     |
| Score 5                                                          | 19       | 1       |                     |
| Score 6                                                          | 12       | 0       |                     |
| Score 7                                                          | 6        | 0       |                     |
| Score 8                                                          | 3        | 0       |                     |
| Score 9                                                          | 5        | 0       |                     |
| Score 10                                                         | 3        | 0       |                     |
| Score 11                                                         | 3        | 0       |                     |
| Score 12                                                         | 1        | 0       |                     |
| Score 13                                                         | 0        | 0       |                     |
| Score 14                                                         | 0        | 0       |                     |
| Score 15                                                         | 0        | 0       |                     |
| Score 16                                                         | 0        | 0       |                     |
| Score 17                                                         | 0        | 0       |                     |
| Score 18                                                         | 0        | 0       |                     |
| Score 19                                                         | 0        | 0       |                     |
| Score 20                                                         | 0        | 0       |                     |

PD – Probing depth. Statistical significance considered with the P (Probability)-value less than 0.05.
Comparing the baseline and 2-year variables, several significant differences were noted [Table 1]. At baseline, 100% (25 patients) of the patients enrolled in the study were smokers with 88% of the patients being occasional smokers. At 2 years 89.5% of the patients had quit smoking while 10.5% of the patients continued to be occasional smokers (3 Patients). Thus, the majority of the study patients were able to quit the smoking by the end of 2 years. With regard to probing depth and mobility, a score of 0 was noted for 100% of the teeth at 2 years for factors probing depth (probing depth <5 mm) and mobility (no detectable mobility). However, 8.5% of the teeth presented with furcation involvement. (furcation score of 1 or more) at 2 years. The average MMPPI score at the end of 2 years for the individual teeth were 1.25 ± 1.2. There is an observable decrease in the scores when compared to baseline [Table 1]. Of the 200 teeth, a total of 3 (1.5%) teeth were extracted over the observation period of 2 years, so the mean number of molar loss over 2 years was 0.015.

Results of the Cox proportional hazard model hazard ratio are summarized in Table 2. Significant, high HR were noted for three prognostic factors; mobility (HR = 5.57, P = 0.02), smoking (HR = 3.35, P = 0.04), and furcation (HR = 7.30, P = 0.01), whereas nonsignificant HR were noted for the other component factors in MMPPI (age, molar type, and probing depth). The total Miller–McEntire score showed significantly raised HR (1.70, P = 0.01), which can be interpreted as 1.7 times higher likelihood of molar loss over 2 years, for every unit increase in MMPPI score. This finding validated the prognostic significance of the MMPPI incorporating the five-level smoking score criterion for predicting molar survival.

**DISCUSSION**

A Cox proportional hazards model was used to evaluate the effect of the prognostic factors incorporated in MMPPI on molar survival.[14,15] The earlier study utilizing the MMPPI,[16] though having a larger sample, was based on retrospective data.

The retrospective approach may have precluded an understanding of the prognostic value of the index after accounting for adequate periodontal therapy and maintenance, as these would vary across a retrospective sample. In addition, in this study, smoking was addressed as a binary prognostic factor, without any attention to the dose–response effect of smoking on periodontal disease risk and severity. Thus, first, the current study was designed to prospectively evaluate the validity of MMPI to predict molar survival assessed after 2 years, wherein appropriate periodontal therapy and supportive care were provided. Second, the score for smoking was expanded to a five-level ordinal score indicating the dose of smoking.

When comparing the baseline and 2-year data, significant and large reductions were notable in the tooth-level prognostic factors: probing depth, mobility, and furcation involvement scores. These findings affirm the effectiveness of periodontal therapy on the clinical health of surviving molars. Among the patient-level prognostic factors, a large and significant decline in smoking scores indicates the overall effectiveness of the smoking cessation counseling provided as a part of patient education and reinforced at recall visits. Very possibly, one reason for the noted high “quit rate” was that most smokers in this cohort were scored as “occasional smokers” and the proportion of smokers who smoked half pack or more of cigarettes was very low at 3 patients out of total 25 patients at the beginning of the study. At the end of 2 years, the 98.5% of the molars were surviving. This was considerably higher than that noted in the retrospective evaluation of MMPI[17] which noted 78% molar survival over a mean duration of 24 years. In the current study, a much shorter evaluation duration (2 years) and the provision of appropriate periodontal therapy are both likely causes for the noted higher molar survival rate.

Significant and positive hazard risk ratios (HRs) were noted for smoking, mobility, and furcation involvement, indicating that these factors were predictive of molar loss, when using the MMPI scoring thresholds described. The finding that baseline smoking significantly raised the likelihood of molar loss by 3.35 times per unit increase in smoking score, despite the high quit rate in this cohort is a key finding of the study. While this finding was very close to the hazard ratio for smoking noted by Miller et al. (3.46), it is notable that during the study, most smokers transitioned into former smokers. A Cochrane Systematic Review concluded that as opposed to self-motivation, professionally delivered behavioral support in the form of brief counseling and motivational interviewing significantly enhanced smoking cessation rate.[16] Another study has also noted similar cessation rate of around 70% when counseling was provided.[17] It may be speculated that the high cessation rate observed over the study period may be attributable to the repeated behavioral support and counseling offered during the maintenance visit. Several factors such as patients older age and preexisting dependence level can determine smoking cessation and relapse rate. The current study of 2-year observation may not represent the actual cessation rate maintained over longer periods of time.

Detrimental effects of smoking persist in former smokers, who may be viewed as intermediaries between active and never smokers in terms of biological effects.[18] The current study duration was 2 years. It is likely that over longer durations, the ill effects of former smoking would normalize and this could manifest as lowering of hazard ratio of baseline smoking among former smokers. These findings also concur with the findings of the studies by McGuire and Nunn[41] (relative risk [RR] = 2.06), Fardal et al.[19] (odds ratio [OR] = 4.18), and Dannewitz et al.[19] (HR = 1.40) that found smoking has a significant role in determining the prognosis of molar survival. However, these findings need to be viewed in light of the limitation of

| Prognostic factor | Parameter estimate | SE | P    | HR   |
|-------------------|--------------------|----|------|------|
| Age               | 1.65               |    | 1.26 | 0.18 | 5.14 | 0.47-56.27 |
| Probing depth     | -0.15              |    | 0.85 | 0.86 | 0.01 | 1.40-10.54 |
| Mobility*         | 1.72               |    | 0.76 | 0.02 | 5.57 | 1.26-24.62 |
| Smoking*          | 1.21               |    | 0.60 | 0.04 | 3.35 | 1.09-10.81 |
| Furcation involvement* | 1.45       |    | 1.22 | 0.01 | 7.30 | 1.56-34.24 |
| Molar-type        | 1.50               |    | 0.94 | 0.11 | 4.43 | 0.71-27.43 |
| Miller-McEntire Score* | 0.53      |    | 0.19 | 0.01 | 1.70 | 1.62-2.45 |

| Statistical significance considered with the P(Probability)-value less than 0.05. |
| CIs – Confidence intervals; HR – Hazard risk ratio; SE – Standard error |

Table 2: Multivariable Cox proportional hazards model results for molar extraction (n=200)
categorization of smoking in the current index, which did not define the smoking dose in highly precise terms such as pack-years. An important feature of an index is rapid clinical usability which may entail a certain degree of compromise as compared to precise estimation of prognostic factors.

Among the tooth-level prognostic factors, the highest HR was found for furcation involvement (7.30). This finding concurs with the findings of earlier studies by McGuire and Nunn[4] (RR = 1.29) and Dannewitz et al.[5] (HR = 3.25) and Miller et al.[6] (HR = 3.39) who found that furcation involvement has a significant role in determining the prognosis of molar survival. Several other studies[26-28] also confirm that furcation involvements were a significant prognostic factor. This finding may also be correlated with the fact that the risk for continued disease progression in sites with furcation involvement can persist despite periodontal therapy, owing to the clinical challenge of adequate debridement of furcation areas. The MMPPI scores furcation involvement as the numbers “present” or “absent.” However, it does not take into account the severity of the furcation involvement in terms of its horizontal or vertical components. The lack of this information may preclude additional conclusions regarding the effect of severity of furcation involvement on molar prognosis, within the framework of this particular index. The increased risk for tooth loss when multiple furcations are involved or through and through mandibular furcation involvement is present can also be correlated to the challenges in successful regeneration in such cases. Baseline tooth mobility had a significant impact on prognosis, showing a 5.57 times rise in risk of molar loss for every unit increase in mobility score. Clinical mobility significantly impairs the gain in clinical attachment after periodontal therapy.[29] Moreover, mobility is associated with progressive attachment loss[30] and further increases the risk of tooth loss when present together with furcation involvement.[31] However, it is important to recognize that the mobility assessment and scoring are subjective in nature and may be thus liable to inter- or intraexaminer variability, which could impact the precision of its prognostic value. Future prognostic studies should address the issue of reliability of tooth mobility scores.

Age, molar type, and probing depth showed positive but nonsignificant hazard ratios for molar loss. Such a finding seems to indicate that smoking, furcation involvement, and tooth mobility are dominant factors affecting the prognosis. Age was not noted a significant factor by Miller et al.[2] and in the other research.[4,20,26,27] However, it is feasible that over longer durations of follow-up an effect of age on tooth loss may be evident. Residual pockets with a depth of 6 mm or more form niches for the growth of periodontal pathogens and are susceptible for further periodontal breakdown.[24] Supportive care is a key factor in maintaining periodontal health and preventing recurrent disease.[28-30] In the current study, the periodontal treatment was effective in pocket reduction and none of the initially deep probing sites showed probing depths of >5 mm. It is likely that the high degree of compliance and regular supportive therapy was effective in preventing recurrent pocketing and possibly bringing about a state of quiescence in the periodontal disease process.

A key finding of the current study is that the total MMPI score had a significant and positive hazard ratio for molar survival as an outcome. The fact that this relationship was noted in a population of adequately treated and maintained cohort of patients can be seen as a validation of the MMPI as a clinically relevant prognostic index. Furthermore, as the cohort was restricted to smokers and five-level smoking score was used as a component criterion, this particular scoring system can also be considered as validated. A strength of the MMPI is that all component factors and their thresholds are very easily clinically documented. The role of genetic[31] and microbiome[32] in oral immune-inflammatory disease susceptibility is being increasingly being unraveled, but a set of prognostic host molecular, genetic, and microbial indicators for periodontitis remains elusive. It is possible that in future, advances in these fronts would support additional laboratory prognostic variables to be incorporated, especially in the form of chairside testing. The findings of the current study must be considered in light of its limitations: the small sample size, limited duration of follow-up, and a hospital-based population under specialist care. As this was a preliminary study, no prior sample size computation was made, which is a limitation. The relevance of the MMPI must be explored in larger cohorts before the findings of this study may be extrapolated to periodontal populations.

CONCLUSION

The results of this study indicate that apart from the prognostic factors namely age, furcation and molar type, smoking is also a significant factor for the survival of the molar teeth. These results confirm and validate the findings of the original study by Miller et al[2] and has also determined a more accurate score for smoking over a two year period. It also implicates that if smoking can be controlled by cessation of the habit by the patient slowly through constant motivation, one will have an excellent prognosis in the survival of molar teeth.

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Conflicts of interest
There are no conflicts of interest.

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