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Patient-based assessments of clinical periodontal conditions in relation to alveolar bone loss

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Abstract

Background: Limited subject-based information exists on the relationship between clinical and radiographic periodontal data.

Aims: To use subject-based data to assess the extent of concurrence between clinical and radiographic information, and to study what clinical information best predicts alveolar bone loss (ABL).

Material and Methods: Subject-based data on smoking habits, bleeding on probing, plaque scores, pocket probing depth (PD), and evidence of alveolar BL were obtained, and functional periodontal pentagon risk diagrams (PPRDs) were studied from 168 consecutive subjects attending a medical clinic.

Results: The mean age of the subjects was 62.7 years (SD ± 9.0). The average number of teeth was 21.3 (SD ± 8.0) with on average 5.6 molars remaining (SD ± 3.9). In this subject cohort, 33.1% had never smoked, 44.2% had quit smoking, and 22.7% were currently smokers. Mean plaque and bleeding scores were high or 60.2% (SD ± 24.0) and 53.1% (SD ± 23.6), respectively. PDs $\geqslant$6.0 mm were found in 55.9% of the subjects. Binary logistic regression analysis demonstrated that tooth loss and proportional plaque scores were the predominant factors included in the equations associated with ABL. Wald coefficients varied between 3.99 and 9.15, and with *p*-values between 0.05 and 0.01. When included, the PPRD score became the exclusive factor at several cut-off levels (Wald's coefficients between 19.8 and 15.6, $p<0.001$). Consequently, the best receiver operator curve was identified for the PPRD at the $>40\%$ cut-off ABL level (area under the curve: 0.81; 95% CI: 0.74–0.89; $p<0.001$).

Conclusions: The number of teeth lost and the proportion of plaque scores provided significant predictive factors for ABL. The functional PPRD demonstrated an exclusive and highly predictable association with ABL. Subject-based proportional data for PDs >4.0 mm provided poor substitute measures for the extent of ABL.

Key words: alveolar bone height; bleeding on probing; periodontal; periodontitis; plaque index; probing depth; smoking; subject-based data; tooth loss

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Best dental practice requires that a periodontal examination includes assessments of systemic, socio-behavioral, and intra-oral conditions of care seeking patients. When clinical evidence suggests that a subject has periodontitis, a clinical decision should be made to use oral radiological methods to further appraise the conditions. At the time of assessment, clinical measures of gingival inflammation and probing depth (PD) provide information about the current clinical conditions. Radiographic data provide information about accumulated bone changes and tooth losses in the past. Neither data obtained from clinical examination nor from radiographs may accurately predict future periodontal disease activity. Information derived from such examination procedures provides tooth/site-based information. A computer-supported literature search using MEDLINE and the Cochrane Oral Health Group Specialty Trials Register using subject-based data as inclusion criteria failed to retrieve studies that had assessed the link between patient-based data for routine clinical periodontal parameters and bone height measurements made from dental radiographs (Renvert & Persson, 2002).

Different methods for the assessment of alveolar bone height, including direct measurements with millimeter graded rulers or with more elaborate projection methods employing digital imaging and computer software programs, have been used in periodontal research. Predominantly, the inter-proximal site has been used as the unit of observation (Björn & Holmberg 1966, Håkansson et al. 1981, Gröndahl et al. 1983, Brägger et al. 1988, Persson et al. 2000, Zybutz et al. 2000). The assessment of bone height from intra-oral radiographs usually underestimates the extent of ABL or the extent of vertical defects when compared on a site-by-site basis (Renvert et al. 1981, Tonetti et al. 1993). The extent of underestimation of ABL assessed from intra-oral radiographs as compared with direct measurements during surgery is however less than 20% (Åkesson et al. 1992). When site-based data were used, bone height measurements from intra-oral radiographs demonstrated positive and significant correlations with clinical measures of attachment level gain after treatment (Machtei et al. 1998). In subjects with or without periodontitis, site-based studies have suggested that the distance between the cementoenamel junction (CEJ) and bone level appears to increase to the age of approximately 50 and will then level out (Papapanou & Lindhe 1992). If the distance between CEJ and bone level exceeds approximately 4.0 mm, it can be assumed that periodontal pathology exists (Persson et al. 1998).

Studies have demonstrated that site-based clinical periodontal information such as bleeding on probing, plaque scores, and PDs greater than certain thresholds have poor predictive value for future clinical attachment loss (Badersten et al. 1981, 1990). The absence of bleeding on probing over time may be a good predictor of stable periodontal conditions using the site as the unit of observation (Lang et al. 1990, Joss et al. 1994).

The purpose of the present study was to use subject-based data and to explore the relationship between clinical information and radiographic findings, and to study what clinical information is explanatory to alveolar ABL.

Material and Methods

The Institutional Review Board (IRB) at the University of Lund, Sweden approved the study. Consecutive consenting subjects with severe cardiovascular disease and age- and gender-matched adult control subjects who had all received a medical examination at the Central Hospital, Kristianstad were enrolled in the study. Details of the study population have been described elsewhere (Persson et al., in press). At the time of study, these subjects would otherwise not have been seeking dental care. Subjects were furthermore excluded if they, during the preceding 5 years, had received periodontal therapy by a periodontist. The enrolled subjects received a comprehensive oral examination at the Kristianstad University Dental Clinic. The examination included an assessment of the extent of plaque, bleeding on probing, gingival recession, and PDs at four sites per tooth (mesio-buccal, mid-buccal, disto-buccal, and mid-lingual). Patient-based data for each of these parameters were then calculated as the proportional distributions at distinctive cut-off levels relative to the total number of observed sites. The history of smoking was obtained, and information about the number of cigarettes smoked per day and the number of smoke-years was calculated for those subjects who reported that they were either current or past smokers.

The appropriate number of intra-oral radiographs using Kodak e-speed film for each subject was taken. The films were processed using an automatic film processor (Dürr, Periomat Plus, Bietigheim-Bissingen, Germany). The intra-oral X-ray films were digitized and computer processed using a custom-made image analysis software program (Brägger et al. 1994, Fourmousis et al. 1998). The assessment of the distances between the CEJ and the most apical level of the alveolar bone level was made at the mesial and distal aspects of each tooth. If the CEJ could not be identified, the CEJ at the adjacent tooth and other tooth characteristics were used to estimate the position of the CEJ. In cases where the CEJ could not be identified or the inter-proximal spaces were not properly projected, the surface was not read. One examiner (GRP), who had been trained and calibrated in reading intra-oral radiographs, assessed all the radiographs (Persson et al. 2000). The proportion of mesial and distal sites with a recorded distance $\geqslant$4.0 mm between the CEJ and the most apical level of the alveolar bone was calculated, thereby providing subject-based data on BL status using $<$10% through $>$60% (steps with 10% increases). The $\geqslant$4.0 mm BL cut-off level was chosen based on published data on the critical cut-off value for ABL for the present study population (Persson et al. 1998).

In addition, a multi-factorial periodontal risk diagram was constructed based on clinical periodontal information and consistent with a method presented previously (Persson et al. 2003a, b). Briefly, information about the proportion of sites with bleeding on probing, number of sites with PDs $>$5.0 mm, number of teeth lost, extent of ABL for the worst site, and smoking habits were included, and a score for each subject was calculated and used for this periodontal pentagon risk diagram (PPRD) (Persson et al., 2004).

Statistical Analysis

Descriptive statistics were used to present the study population characteristics. The correlation coefficients between study parameters were studied to identify associated parameters (Spearman's rank correlation coefficient for non-parametric data and Pearson's correlation for parametric and normal distributed data). Binary logistic stepwise regression analysis was used to assess the associations between different proportional radiographic bone height cut-off levels as the evidence of periodontitis and relative to clinical parameters and history of smoking habits to identify what clinical information would best agree with the radiographic findings. Areas under the receiver operator characteristic curve (ROC) were studied to compare the performance of clinical variables relative to the radiographic assessments (Hanley & McNeil 1983). Statistical analysis was performed with the SPSS 10.1.3 software for PC (Chicago, IL, USA).

Results

Data were obtained from 168 consecutive subjects attending a medical clinic. The mean age of the subjects was 62.7 years (SD $\pm$ 9.0, range: 41–80 years). Most subjects (85.3%) were males. Diabetes mellitus was diagnosed in 10.1% and cardiovascular disease in 50% of the subjects. Smoking habits varied greatly in that 33.1% had never smoked, 44.2% had quit smoking, and 22.7% were current smokers. The average number of years of smoking among current and past smokers was

33.1 years (SD ± 13.1) with an estimated 305/cigarette/packs per year. Clinical periodontal characteristics are presented in Table 1. The absence of sites with a distance between CEJ–ABL ⩾4.0 mm was found in 6.0% of the subjects. The subject-based proportion of radiographic evidence of ABL expressed as a distance ⩾4.0 mm from the CEJ to bone crest (BL) among subjects is presented (Fig. 1).

The relationship between clinical and radiographic parameters was studied by Pearson's and Spearman's rank correlation coefficients. The best relationship between radiographic and individual clinical parameters was found between the number of teeth lost and the worst extent of BL (>60%) ($r = -0.26$, $p<0.01$) followed by the proportional distribution of plaque at the >10% bone height cut-off level ($r = 0.22$, $p<0.01$).

Binary logistic regression analysis was performed to identify predictive factors for ABL at the ⩾4.0 mm cut-off levels. The factors included in the best explanatory models in the stepwise regression analysis at the different CEJ–ABL threshold values are presented (Table 2). It was noticeable that for the severity levels >30%, >40%, >50%, and 60% ABL, tooth loss and the proportion of PDs <4.0 mm were included in the model equation. At the >20% level only proportion plaque scores and at the >30% ABL level only the proportion of BOP were identified. The proportion of BOP was also included in the models for >30% and >40% levels. No factor demonstrated a very predictable level.

Table 1. Clinical periodontal characteristics of the study population

Variable	Range	Mean	SD (±)
number of remaining teeth	3–32	21.3	8.0
proportional distribution of plaque scores (subject based)	0–100	62.1	21.9
proportional distribution of bleeding on probing	0–100	54.4	22.2
number of teeth with vertical defect ⩾3.0 mm	0–9	0.6	1.5
proportion of tooth surfaces with gingival recession	0–56	17.6	16.2
proportion of teeth with PD ⩽3.0 mm	0–90	54.0	11.5
proportion of teeth with PD 4–5 mm	0–83	21.6	42.5
proportion of teeth with PD ⩾6.0 mm	0.0–33.0	3.3	5.9

PD, probing depth.

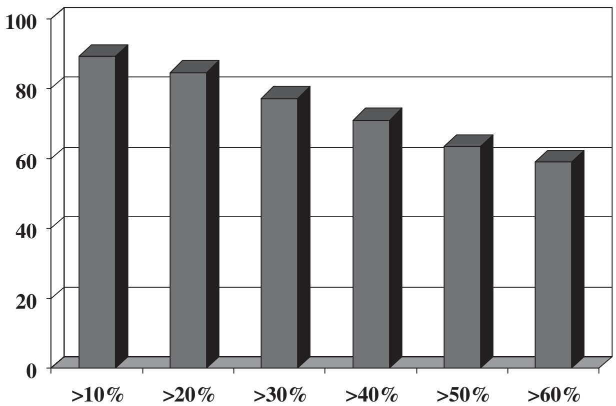

Fig. 1. Distribution of subject-based values for alveolar bone loss (CEJ–ABL) at six cut-off levels from >10% of sites through >60% of sites with evidence of a distance CEJ–ABL ⩾4.0 mm.

Table 2. Explanatory variables to the extent of alveolar bone loss at different threshold values as defined by binary logistic stepwise linear regression analysis

CEJ–BL cut-off levels	Explanatory variables	β	SE	Wald	Sign.	95% CI lower	95% CI upper
>10%	% plaque	−0.02	0.01	4.72	0.03	0.95	0.99
>20%	% BOP	−0.04	0.02	4.08	0.05	0.93	1.00
>30%	tooth loss	−0.15	0.06	6.33	0.01	0.77	0.96
	% PD⩽4.0 mm	−8.01	3.02	7.15	0.01	0.00	0.12
	% BOP	0.03	0.01	3.99	0.05	1.00	1.05
>40%	tooth loss	−0.14	0.06	6.67	0.01	0.78	0.97
	% PD⩽4.0 mm	−5.66	2.68	4.46	0.05	0.00	0.67
	% BOP	0.03	0.01	4.03	0.05	1.00	1.05
>50%	tooth loss	−0.12	0.05	7.95	0.01	0.80	0.96
	% PD⩽4.0 mm	−4.43	2.15	4.14	0.05	0.00	0.85
>60%	tooth loss	−0.14	0.04	9.51	0.01	0.80	0.95
	% PD⩽4.0 mm	−5.20	2.21	5.53	0.02	0.00	0.42

CEJ, cemento-enamel junction; ABL, bone loss; PD, probing depth.

The multi-factorial periodontal risk diagram (PPRD)

When the PPRD scores were included in the binary stepwise logistic regression analysis, all other factors studied above were excluded in the equation using the >60%, >50%, and >40% ABL cut-off values as dependent factors, respectively. The Wald coefficient factor ranged from 19.8 to 18.3, respectively ($p<0.000$), and the Nagelkirke coefficient r^2 from 0.37 to 0.35. At the >30% cut-off, the proportion of plaque scores and the PPRD score were included (Nagelkirke's coefficient $r^2 = 0.37$, Wald's coefficient = 4.5 and 15.6 with p-values 0.05 and 0.001, respectively). At the 20% cut-off level, the PPRD score was excluded and replaced with tooth loss as the explanatory variable in addition to the proportion of plaque scores. The Nagelkirke coefficient r^2 for this model was 0.32 with the Wald coefficient = 7.5 for both factors ($p<0.01$). At the >10% ABL cut-off, the PPRD score as well as the proportion of plaque were again included in the model (Nagelkirke's coefficient $r^2 = 0.32$, Wald's coefficient = 5.9 and 7.7.8, respectively, $p<0.01$).

Receiver Operator Curves

ROCs providing visual representation of the best balance between sensitivity and specificity for clinical measures of periodontal status and radiographic evidence of ABL were studied. The area under the curve for each potential explanatory factor was calculated. In order to illustrate the relationship between factors studied, ROCs are presented for the $<20\%$, $>40\%$, and $>60\%$ cut-off points for alveolar BL (Figs. 2–4). The largest area under the curve was identified for the PPRD with the best result at the $>40\%$ cut-off (area = 0.81, 95% CI: 0.74–0.89; $p<0.001$) (Fig. 3).

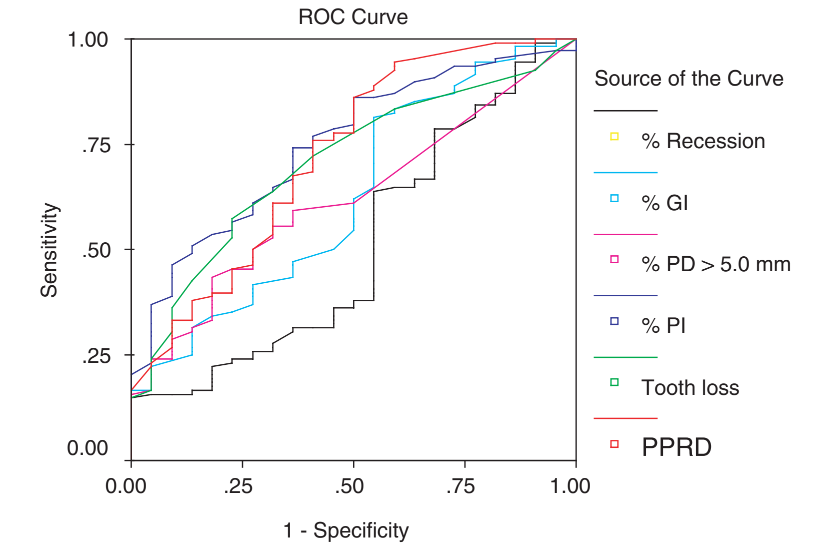

Fig. 2. Receiver operator curve for variables studied at the $>20\%$ bone loss cut-off value.

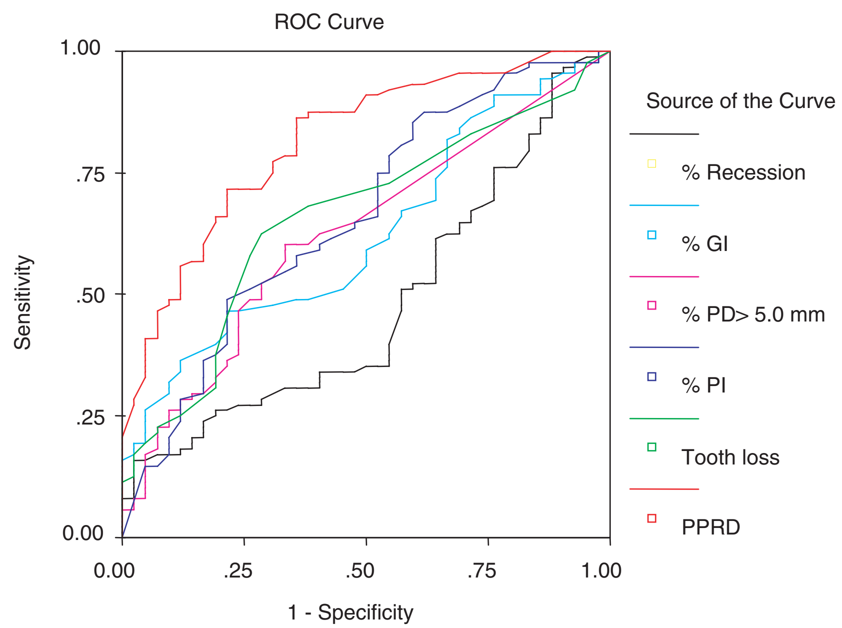

Fig. 3. Receiver operator curve for variables studied at the $>40\%$ bone loss cut-off value.

Discussion

In the present study, a large proportion of the subjects had clear evidence of a past history of periodontitis. This was documented from intra-oral radiographs as ABL and as the presence of PDs $\geqslant 6.0$ mm. One explanation for the relatively high prevalence of periodontitis in the present study might be the age range of the subjects, and the present findings are in agreement with reports elsewhere (Albandar et al. 1999). Another explanation might be the fact that these subjects were not actively seeking or receiving periodontal care. However, judging from the intra-oral radiographs regarding the number of restored tooth surfaces, the distribution of endodontically treated teeth, and the low number of teeth/subjects with radiographic evidence of caries (data not presented), it appeared that the study population consisted of dental care seeking individuals. The present study demonstrated that age was not a factor correlated to the extent of BL, arguing against the first explanation.

The high proportional scores for plaque and gingival bleeding further demonstrated that these subjects did not represent periodontally well-maintained subjects (Axelsson & Lindhe 1981). The absence of bleeding on probing may be a good indicator of periodontal health or low risk for disease progression (Lang et al. 1990, Joss et al. 1994). However, bleeding on probing was not identified as an explanatory factor at any of the ABL cut-off levels. Studies have shown that poor oral hygiene is associated with gingivitis and periodontitis (i.e. Axelsson & Lindhe 1981, Haffajee et al. 1985, Dahlén et al. 1992). It is therefore of interest that subject-based data on the proportion of tooth sites with the presence of plaque was a factor at the $>10\%$ and $>20\%$ ABL level, but was not an explanatory variable at any of the other cut-off levels.

The present study demonstrated that tooth loss was associated with ABL at all levels except the $>10\%$ and $>20\%$ levels of ABL. Tooth loss per se cannot be considered as a risk factor for alveolar ABL. However, it is logical that subjects with advanced alveolar ABL have lost more teeth. Further studies of what factors are involved in tooth loss would be of value. The present study results failing to associate common clinical parameters with ABL are consistent with the findings reported by others suggesting that clinical periodontal parameters are poor substitute measures of potential tooth loss (Hujoel et al. 1997, 1999).

Several studies have reported clinical measures of pocket PD, plaque index, and bleeding on probing, on a tooth site basis, to be poor predictors of periodontal disease activity relative to clinical attachment level changes (Badersten et al. 1981, 1990, Hujoel et al. 1997, McGuire & Nunn 1997). In the present

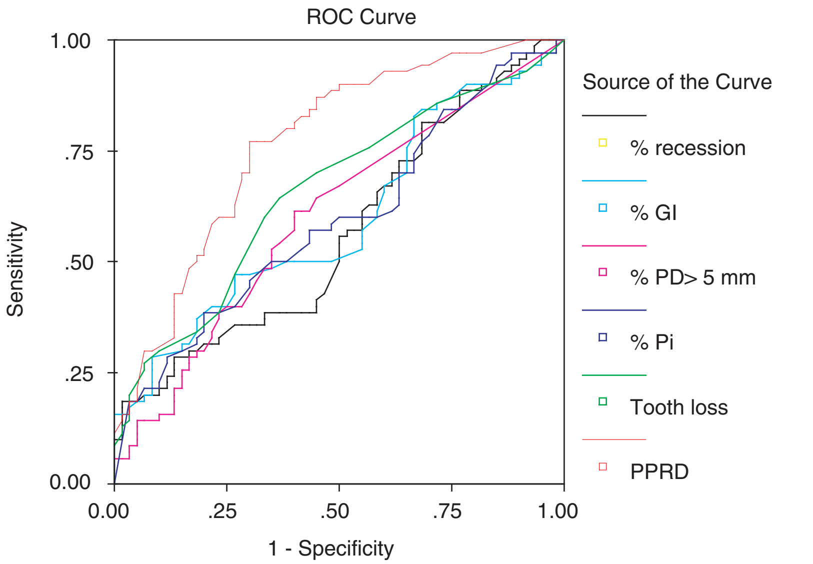

Fig. 4. Receiver operator curve for variables studied at the >60% bone loss cut-off value.

study, clinical attachment levels were not assessed. However, the extent of gingival recession was studied and gingival recession failed to be included in all of the explanatory models. It is of interest that the proportion of sites with PDs > 4.0 mm was included as a factor for several cut-off levels for ABL but not the > 6.0 mm PDs. The proportional distribution of PDs was correlated with the number of teeth lost.

In many other studies, cigarette smoking has been associated with an increased risk for periodontitis (i.e. Krall et al. 1999, Bergström et al. (2000), Bergström & Boström 2001). In the present study smoking was accounted for as the number of years the subject had been smoking and the estimated number of cigarettes/year, but neither of these two parameters were included for any of the cut-off levels. However, smoking was included in the PPRD.

Studies have shown that changes in bone height assessed by direct clinical measurements or bone sounding are in agreement with radiographic evidence of changes in bone height (Papapanou & Wennström 1989, Tonetti et al. 1993, Zybutz et al. 2000). On the other hand, studies have also shown a weak correlation between alveolar bone height and clinical PD changes (Pilgram et al. 1999). In spite of the fact that it might be anticipated that for the individual site the radiographic reading should be in agreement with clinical conditions, the present study demonstrated a relatively poor agreement at the subject-based level between radiographic and clinical assessments. Additional studies are therefore necessary to further explore the impact on subject- versus site-based data in periodontal research. Systemic health/disease conditions were not included in this analysis, but the associations between systemic conditions and periodontal status will be reported elsewhere (Persson et al., in press).

The use of a comprehensive risk diagram has been suggested for the monitoring of patients on supportive periodontal care (Lang & Tonetti 2003, Persson et al. 2003a, b). The present study demonstrated that although individual clinical periodontal variables were poor predictive factors for alveolar ABL, the combination of such factors became significantly associated with the extent of ABL.

In conclusion, the present study demonstrated that subject-based data for routine clinical measures including % bleeding on probing, % PDs at various cut-off levels, and the extent of gingival recession were not consistently in agreement with the findings of BL from intra-oral radiographs. The number of teeth lost and proportional plaque scores were predictive in cases of less severe generalized periodontitis, while information regarding smoking history and tooth loss provided predictability in defining subjects with more severe periodontitis as defined by radiographic analysis of BL. The functional PPRD demonstrated an exclusive and highly predictable association with alveolar BL. Subject-based proportional data for PDs > 4.0 mm provided poor substitute measures for the extent of ABL.

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References

Åkesson, L., Håkansson, J. & Rohlin, M. (1992) Comparison of panoramic and intraoral radiography and pocket probing for the measurement of the marginal bone level. *Journal of Clinical Periodontology* **19**, 326–332.

Albandar, J. M., Brunelle, J. A. & Kingman, A. (1999) Destructive periodontal disease in adults 30 years of age and older in the United States, 1998–1994. *Journal of Periodontology* **70**, 3–29.

Axelsson, P. & Lindhe, J. (1981) The significance of maintenance care in the treatment of periodontal disease. *Journal of Clinical Periodontology* **8**, 281–294.

Badersten, A., Nilveus, R. & Egelberg, J. (1981) Effect of non-surgical periodontal therapy. VII. Bleeding, suppuration, and probing depth in sites with probing attachment loss. *Journal of Clinical Periodontology* **12**, 432–440.

Badersten, A., Nilveus, R. & Egelberg, J. (1990) Scores of plaque, bleeding on probing, suppuration and probing depth to predict probing attachment loss. 5 years of observations following non-surgical periodontal therapy. *Journal of Clinical Periodontology* **17**, 102–107.

Bergström, J. & Boström, L. (2001) Tobacco smoking and periodontal hemorrhagic responsiveness. *Journal of Clinical Periodontology* **28**, 680–685.

Bergström, J., Eliason, S. & Dock, J. (2000) A 10 year prospective study of tobacco smoking and periodontal health. *Journal of Periodontology* **71**, 1338–1347.

Björn, H. & Holmberg, K. (1966) Radiographic determination of periodontal bone destruction in epidemiological research. *Odontologisk Revy* **17**, 232–240.

Brägger, U., Pasquali, L., Rylander, H., Carnes, D. & Kornman, K. S. (1988) Computer-assisted densitometric image analysis in periodontal radiography. A methodological study. *Journal of Clinical Periodontology* **15**, 27–37.

Brägger, U., Schield, U. & Lang, N. P. (1994) Effect of Chlorhexidine (0.12%) rinses on periodontal tissue healing after tooth extraction. (II) Radiographic parameters. *Journal of Clinical Periodontology* **21**, 422–430.

Dahlén, G., Lindhe, J., Sato, K., Hanamura, H. & Okamoto, H. (1992) The effect of supragingival plaque control on the subgingival microbiota in subjects with periodontal disease. *Journal of Clinical Periodontology* **19**, 802–809.

Fourmousis, I., Tonetti, M. S., Mombelli, A., Lehmann, B., Lang, N. P. & Brägger, U. (1998) Evaluation of tetracycline fiber therapy with digital image analysis. *Journal of Clinical Periodontology* **25**, 737–745.

Gröndahl, K., Gröndahl, H.-G. & Webber, R. L. (1983) Digital subtraction radiography for diagnosis of periodontal bone lesions with simulated high-speed systems. *Oral Surgery, Oral Medicine and Oral Pathology* **55**, 313–318.

Haffajee, A. D., Socransky, S. S., Goodson, J. M. & Lindhe, J. (1985) Intra-class correlations of periodontal measurements. *Journal of Clinical Periodontology* **12**, 216–224.

Håkansson, J., Björn, A-L. & Jonsson, B. G. (1981) Assessment of the proximal periodontal bone height from radiographs with partial reproduction of the teeth. A methodological study. *Swedish Dental Journal* **5**, 147–153.

Hanley, J. A. & McNeil, B. J. (1983) A method comparing the areas under receiver operator curves derived from the same cases. *Radiology* **148**, 839–843.

Hujoel, P. P., Leroux, B. G., deRouen, T. A., Powell, L. V. & Kiyak, H. A. (1997) Evaluating the validity of probing attachment loss as a surrogate for tooth mortality in a clinical trial on elderly. *Journal of Dental Research* **76**, 858–866.

Hujoel, P. P., Löe, H., Anerud, A., Boysen, H. & Leroux, B. G. (1999) The informativeness of attachment loss on tooth mortality. *Journal of Periodontology* **70**, 44–48.

Joss, A., Adler, R. & Lang, N. P. (1994) Bleeding on probing. A parameter for monitoring periodontal conditions in clinical practice. *Journal of Clinical Periodontology* **21**, 402–408.

Krall, E. A., Garvey, A. J. & Garcia, R. I. (1999) Alveolar bone loss and tooth loss in male cigar and pipe smokers. *Journal of the American Dental Association* **130**, 57–64.

Lang, N. P., Adler, R., Joss, A. & Nyman, S. (1990) Absence of bleeding on probing. An indicator of periodontal stability. *Journal of Clinical Periodontology* **17**, 714–721.

Lang, N. P. & Tonetti, M. S. (2003) Periodontal risk assessment (PRA). *Oral Health and Preventive Dentistry* **1**, 7–16.

Machtei, E. E., Hausmann, E., Schmidt, M., Grossi, S. G., Dunford, R., Schifferle, R., Munoz, K., Davies, G., Chandler, J. & Genco, R. J. (1998) Radiographic and clinical responses to periodontal therapy. *Journal of Periodontology* **69**, 590–595.

McGuire, M. K. & Nunn, M. E. (1997) Prognosis versus actual outcome. II. The effectiveness of clinical parameters in developing an accurate prognosis. *Journal of Periodontology* **67**, 658–665.

Papapanou, P. N. & Lindhe, J. (1992) Preservation of probing attachment and alveolar bone levels in 2 random population samples. *Journal of Clinical Periodontology* **19**, 583–588.

Papapanou, P. N. & Wennström, J. L. (1989) Radiographic and clinical assessments of destructive periodontal disease. *Journal of Clinical Periodontology* **16**, 609–612.

Persson, G. R., Falk, H. & Laurell, L. (2000) A retrospective radiographic outcome assessment study of intra-bony defects treated by osseous surgery or by bone graft procedures. *Journal of Clinical Periodontology* **27**, 104–108.

Persson, G. R., Matiulienė, G., Ramseier, C., Persson, R. E., Tonetti, M. S. & Lang, N. P. (2003a) Interleukin 1 polymorphism and increased risk for re-infection during supportive periodontal therapy. *Oral Health and Preventive Dentistry* **1**, 17–27.

Persson, G. R., Ohlsson, O., Lang, N. P. & Renvert, S. (2004) Analysis of periodontal risk profiles in adults with and without a history of myocardial infarction. *Journal of Clinical Periodontology* **31**, 19–24.

Persson, R. E., Hollender, L. G., MacEntee, M. I., Wyatt, C. C. I., Kiyak, H. A. & Persson, G. R. (2003b) Assessment of periodontal and systemic health comparing panoramic radiographs and self-reported history in older persons. Focus on diabetes mellitus. *Journal of Clinical Periodontology*, 207–213.

Persson, R. E., Hollender, L. G. & Persson, G. R. (1998) Assessment of alveolar bone levels from intra-oral radiographs in subjects between ages 15 and 94 years seeking dental care. *Journal of Clinical Periodontology* **25**, 647–654.

Pilgram, T. K., Hildeboldt, C. F., Yokoyama-Crothers, N., Dotson, M., Cohen, S. C., Hauser, J. F. & Kardaris, E. (1999) Relationships between longitudinal changes in radiographic alveolar bone height and probing depth measurements: data from postmenopausal women. *Journal of Periodontolgy* **70**, 829–833.

Renvert, S., Badersten, S. A., Nilveus, R. & Egelberg, J. (1981) Healing after treatment of periodontal intra-osseous defects (I) Comparative study of clinical methods. *Journal of Clinical Periodontology* **8**, 387–399.

Renvert, S. & Persson, G. R. (2002) A systematic review on the use of residual robbing depth, bleeding on probing and furcation status following initial periodontal therapy to predict further attachment and tooth loss. *Journal of Clinical Periodontology* **29**(Suppl. 3), 82–89.

Tonetti, M. S., Pini Prato, G., Williams, R. C. & Cortellini, P. (1993) Periodontal regeneration of human infrabony defects. III. Diagnostic strategies to detect bone gain. *Journal of Periodontology* **64**, 269–277.

Zybutz, M., Rapoport, D., Laurell, L. & Persson, G. R. (2000) Comparisons of clinical and radiographic measurements of inter-proximal vertical defects before and 1 year after surgical treatments. *Journal of Clinical Periodontology* **27**, 179–186.

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