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Can nonstandardized bitewing radiographs be used to assess the presence of alveolar bone loss in epidemiologic studies?

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Abstract – *Objective:* To compare periodontitis-associated alveolar bone loss assessment by standardized and nonstandardized radiographs in clinical and epidemiologic studies *Methods:* Participants included 37 patients aged 21–66 years with prior nonstandardized bitewing radiographs scheduled to receive bitewing radiographs as part of their next routine dental care visit. Standardized bitewing radiographs were taken with a Rinn film holder to position the film in the mouth and align the X-rays so that they were at 90° to the film. Before taking the radiograph the bite was registered in centric relation using a polyether impression material. One registered dental hygienist took and processed all the standardized radiographs. One dentist read all radiographs using a viewing box, magnifying lens, and periodontal probe with William's markings. Radiographic bone loss was measured to the closest millimeter at mesial and distal sites of the posterior teeth excluding third molars. The examining dentist was blinded to the participant's name, age, gender, or if the radiograph was standardized or nonstandardized. *Results:* Mean bone loss (±SD) was similar in the standardized and nonstandardized groups (1.60 ± 0.72 mm versus 1.64 ± 0.85 mm), and the correlation was high ($r = 0.95$). Periodontitis was defined as present if the participant had at least one site with 3, 4 and 5 mm bone loss. The Kappa statistics for concordance using these three cutoffs were good and ranged from 0.60 to 0.65. The sensitivity ranged from 72.7 to 80.8% and specificity from 88.5 to 90.9%. *Conclusions:* Periodontitis assessed as mean alveolar bone loss or the prevalence of disease based on alveolar bone loss can be accurately and reliably evaluated from nonstandardized radiographs.

Key words: bitewing; epidemiologic study; nonstandardized radiograph; periodontitis assessment; sensitivity and specificity; standardized radiograph

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It is compelling to use preexisting dental radiographs for periodontitis assessment in epidemiologic studies for several reasons. First, dental radiographs are taken frequently (usually every year) as part of routine oral health care. Secondly, it is feasible to obtain these radiographs from dental practices (1). Thirdly, periodontitis can be reliably and quantitatively be measured from them (2). Fourthly, the patient does not have to be present when the assessment is made. Fifthly, temporal sequence can be established from the date at which the radiographs were taken. Sixthly, periodontal destruction is more reliably measured from radiographs (3) than clinical examination (4). Finally, periodontal assessment using preexisting dental radiographs is less expensive than clinical examination.

Distortion of images of the teeth and their supporting structures on the film can occur while taking dental radiographs. Distortion is minimal if the film is parallel to the teeth and the angulation of the X-ray beam when it strikes the radiographic film is 90° (5, 6). Misangulation can occur as a result of operator error or anatomic features like a deep palate that make it difficult for the patient to keep the film in its correct position. Bringing the teeth together improperly can also cause misangulation and consequent distortion of the radiographic image (5). Several techniques have been proposed to minimize radiographic distortion from these sources (5, 7). All such techniques propose the use of a device to ensure that the radiographic film is held in the mouth in its correct position, the patient brings his or her teeth together in a reproducible manner, and the source of the X-rays is aligned at 90° to the film. Other sources of errors are the type of X-ray machine used to take the radiographs, process for development of the film, and individual technique. Radiographs taken with techniques and devices to restrict errors due to misangulation and irreproducible bite are called standardized radiographs. Radiographs taken in the usual clinical setting may or may not use these procedures and are called nonstandardized radiographs. Although nonstandardized radiographs have been used in epidemiologic studies to assess periodontitis (8, 9) there have been concerns that its assessment would be imprecise. Studies have shown there was good correlation between bone loss from assessed radiographs with attachment loss measured by clinical examination (10, 11), but there are no studies comparing bone loss assessment by standardized and nonstandardized radiographs. We therefore conducted this study to evaluate the diagnostic accuracy of nonstandardized radiographs.

Methods

Study population

The participants of this study were English-speaking patients aged 21–66 years who received follow-up care at Windsor Street Dental Clinic, Cambridge, MA. The clinic is affiliated to the Harvard School of Dental Medicine, and is part of the Medicaid health plan network of the Cambridge Department of Public Health. The 100 mostly low-income patients seen at this clinic every day receive comprehensive dental care. The patients needed bitewing radiographs as part of routine dental care and had previous radiographs in their dental records that were available for comparison. We excluded pregnant and lactating women, persons who were cognitively impaired, or those who could not use a film holder either because they gagged or had missing posterior teeth. We recruited all eligible consenting patients in July and August 2003. The study was approved by the Cambridge Health Alliance Institutional Review Board.

Data collection

Standardized radiographs

All the standardized radiographs were taken with the Rinn film holder (7). This device consists of film holder into which the dental radiograph fits, a plastic plate, which the patient bites on, and a rod connected to the film holder that protrudes from the patient's mouth to allow parallel alignment of the X-ray tube (7). To ensure that the patient's bite was reproducible in the standardized group of radiographs, the X-ray technician placed an impression material (Henry Schein BLU-BITE Vinyl Polysiloxane Derivative Registration Material: Henry Schein Inc., Melville, NY) on the plastic bite block. This material is routinely used to take impressions for dental prostheses. An adhesive liquid (3M ESPE Vinyl Polysiloxane Tray Adhesive: 3M, Maplewood, MN) was used to secure the position of the impression material on the block. The patient was instructed to bite on the bite block while holding his or her teeth in their most posterior position (centric relation). Once the impression material set the film holder was removed from the mouth. The film was then added; the patient set his or her teeth in the registered bite, and the X-ray was taken. The procedure was carried out on both sides of the mouth. A designated dental hygienist took all the radiographs on the same machine (Gendex, GX-770: Gender Dental Systems, Des Plains, IL). Radiographs taken in this manner have been shown to have minimum distortion because of the parallel alignment of the X-rays and reproducible bite (5, 7). The entire process took approximately 3 min.

The nonstandardized radiographs used were the most current bitewing radiographs present in the patient's dental record before the current standardized radiographs were taken. These radiographs were taken in a normal clinical setting. A Rinn film holder may have been used about half of the time but the person taking the radiograph and the X-ray machine varied. Bite registration is not utilized in nonstandardized radiographs. There were four bitewing radiographs in every case.

Radiograph assessment

A calibrated dentist read all radiographs using a viewing box and magnifying lens to aid in the detailed assessment of the landmarks. Fifteen percent of the radiographs were randomly selected and re-evaluated; the intra-examiner correlation was 0.92. Radiographic bone loss was measured to the closest millimeter between the cementoenamel junction and the alveolar bone crest using a standard Williams-marking periodontal probe (Hu-Friedy, Chicago, IL, USA). Measurements of alveolar bone loss were recorded at the mesial and distal sites of each posterior tooth. If the same site was seen in more than one radiograph, the most severe reading was recorded. Standardized and nonstandardized radiographs from the same participant were read on separate days. The dentist evaluating the radiographs did not know the participant's name, age, gender, or if the radiograph was standardized or nonstandardized.

Statistical analysis

Age, gender, and time between standardized and nonstandardized radiographs were summarized for all the participants. Mean alveolar bone loss was calculated for all posterior teeth except third molars for each participant. Spearman correlation coefficients were calculated to compare the readings of standardized and nonstandardized radiographs using the mean bone loss computed for each participant. The adjusted R^2 was obtained from multiple linear regression models to predict the mean bone loss from standardized radiographs with mean bone loss from nonstandardized radiographs as the independent variable adjusting for age (continuous), gender (dichotomous) and time between the radiographs (continuous). We calculated the discrepancy by subtracting the alveolar bone loss determined by standardized from nonstandardized radiographs and computed the mean. These analyses were repeated stratified by age (<45 years versus ≥45 years), gender (female versus male), and time between standardized and nonstandardized radiographs (≤1 year versus >1 year).

We defined three dichotomous measures of periodontitis as having at least one site with alveolar bone loss ≥3, 4 and 5 mm. The Kappa statistic was used to assess agreement between the prevalence of periodontitis in standardized and nonstandardized radiographs. We calculated the sensitivity and specificity of nonstandardized radiographs using standardized radiographs as the reference.

If individual readings for the standardized and nonstandardized radiographs were within 1 mm of each other we considered them to be acceptable agreement. A similar criterion was used for attachment loss in the NHANES examinations (12). It has been shown that bone loss from dental radiographs can be measured to the nearest 1 mm (13). We calculated the percentage of sites comparing standardized and nonstandardized radiographs that were within 1 mm of each other. We followed the STARD checklist in preparing this manuscript (14).

Results

We recruited 40 participants in this study; three of the participants could not bite on the Rinn bite block because they had missing posterior teeth and were excluded leaving 37 participants and 37 pairs of radiographs for analysis in this study. Participants ranged from 21 to 66 years in age (mean = 39.8, SD = 12.4 years). Of them 24 (65%) were female. Sixty-five percent (24/37) had at most one missing posterior tooth visible on the radiographs (Table 1). Most (65%) had the standardized and nonstandardized radiographs taken within a year, and just three lost teeth within that period (Table 1).

About 97% of the readings were acceptable with the standardized and nonstandardized radiographs being within 1 mm of each other. The mean bone loss (SD) was similar in the standardized and nonstandardized groups (1.60 ± 0.72 mm versus 1.64 ± 0.85 mm), and the correlation was high

Table 1. Characteristics of study population

Characteristic	*n* (%)
Age (years)	
<45	24 (65)
≥45	13 (35)
Gender	
Female	24 (65)
Male	13 (35)
Missing posterior teeth at time of nonstandardized X-ray	
0	16 (43)
1	7 (19)
2	6 (14)
3	5 (16)
4	2 (5)
7	1 (3)
Posterior teeth lost between radiographs	
0	34 (92)
1	1 (3)
2	2 (5)
Years between radiographs	
≤1	24 (65)
1–2	9 (24)
2–3	3 (8)
4+	1 (3)

Table 2. Comparison of mean alveolar bone loss between standardized and nonstandardized radiographs

Group	Mean bone loss measure				
	Mean bone loss score (mean ± SD)				
	Standardized radiographs	Nonstandardized radiographs	Discrepancy score	Spearman correlation coefficient (unadjusted)	[a]Adjusted R^2
All radiographs (n = 37 pairs)	1.60 (0.72)	1.64 (0.85)	0.04	0.95	0.94
Age (years)					
<45 (n = 24 pairs)	1.35 (0.47)	1.28 (0.49)	−0.08	0.94	0.88
≥45 (n = 13 pairs)	2.05 (0.89)	2.31 (0.98)	0.26	0.97	0.95
Gender					
Male (n = 13 pairs)	2.01 (0.67)	2.00 (0.78)	−0.01	0.95	0.90
Female (n = 24 pairs)	1.38 (0.65)	1.45 (0.84)	0.07	0.94	0.95
Time interval (years) between two sets of radiographs					
≤1 (n = 24 pairs)	1.65 (0.83)	1.71 (0.97)	0.07	0.95	0.95
>1 (n = 13 pairs)	1.50 (0.47)	1.51 (0.58)	0.00	0.87	0.88

[a]Adjusted for age (continuous), gender (dichotomous), time between radiographs (continuous).

(0.95) (Table 2). Further adjustment for age, gender and time between radiographs did not materially alter the results. The results were similar when we stratified by age, gender and time elapsed between standardized and nonstandardized radiographs (Table 2). The results did not change substantially when we excluded the three persons who lost teeth between the taking of the standardized and nonstandardized radiographs. The mean bone loss comparing standardized and nonstandardized radiographs was 1.51 (SD = 0.65) and 1.53 (SD = 0.75) mm, respectively, and the Spearman correlation was 0.94. The overall discrepancy was 0.04 mm and ranged from −0.08 to 0.26 across the subgroups.

We used three alternative cutoff points of bone loss to define dichotomous measures of periodontitis. Periodontitis was defined as present if the participant had at least one site with 3, 4 and 5 mm bone loss. The sensitivity ranged from 72.7 to 80.8% and specificity from 88.5 to 90.9%. The Kappa statistic for concordance ranged from 0.60 to 0.65 (Table 3). The study was not large enough to conduct a stratified analysis for the categorical data.

Discussion

The findings of this analysis show that periodontitis assessed by mean bone loss and prevalence measures using three different cutoffs measured by nonstandardized bitewing radiographs was reasonably accurate and valid. The results were consistent within subgroups of age, gender, the number of years elapsed between taking the standardized and nonstandardized radiographs, and after excluding persons losing teeth in this time. The ideal comparison between standardized and nonstandardized radiographs would have been if they were taken on the same person at the same time. We did not do this because it was ethically unjustifiable to subject the participants to unnecessary radiation solely for research purposes. The effect of a time lag between the standardized and nonstandardized radiographs would make them more different and therefore attenuate any correlation. We would expect the attenuation to be minimal because the rate of alveolar bone loss is low (0.1 mm/year) (15) especially among those people receiving dental treatment (16). Most of the participants (89%) had the radiographs taken

Table 3. Comparison of periodontitis between standardized and nonstandardized radiographs

	Standardized radiographs	Nonstandardized radiographs	Sensitivity, n (%, 95% CI)	Specificity, n (%, 95% CI)	Kappa (95% CI)
Prevalence of at least one site with bone loss					
≥3 mm	26/37	22/37	21/26 (80.8, 62.1–91.5)	10/11 (90.9, 62.3–98.4)	0.65 (0.40–0.90)
≥4 mm	11/37	11/37	8/11 (72.7, 43.4–90.3)	23/26 (88.5, 71.0–96.0)	0.61 (0.33–0.89)
≥5 mm	5/37	7/37	4/5 (80.0, 37.6–96.4)	29/32 (90.6, 75.8–96.8)	0.60 (0.26–0.95)

within 2 years, and all of them were receiving dental care. The results were very similar when we stratified by time between the radiographs.

We did not have information on smoking, but confounding was not an issue in this study because standardized and nonstandardized radiographs were taken from the same people. We adjusted for age, gender and time between radiographs in the multivariate models to reduce extraneous variation not to adjust for confounding. As expected, the adjusted and unadjusted results were very similar (Table 2). Potential underestimation of disease because only posterior teeth are considered in bitewing radiographs is slight and projected to be about 5% (17).

The mean bone loss was not significantly different for standardized radiographs compared with nonstandardized radiographs. As the difference we observed was small (0.04 mm) it is likely that this was due to chance. It is also possible that this is a reflection of less distortion among the standardized radiographs (6), as we could also see from the smaller SD. Yet another possibility is that periodontal treatment following the taking of the nonstandardized radiograph restored bone loss (16). Most of our participants received at minimum dental prophylaxis following the initial nonstandardized radiograph.

The sample size of this study was not large enough for us to evaluate the dichotomous variables for periodontitis within subgroups. We did, however, evaluate the dichotomous measures using different cutoffs. Concordance between standardized and nonstandardized radiographs was robust and consistent in all the categories we examined. Nonstandardized radiographs measured alveolar bone loss reliably (high Kappa statistics) and validly (combined sensitivity and specificity greater than 160) when compared with standardized radiographs.

One reason why we obtained good correlation between standardized and nonstandardized radiographs could be that we used bitewing radiographs. To take bitewing radiographs the film is aligned parallel to the long axes of the teeth and the X-ray beam strikes the film at 90° (6). Moreover, it has been shown that distortion in bitewing radiographs is minimal if misangulation is up to 10° (18). Even nonstandardized bitewing radiographs probably did not have much distortion (6). Standardized bitewing radiographs compared with periapical radiographs assessing mean bone loss had correlations ranging from 0.60 to 0.82, which were good but lower than what we observed in this study ($r = 0.95$) (19). This finding is consistent with the explanation that there is less distortion in bitewing as compared with periapical radiographs.

Alveolar bone loss determined by nonstandardized radiographs and clinical attachment loss are highly correlated ($r = 0.72$–0.80) (10, 11). Machtei et al. evaluated clinical attachment loss and radiographic bone loss as periodontitis outcome measures in a longitudinal study using vertical bitewings and anterior periapical films (10). They concluded that the measures are highly correlated, and either is a valid measure of periodontitis in long-term prospective studies (10). The sources of errors in measuring clinical attachment loss are degree of inflammation, probing force, probe angulation, position and thickness (20). Other factors that may influence this measurement include patient discomfort, anatomical variations in tooth contours or position, and within and between examiner variability (21).

Clinical attachment loss not only has more sources of error associated with its measurement but also is less reliably measured than radiographic bone loss. The Kappa agreement at the site level for within and between examiners, respectively, was ≥0.75 for radiographs versus 0.48–0.69 for clinical attachment loss, and 0.72–0.83 for radiographs (3) versus 0.3–0.39 for clinical attachment loss (4).

As both measures, clinical attachment loss and alveolar bone loss, are highly correlated, valid, and assess the same disease process it may be sufficient to select one of them to evaluate periodontitis in epidemiologic studies. For the conduct of epidemiologic studies assessing the same condition with both measures would not only be expensive, inefficient and redundant but may introduce type 1 error because of multiple testing. Preexisting radiographs are only available for those people who receive dental care. This is a disadvantage if the objective is to estimate prevalence of disease or treatment needs of a population, which includes nonusers of dental services. In such situations it is necessary to use clinical examination, as is done in NHANES, to estimate periodontitis prevalence. However in epidemiologic research, evaluating the relation between exposure and outcome, where we need good internal validity (22), preexisting radiographs are probably the method of choice to assess periodontitis. Periodontitis can be reliably and efficiently measured from nonstandardized radiographs when compared with clinical attachment loss.

Periodontitis assessed as mean alveolar bone loss or the prevalence of periodontitis defined on the basis of alveolar bone loss can be accurately assessed from nonstandardized radiographs. The use of nonstandardized radiographs is a practical, inexpensive, reliable, and valid way to assess periodontitis in epidemiologic studies.

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