J Clin Periodontol 2005; 32: 1129–1133 doi: 10.1111/j.1600-051X.2005.00834.x

Journal of Clinical Periodontology

Relationship between bleeding on probing and periodontal disease progression in community-dwelling older adults

A. Rahardjo[1], A. Yoshihara[1], N. Amarasena[1,2], H. Ogawa[1], K. Nakashima[3] and H. Miyazaki[1]

[1]Department of Oral Health Science, Division of Preventive Dentistry, Graduate School of Medical and Dental Sciences, Niigata University, Niigata, Japan; [2]Department of Community Dental Health, Faculty of Dental Science, University of Peradeniya, Peradeniya, Sri Lanka; [3]Department of Periodontology and Endodontology, School of Dentistry, Health Sciences University of Hokkaido, Hokkaido, Japan

Rahardjo A, Yoshihara A, Amarasena N, Ogawa H, Nakashima K, Miyazaki H. Relationship between bleeding on probing and periodontal disease progression in community-dwelling older adults. J Clin Periodontol 2005; 32: 1129 –1133. doi: 10.1111/j.1600-051X.2005.00834.x. © Blackwell Munksgaard 2005.

Abstract

Objective: The main objective of this study was to determine the relationship between bleeding on probing (BOP) and periodontal disease progression in community-dwelling older adults.

Methods: A 3-year longitudinal study was carried out in 229 non-smoking healthy older adults aged 70 years. Using pressure-controlled periodontal probes, BOP, pocket depth and attachment level at 13,289 sites were measured annually. Periodontal disease progression was defined as an increase in attachment loss of $\geqslant 3$ mm from the baseline to the final examination. The backward stepwise logistic regression analysis was performed to assess the relationship between the total number of sites with BOP in the four examinations and periodontal progression.

Results: Logistic regression analysis showed that the odds ratios of BOP frequency for periodontal disease progression ranged from 1.4 to 6.2 after controlling for pocket depth $\geqslant 4$ mm at baseline, number of missing teeth, jaw type and tooth site.

Conclusion: Increasing frequencies of bleeding might increase the probability of periodontal disease progression in community-dwelling older adults.

Key words: bleeding on probing; longitudinal study; older adults; periodontal disease progression

Accepted for publication 12 July 2005

Untreated periodontal disease leads to tooth loss, which is a major public health problem affecting a large number of older adults. The Japanese national oral health survey in 1999 showed that the mean number of missing teeth was 8.01, 15.56 and 20.77 for 60–64-, 70–74- and 80–84-year-olds, respectively (Ministry of Health and Welfare Japan 2003). According to a previous study, 22–65% of senior citizens (65 years and older) in Japan were edentulous (Miyazaki et al. 1995). As more teeth are lost because of periodontal reasons with increasing age (Splieth et al. 2002, Taani 2003), a strategy for periodontal disease prevention is necessary not only for younger adults but also for older adults.

Bleeding on probing (BOP) correlates with gingival inflammation (Greenstein et al. 1981, Goodson et al. 1982, Haffajee et al. 1983, Abbas et al. 1986, Grbic & Lamster 1992, Chaves et al. 1993, Newbrun 1996, de Souza et al. 2003) and is widely used in evaluating the risk of periodontal disease progression during periodontal therapy or maintenance (Badersten et al. 1985, Lang et al. 1986, 1990, Joss et al. 1994). However, it has been shown that many sites with no progression of periodontal disease exhibited bleeding and thus, BOP has been considered as a poor prognostic indicator for attachment loss in spite of its high degree of specificity (Newbrun 1996). The relationship between BOP and periodontal progression is difficult to establish, as the results may be easily confounded by other factors such as smoking. It has been observed that smokers have less gingival bleeding compared with non-smokers (Fung & Corbet 1995, Amarasena et al. 2002, 2003). Even though several studies have reported a correlation between BOP and periodontal disease progression, controlling for smoking status (Badersten et al. 1985, Lang et al. 1986, Joss et al. 1994), investigations on periodontal progression, particularly in older people, using biochemical assessment of smoking status have not been conducted over the last 2 decades. Accordingly, this study was carried out to determine the relationship between BOP and periodontal disease progres-

sion in older adults, after controlling for smoking status.

Material and Methods

Subjects

A longitudinal study was conducted in older adults who reside in Niigata City, Japan. Initially, questionnaires were sent to all 4542 residents aged 70 years (born in 1927). Out of them, 600 people were randomly selected in order to have approximately the same number from each gender for the baseline survey. The participants were asked to sign consent forms regarding the protocol, which had been approved by the Ethics Committee of Niigata University School of Dentistry.

The subjects were assessed by TMIG-Index of Competence subscale questionnaires. The TMIG-Index of Competence is used to assess functional capacity in older participants. The ability to perform a given function is indicated by ''Yes'' or ''No''. The highest score of the TMIG-Index subscales is 13 (Koyano et al. 1991). The mean score of the TMIG-Index subscales of the subjects in the present study was 11.9 ± 1.4. The results of this assessment pointed to a high level of competence among the participants of this study, which in turn proved that they were healthy.

The past medical history of the subjects and the number of diseases they have had (heart disease, blood disease, liver disease, kidney disease, diabetes mellitus, high blood pressure, rheumatism, respiratory disease, lumbago, allergies, digestive disease and cerebral apoplexy) at baseline were evaluated. The mean number of diseases experienced by the subjects was 1.9 ± 1.1. In addition, the percentage of persons who received professional care, such as removal of dental plaque and calculus more than once a year during the observation period, was 25.8%.

Subjects with serum cotinine levels less than 75 ng/ml were defined as non-smokers (Tangada et al. 1997). Cotinine was analysed with double-antibody liquid-phase radioimmunoassay using reagents from Diagnostic Products Corporation (Los Angeles, CA, USA), Initially, 25 µl of serum sample or standard, 100 µl of I-labelled cotinine and 100 µl of nicotine metabolite antiserum were introduced into polypropylene tubes; subsequently, tubes were incubated for 30 min. at room temperature. Following the addition of cold precipitating solution, tubes were centrifuged for 15 min. at $3000 \times g$. Having removed the supernatant, the precipitate was measured with a Gamma counter. Thereafter, the serum cotinine levels were calculated from the standard curve.

The periodontal examination included the assessment of probing pocket depth (PPD), clinical attachment level (CAL) (Glavind & Löe 1967) and BOP (Ainamo & Bay 1975) at six sites around each tooth. Probing was performed using a pressure constant probe (Vivacare TPS Probe®, Schaan, Liechtenstein) at a probing force of 20 g. The periodontal examination was carried out by four trained and calibrated dentists under sufficient illumination using artificial light. Calibration of the examiners was carried out in volunteer patients of the Faculty Hospital. As determined by replicate examinations in 18 patients, the percent agreement (within ± 1 mm) ranged from 85.5% to 100% for PPD and from 70.0% to 100% for CAL. The κ (within ± 1 mm) ranged from 0.77 to 1.00 for PPD and from 0.62 to 1.00 for CAL.

Data analysis

Out of 260 non-smokers, 229 subjects who had at least one tooth intact were selected. Consequently, 13,289 intact sites (5110 sites in the maxilla and 8179 sites in the mandible) in the selected subjects were included in the analysis. In our study, an additional attachment loss (AAL) of 3 mm or greater was set as a conservative estimate of actual change taking place in conformity with the definition of Brown et al. (1994).

Univariate statistical analyses were performed to describe the prevalence of BOP and PPD of $\geqslant 4$ mm at baseline examination, and AAL $\geqslant 3$ mm over a 3-year period. Then, BOP frequency (Bf) was calculated by the total number of sites presented with BOP(+) in the four examinations (one time at baseline and three times at annual recalls) for all sites, and divided into five categories. The proportion of sites with AAL of $\geqslant 3$ mm over 3 years by different frequencies of BOP was calculated, and Chi-square analysis was used to determine the statistical significance.

To evaluate the relationship between BOP and periodontal disease, firstly, we conducted subject-based data analysis using multiple linear regression analysis. The percentage of sites exhibiting AAL $\geqslant 3$ mm over the 3-year period per person was selected as a dependent variable, and the percentage of sites with BOP(+), the percentage of sites with PPD of 4 mm, the number of missing teeth at baseline and gender were selected as independent variables. Next, the backward stepwise logistic regression analysis using site-based data was performed to evaluate the relationship between Bf and periodontal disease progression. The dependent variable, periodontal disease progression, was defined as sites exhibiting AAL $\geqslant 3$ mm. The independent variables used were gender, Bf, PPD at baseline, jaw type (Upper or Lower), tooth type, tooth site and the number of missing teeth. The odds ratios with 95% confidence intervals (CI) were calculated.

In the stepwise logistic regression analysis, $p < 0.05$ was used as the entry criterion while $p > 0.10$ was the removal criterion. The Hosmer and Lemeshow Goodness-of-Fit test statistic was fixed at $p > 0.05$ (Lemeshow & Hosmer 1982). The software of Statistical Package for Social Sciences (SPSS for Window, Release 11.5) was used for all calculations and analyses.

Results

Out of the total number of subjects selected, 69.2% (females: 75%, males: 64%, $N = 229$) exhibited AAL $\geqslant 3$ mm at one or more sites over 3 years. The mean number of sites with AAL $\geqslant 3$ mm per person was 3.48 ± 3.39 for females and 3.90 ± 5.29 for males. However, there was no statistically significant difference between the mean number of sites with AAL $\geqslant 3$ mm in females and males (Student's t-test $p > 0.50$). The number of missing teeth of the subjects was 7.88 ± 7.61 at baseline.

Table 1 shows a multivariate linear regression model for subjects who were followed up over the 3-year period. In this regression model, three variables, namely, percentage of BOP(+) sites, percentage of sites with PPD $\geqslant 4$ mm and the number of missing teeth at baseline, were significantly associated with the percentage of sites with AAL $\geqslant 3$ mm during the 3-year observation period.

Figure 1 shows the relationship between the proportion of sites with AAL $\geqslant 3$ mm and Bf. A highly significant ($p < 0.001$) relation between the increasing frequencies of BOP(+) and AAL

Table 1. Subject-based analysis with multiple linear regression and associated *p*-values

Baseline parameter	Dependent variable % of sites exhibiting additional attachment loss 3+mm during 3 years				
	Coefficient	SE	*p*-value	95% CI	
% BOP positive	0.134	0.039	0.001	0.056	0.211
% PPD 4+mm	0.112	0.038	0.003	0.038	0.186
No. of missing teeth	1.707	0.550	0.002	2.790	0.625
Gender	− 1.437	0.794	0.072	− 3.001	0.127
Constant	8.810	1.986	<0.001	4.900	12.720

Number of subjects: 260.
Prob > *F*: <0.001
R^2: 0.167.
BOP, bleeding on probing; PPD, probing pocket depth; CI, confidence interval; SE, standard error.

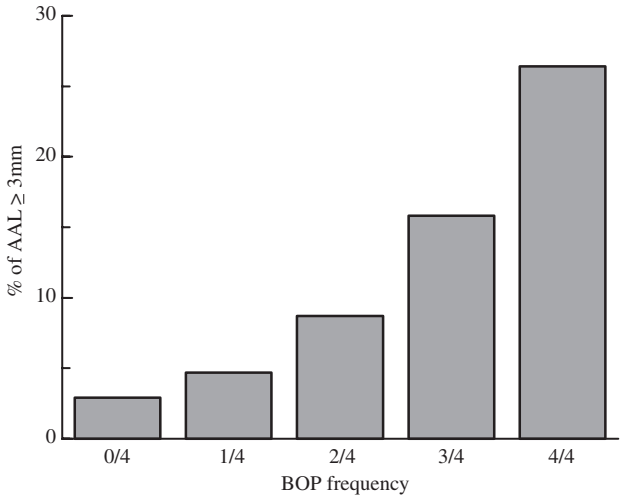

Fig. 1. Proportion of sites that had additional attachment loss (AAL) ⩾3 mm over 3 years by different frequencies of bleeding on probing (BOP). Frequency of bleeding on probing (BOP frequency) was calculated by the total number of sites that presented with BOP (+) in the four examinations (one at baseline and three times at annual recalls) for all sites and divided into five categories as follows: 0/4, BOP+ at none of four examinations; 1/4, BOP+ at one out of four examinations; 2/4, BOP+ at two out of four examinations; 3/4, BOP+ at three out of four examinations; and 4/4, BOP+ at all four examinations.

Table 2. Sensitivity, specificity and predictive values for additional attachment loss of 3+mm in relation to the frequency of bleeding on probing

Bf	Sensitivity	Specificity	PPV	NPV
0/4	67.3	19.0	3.4	93.3
1/4	18.4	85.8	5.1	96.2
2/4	8.8	96.3	9.2	96.2
3/4	4.0	99.1	15.5	96.1
4/4	1.5	99.8	26.1	96.0

Bf, frequency of bleeding on probing; PPV, positive predictive value; NPV, negative predictive value.

⩾3 mm was observed. The proportions of disease progression in the five categories were 2.9% (0/4), 4.7% (1/4), 8.7% (2/4), 15.8% (3/4) and 26.4% (4/4), respectively. Table 2 shows the sensitivity, specificity, positive and negative predictive values (PPV and NPV). It is apparent that the NPV for the absence of BOP was high, while the PPV was concomitantly increasing with rising Bf. The results of the calculation showed a good relationship between Bf and PPV.

Table 3 shows the results of the backward stepwise logistic regression analysis. Six variables (Bf, PPD ⩾4 mm, upper–lower jaws, molar, inter-proximal and number of missing teeth) remained significant in the final model. As shown in Table 3, Bf was significantly associated with periodontal disease progression after controlling for five other variables. The estimated odds ratios of Bf for periodontal progression were 1.47, 2.54, 4.39 and 6.17 for 1/4, 2/4, 3/4 and 4/4, respectively.

Discussion

Our study has addressed the same issue as reported by Lang et al. (1986) on the relationship between BOP and periodontal disease progression that was defined as an attachment loss of 2 mm or more. However, we used different methods, disease definition and subject specification (the number of subjects, distribution of age and the duration of study). Other distinctions in our study are that we included (1) only intact teeth and (2) non-smoker subjects, as determined by a serum cotinine level of less than 75 ng/ml. In addition, we believe that using multiple linear or logistic regression analysis to measure the relationship between Bf and periodontal progression would be considered a strong point in our study. The reasons for these distinctions are to avoid the confounding effects of smoking and tooth condition (decay, crown, filing and bridge-work) on periodontal disease progression.

The findings of this longitudinal study revealed a highly significant relationship between the increasing bleeding frequencies and periodontal disease progression in community-dwelling older non-smokers. In the stage of subject-based data analysis, which is shown in Table 1, BOP(+) and PPD ⩾4 mm showed significant correlations with periodontal disease progression, as well as the number of missing teeth.

Figure 1 clearly shows that the sites that have the highest score of bleeding frequency showed the greatest proportion of sites with periodontal disease progression during the period under study. Sites with a Bf of 4/4 had a 26% chance of periodontal disease progression. This proportion is slightly higher than that observed by Badersten et al. (1990), and almost equal to that reported by Lang et al. (1986). The proportions of periodontal progression in either of these two studies were not more than 30%.

We also calculated the relationship between the proportion of sites with AAL ⩾3 mm and Bf in smokers as

Table 3. Backward stepwise logistic regression analysis and associated *p*-values

Independent variables	Estimated OR	95% CI	SE	*p*-value
Bleeding frequency				
0/4 (Reference)	1.00			<0.001
1/4	1.47	1.12–1.93	0.14	0.005
2/4	2.54	1.72–3.75	0.20	<0.001
3/4	4.39	2.50–7.70	0.29	<0.001
4/4	6.17	2.21–17.25	0.52	0.001
PPD at baseline ⩾4 mm	1.48	1.05–2.09	0.17	0.024
Upper–Lower				
Lower (Reference)	1.00			<0.001
Upper	1.32	1.07–1.63	0.11	0.011
Molar	1.57	1.18–2.07	0.14	0.002
Inter-proximal	1.38	1.12–1.71	0.11	0.003
Number of missing teeth				
1–9 (Reference)	1.00			<0.001
10–19	2.00	1.58–2.54	0.12	<0.001
20+	2.51	1.72–3.65	0.19	<0.001
Constant	0.02		0.10	<0.001

$N = 13{,}289$; $\chi^2 = 24.756$, $p < 0.001$; Pseudo $R^2 = 0.055$.
Hosmer & Lemeshow: $p = 0.262$.
OR, odds ratio; CI, confidence interval; SE, standard error; PPD, probing pocket depth; Bf, bleeding on probing frequency.

well. The proportions of disease progression in the five categories were 4.5% (0/4, $n = 3432$), 5.3% (1/4, $n = 815$), 5.4% (2/4, $n = 186$), 6.5% (3/4, $n = 31$) and 0% (4/4, $n = 0$). No significant relationship was observed ($p = 0.738$, chi-square test). According to these results, the relationship between Bf and AAL seems to be unclear in smokers in comparison with that observed in non-smokers.

Furthermore, the findings of the backward stepwise logistic regression analysis showed that Bf was positively associated with periodontal disease progression after adjusting for five other local factors. The odds ratios increased concomitantly with increasing Bf. The probability of having periodontal disease progression was approximately 2.5 times greater for sites, which experienced a BOP 2/4 than for sites with no BOP. Moreover, sites that presented with BOP 4/4 had a 6.2 times greater chance of periodontal progression compared with sites that showed no BOP. This finding indicates that Bf may be considered to be a strong risk factor for periodontal disease progression in older people.

On the other hand, the finding that sites with a Bf of 0/4 had only a 2.9% chance of periodontal disease progression pointed to the fact that the absence of BOP might be a criterion for periodontal stability. This is in agreement with the previous studies that BOP is a reliable indicator for periodontal stability (Lang et al. 1986, 1990).

We also evaluated the local factors for periodontal disease progression in this study. The prevalence of BOP, PPD ⩾4 mm and AAL ⩾3 mm tended to be higher in maxilla, molar, inter-proximal sites and the lower anterior. The high prevalence of AAL ⩾3 mm at inter-proximal sites has also been observed in other studies (Heitz-Mayfield et al. 2003, Schätzle et al. 2003). In a longitudinal study in Chinese adults, similar findings were observed (Baelum et al. 1997).

In this study, although a significant relationship between Bf and periodontal disease progression was seen in backward stepwise logistic regression analyses, the pseudo R^2 was low. This finding indicates that the variability in periodontal progression explained by the five independent variables was low (5.5%) and hence, there may be other explanatory factors that could not be accounted for in the present study. Accordingly, further longitudinal studies that incorporate such unaccounted variables and span over more than 3 years may be required to investigate the influence of BOP on periodontal disease progression in community-dwelling older adults.

Notwithstanding such limitations, the present study suggested that there was a significant relationship between Bf and periodontal disease progression and consequently, increasing frequencies of bleeding might increase the probability of having periodontal disease progression in community-dwelling older non-smokers.

Acknowledgements

This study was supported, in part, by a Grant-in-Aid from the Ministry of Health and Welfare of Japan (H10-Iryo-001 and H13-Iryo-001).

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Address:
H. Miyazaki
Department of Oral Health Science
Division of Preventive Dentistry
Graduate School of Medical and Dental Sciences
Niigata University
2-5274 Gakkocho-Dori
Niigata 951-8514
Japan
E-mail: hideomiy@dent.niigata-u.ac.jp

Clinical Relevance

Scientific rationale: Even though several studies have reported a correlation between bleeding on probing (BOP) and periodontal disease progression after controlling for smoking status, investigations on periodontal progression in older people using biochemical assessment of smoking status have not been conducted.

Principal findings: The subjects with serum cotinine <75 ng/ml were defined as non-smokers. The findings of this longitudinal study revealed that in community-dwelling older non-smokers, sites with BOP(+) at annual examinations had a 26% probability of periodontal disease progression over 3 years.

Practical implications: BOP may be considered as a predictor of periodontal disease progression in community-dwelling older non-smokers.