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Clinical and radiographic outcomes following non-surgical therapy of periodontal infrabony defects: a retrospective study

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Abstract

Background and Aim: The aim of this retrospective study was to analyse the clinical and radiographic response of infrabony defects following non-surgical therapy and to detect the factors associated with such a response.

Materials and Methods: Clinical and radiographic data were retrieved from 143 consecutive patients treated with non-surgical periodontal therapy and re-assessed by the same clinician. Linear radiographic measurements of infrabony periodontal defects were performed on baseline and follow-up (12–18 months post-treatment) radiographs. Multilevel analysis was performed to analyse the associations between subject and site factors and healing of infrabony defects.

Results: A total of 126 infrabony defects from 68 of these patients were identified at baseline and included in the analysis. Statistically significant reductions in probing pocket depth, clinical attachment loss, radiographic defect depth and a widening of the radiographic infrabony defect angle were detected following treatment. Initial defect depth and use of adjunctive antibiotics were positively associated with a reduction of radiographic defect depth, whereas smoking showed a negative association.

Conclusions: Within the limitations of a retrospective analysis with no control group, this study shows favourable clinical and radiographic outcomes in periodontal infrabony defects following non-surgical therapy, with complete bone fill in some cases.

Key words: bone fill; infrabony defects; non-surgical treatment; periodontitis; radiographic

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Periodontitis is characterized by an inflammatory destruction of the supporting apparatus of the teeth, including cementum, periodontal ligament and alveolar bone. Periodontal osseous destruction can result in horizontal or vertical bony defects, depending on the direction and extent of the apical propagation of the subgingival plaque-induced lesion (Papapanou & Tonetti 2000). Periodontal vertical bony defects (infrabony defects) have been associated with a higher risk of periodontal progression and eventually tooth loss (Papapanou & Wennstrom 1991). Therefore, the presence of such vertical defects is considered to be an indication for periodontal treatment, when combined with the presence of periodontal pockets. In the past, the treatment of vertical bony defects traditionally aimed at surgical elimination of the defect through ostectomy (Schluger 1949, Friedman 1955). A landmark study a few decades ago showed clinical resolution and radiographic fill of vertical defects following open flap surgery (Rosling et al. 1975). The same was consistently seen in early-onset periodontitis cases (Lindhe & Liljenberg 1984). More recently, these defects have been considered as suitable for periodontal regeneration (Nyman et al. 1982, Cortellini & Tonetti 2000). However, the knowledge on radiographic changes in infrabony defects following non-surgical therapy is very limited.

Conflict of interest and source of funding statement

The authors declare that they have no conflict of interests.
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Most studies have shown no radiographic changes in infrabony defects following non-surgical therapy (Isidor et al. 1985, Schmidt et al. 1988), whereas a more recent study showed an increase in bone density at subtraction radiography (Hwang et al. 2008).

The aim of this retrospective study was to analyse the association between the healing of periodontal infrabony defects and baseline clinical and radiographic variables following non-surgical treatment in a cohort of individuals treated by the same periodontist. In particular, the degree of resolution of the defect (radiographic and clinical) and its association with patient- and site-based factors were studied.

Materials and methods

Study subjects

Clinical and radiographic data were retrieved from periodontal patients under care by the same operator (L. N.) in three different clinics, including two private clinics in London and Hertfordshire (UK) and the Periodontal Unit at the UCL Eastman Dental Institute and Hospital, London. Ethic approval for the analysis was granted by the U.K. National Research Ethics Service. All patients had been referred by their general dental practitioners for periodontal assessment and treatment. Inclusion criteria for the analysis were: (i) a diagnosis of aggressive periodontitis (AgP) or chronic periodontitis (CP) (Lang et al. 1999) with at least one tooth with ≥ 5 mm probing pocket depth (PPD) and clinical attachment loss (CAL) and evidence of radiographic bone loss, (ii) not pregnant, (iii) treated non-surgically by one periodontist (L. N.) throughout the course of the study and (iv) reassessed clinically and radiographically up to 12–18 months after the completion of non-surgical treatment. A total of 143 consecutive suitable patients were identified. The following demographic parameters had been collected from all subjects following a questionnaire: (i) age, (ii) gender, (iii) ethnicity, (iv) medical history, (v) current use of systemic medications, (vi) current or past smoking habit (self-reported) and (vii) known family history of periodontitis.

Clinical examination

The clinical data collected included PPD, CAL, recessions (REC) and full-mouth bleeding on probing scores (FMBS). Single pass, whole-mouth measures of the distance from the free gingival margin (FGM) to the base of the sulcus (PPD, rounded up to the next millimetre), the distance from the cement-enamel junction (CEJ) to the FGM and bleeding on probing were collected using a manual, incremental UNC-15 periodontal probe. Both PPD and REC (REC = CEJ – FGM) measurements were used to determine the CAL (CAL = PPD+REC). Six sites were measured for each natural tooth, one each at the mesiobuccal, buccal, distobuccal, distolingual, lingual and mesiolingual sites encircling the tooth. The measurements were made at the corresponding contact points or their equivalent in the case of a missing tooth and at the midpoint of buccal and lingual surfaces. A dichotomous FMBS was recorded as the percentage of total bleeding surfaces upon probing. A full-mouth dichotomous plaque score was obtained as described previously (Guerrero et al. 2005). Tooth mobility (Laster et al. 1975) and furcation involvement (Hamp et al. 1975) were also recorded. One single examiner (L. N.) carried out all the measurements. The examiner had previously been calibrated to 99.7% agreement of CAL within 2 mm in double measurements of 10 periodontitis patients with at least a 15-min. gap. The 1999 American Academy of Periodontology classification (Lang et al. 1999) was used to distinguish cases of AgP and CP, as described previously (Nibali et al. 2009). All clinical measurements were retaken at re-evaluation (12–18 months) along with a new radiographic assessment of the infrabony defect sites.

Radiographic examination

At first visit, routine long cone periapical radiographs with the parallel technique were obtained using Rinn holders (Updegrave 1951) from all sites showing >4 mm PPD. Follow-up radiographs for further treatment planning were obtained with the same technique on the same teeth after active periodontal therapy (12–18 months after the baseline examination). At baseline, all radiographs were screened to detect the presence of infrabony periodontal effects. Each radiograph was magnified approximately three times. Following the criteria described by Schei et al. (1959) and Bjorn et al. (1969), the following landmarks were identified (Fig. 1):

- CEJ on the tooth with the infrabony defect (A).
- Top of alveolar bone crest (B), defined as the most coronal part of the alveolar bone.
- Bottom of the alveolar bone crest (C), defined as the most apical part of the alveolar bone crest, where the periodontal ligament space was judged to retain its normal width.

The long axis of the tooth was identified as a line running from the tooth apex to its crown (D–E). Perpendicular lines were projected from points A to C to the long axis of the tooth on points A1, B1 and C1, respectively. The distance A1–B1 was defined as the horizontal bone loss component, B1–C1 as the vertical bone loss component and A1–C1 as total bone loss. If a restoration was present, its apical margin was used instead of the CEJ as a fixed reference point. The radiographic defect angle was identified by the lines AC and CB (Steffensen & Weber 1989, Linares et al. 2006).

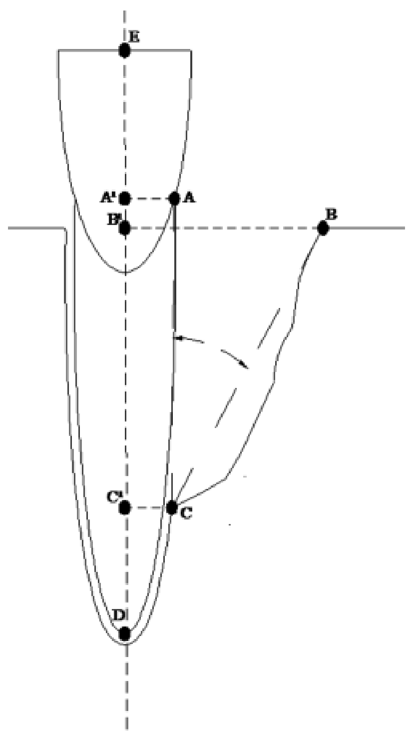

Fig. 1. Schematic representation of reference points for radiographic analysis. A^1–B^1, horizontal (suprabony) component; B^1–C^1, vertical (infrabony) component of the bony defect.

Definition of infrabony defect

Whenever the distance between points B and C was found to be ≥ 2.0 mm, with radiographic signs of bone resorption in the lateral boundary of the defect detected (Papapanou et al. 1988), and associated to PPD ≥ 5 mm in at least one of the interpoximal aspects of the tooth (buccal or lingual), the defect was considered as an infrabony or an angular defect. All teeth where the infrabony defect was associated with perio-endo pathology (as judged by the examining clinician) were excluded.

Radiographic analysis

All radiographs of sites suspected as infrabony through this screening were digitized using a standard scanner imported and analysed using customized image analysis software (Xposeit version 3.01, Torben Jørgensen, Lystrup, Denmark). The restorative status of the tooth (restored/not restored/endodontically treated) and radiographically visible presence of calculus were recorded. All radiographs were coded in a masked way, in order not to disclose whether they had been taken at baseline or at follow-up appointments. All radiographic analyses were performed by a previously trained single examiner (D. P.). Calibration of the radiographic measurements was performed by double measurements of 54 radiographs with at a least 2-h gap. Examiner reproducibility was calculated as the standard error of the mean difference of the duplicate measurements (Linares et al. 2006). This was 0.05 mm for defect depth and 0.4° for defect angle. The intra-class correlation was 0.9 for defect depth and 0.85 for defect angles. Because the before and after-treatment radiographs were not standardized, a latent variable factor analysis approach (Brown 2006) was used to correct for the potential variations in radiographic images due to positioning. The distances of crown length measured at both baseline and re-evaluation were used as the reference variable. First, the ''true'' distance of crown length was estimated by obtaining factor scores from a confirmatory factor analysis using the two radiographic measurements of crown length as the indicator variables. The ratio of the ''true'' and observed crown length was then used as the correction factors (one for baseline and one for re-evaluation) to estimate the ''true'' baseline and re-evaluation ''defect depth'' and ''defect angle'' by adjusting for the possible distortion within pairs of radiographs.

Periodontal treatment

All subjects ($n = 143$) received cause-related periodontal treatment by the same therapist (LN). This consisted of oral hygiene instructions, smoking cessation advice (when applicable), extraction of hopeless teeth and supra- and subgingival tooth debridement under local anaesthesia. In all cases, subgingival debridement was performed using manual (Gracey's curettes, Hu-Friedy, Rotterdam, the Netherlands) and piezoelectric devices (Electro Medical Systems, Nyon, Switzerland or Sirona, Chiswick, UK). In some cases, systemic antibiotics (patients $n = 15$) or local antibiotics ($n = 5$) were used as adjunctive therapy. When systemic antibiotics were used, all patients started the course on the first treatment day, and the non-surgical therapy was completed within 1 week. When applicable, selective occlusal grinding and/or removal of overhanging restoration were also performed. Full-mouth subgingival instrumentation was completed between one and four visits. All subjects were first reviewed 6–10 weeks following the completion of cause-related therapy and then entered a maintenance therapy phase, including 3-monthly visits consisting of full-mouth periodontal measurements, oral hygiene instructions and maintenance supra- and subgingival debridement. Twelve to 18 months after baseline, follow-up periapical radiographs were obtained. All available follow-up radiographs were re-analysed for the presence/persistence of infrabony defects.

Statistical analysis

Clinical data from all patients were entered in an Excel spreadsheet by independent personnel at the UCL Eastman Dental Institute, Periodontology Unit, not involved in the study, and proofed for entry errors. Continuous, normally distributed variables are reported as means ± standard deviations. Comparisons of continuous and categorical data between groups were performed using ANOVA and the χ^2 test, respectively. A one-sample *t*-test was used to detect significant changes between baseline and re-evaluation for defect depth and defect angle measures. As some patients contributed more than one infrabony defect, statistical analysis has to take the clustering of observations into account. Using patients as the unit of analysis by aggregating tooth-level data into patient-level data would result in the loss of information, but using tooth/defect as the unit of analysis may cause inflation of the sample size (Goldstein 1995, Gilthorpe et al. 2000, Hox 2002). Therefore, in this study, multilevel linear regression analyses were performed to analyse the effects of baseline radiographic, clinical and subject variables on the changes in infrabony defect depths and angles using the statistical package Stata (version 11, StataCorp 4905 Lakeway Drive, College Station, TX, USA). Apart from clustering of defects within patients being appropriately accounted for, multilevel analysis is also able to test the associations between the outcomes and explanatory variables at different levels (such as patient and defect) within the data structure. The command xtmixed in Stata was used for the multilevel analyses using the restricted maximum likelihood estimation method. The statistical significance level was set to 5% throughout the analysis.

Results

Baseline presentation

The demographic and clinical characteristics of the subjects included in the study are presented in Table 1. The great majority of patients (92%) were Caucasians. Sixty-four per cent were females and 20% of the subjects were current smokers. The average age was 51 years. The patients had an average of nearly 26 teeth present, with an average of 23 PPDs ≥ 5 mm detected. Sixty-eight of these patients had at least one radiographic infrabony defect. The total number of radiographic infrabony defect detected ($n = 135$) represented 1.8% of the total 7540 interproximal aspects examined across all individuals. Nearly 4% of all examined teeth exhibited at least one infrabony defect. Sixty-one infrabony defect were detected in the maxilla and 74 in the mandible. Thirty-six defects were located on anterior teeth, 42 on pre-molars and 57 on molars. Seventeen defects (12%) were associated with furcation lesions on the buccal sites, while 17% had a lingual furcation detected. Thirty-seven per cent

Table 1. Demographic and clinical parameters of consecutive patients treated with non-surgical periodontal therapy and included in this study

	Patients	
	($n = 143$)	%
Age	51.4 ± 10.7	–
Gender		
Male	51	35.7
Female	92	64.3
Ethnicity		
Caucasian	132	92.3
Other	11	7.7
Smoking		
No smokers	76	53.1
Former smokers	38	26.6
Current smokers	29	20.3
Diagnosis		
CP	136	95.1
AgP	7	4.9
Family history		
Positive	50	35.0
Negative	93	65.0
# Teeth present	26.4 ± 3.8	–
# PPD > 4 mm	22.7 ± 18.9	–
FMPS	–	28.5 ± 18.5
FMBS	–	26.3 ± 17.2

FMPS, full-mouth plaque score, FMBS, full-mouth bleeding on probing score; CP, chronic periodontitis; AgP, aggressive periodontitis; PPD, probing pocket depth.

of defects were on teeth with grade I to III mobility.

Clinical outcomes

In the 143 patients included in the study, 135 infrabony defects were identified. Out of these, four teeth were extracted as part of the initial therapy (as considered hopeless/irrational to treat). Five of the remaining follow-up radiographs were not comparable to their baseline images because different angulations of the films made the infrabony defect sites not visible. Therefore, 126 infrabony defects in 68 patients had baseline and re-assessment radiographic and clinical data available (Table 2). For these defects, the average PPD reduction from baseline to re-evaluation was 2.24 and 2.29 mm, respectively, for the buccal ($p<0.001$) and lingual ($p<0.001$) interproximal aspects of the infrabony defect. The average CAL gain from baseline to re-evaluation was 1.42 and 1.50 mm, respectively, for the buccal ($p<0.001$) and lingual ($p<0.001$) interproximal aspect of the infrabony defect. These figures for initial PPDs < 7 mm were, respectively, 1.11 and 1.33 mm (mesio- or disto- buccal and lingual PPD reduction) and 0.56 and 0.65 mm (mesio- or disto-buccal and lingual CAL gain), while for initial PPDs ≥ 7 mm, they were 3.32 and 3.09 mm (mesio- or disto-buccal and lingual PPD reduction) and 2.29 and 2.31 mm (buccal and lingual CAL gain) (data not presented in tables). The overall full-mouth plaque score in all patients was reduced from an average of 27% at baseline to 15% (data not presented).

Radiographic outcomes

Following non-surgical therapy, the horizontal (suprabony) component of the defects remained largely unchanged, while the average radiographic vertical defect depth and average defect angle changed from 3.77 mm and 37.4° at baseline to 3.08 mm and 44.1°, respectively, at re-evaluation ($p<0.001$ for both parameters). Eighty-nine of these defects had persistent radiographic defect depth ≥ 2.0 mm at follow-up, while 37 of them (29%) were reduced to < 2.0 mm. The average radiographic defect depth reduction amounted to 0.92 mm in non-smokers ($p<0.001$) and to 0.07 mm in smokers ($p = 0.739$). Among non-smokers, 39% of the original defects had reduced to < 2 mm, while the same figure for smokers was 8% (data not presented in tables). The defect angle change was equal to +9° in non-smokers ($p<0.001$) and +1° in smokers ($p = 0.648$). Several sites (see Figs 2 and 3) showed a remarkable reduction in the defect depth measurements, accompanied by

Table 2. Comparison between baseline and re-evaluation (following non-surgical periodontal treatment) of infrabony defects

	Infrabony defects ($n = 126$)		
	baseline (mean ± SD)	re-evaluation (mean ± SD)	*t*-–test
PPD (mesio- or distobuccal) (mm)	6.5 ± 0.2	4.2 ± 0.1	$p<0.0001$
PPD (mesio- or distolingual) (mm)	6.7 ± 0.1	4.4 ± 0.1	$p<0.0001$
REC (mesio- or distobuccal) (mm)	0.7 ± 0.1	1.5 ± 0.1	$p<0.0001$
REC (mesio- or distolingual) (mm)	0.5 ± 0.1	1.3 ± 0.1	$p<0.0001$
CAL (mesio- or distobuccal) (mm)	7.2 ± 0.2	5.7 ± 0.2	$p<0.0001$
CAL (mesio- or distolingual) (mm)	7.2 ± 0.2	5.7 ± 0.2	$p<0.0001$
Total bony defect (mm)	8.3 ± 0.2	7.4 ± 0.2	$p<0.0001$
Suprabony defect (mm)	4.5 ± 0.2	4.3 ± 0.2	$P = 0.246$
Infrabony defect depth (mm)	3.8 ± 0.1	3.1 ± 0.2	$p<0.0001$
Defect angle (°)	37.4 ± 0.8	44.1 ± 1.5	$p<0.0001$

t-test values for differences between the two time points are presented in the last column.
CAL, clinical attachment loss; REC, recessions; PPD, probing pocket depth.

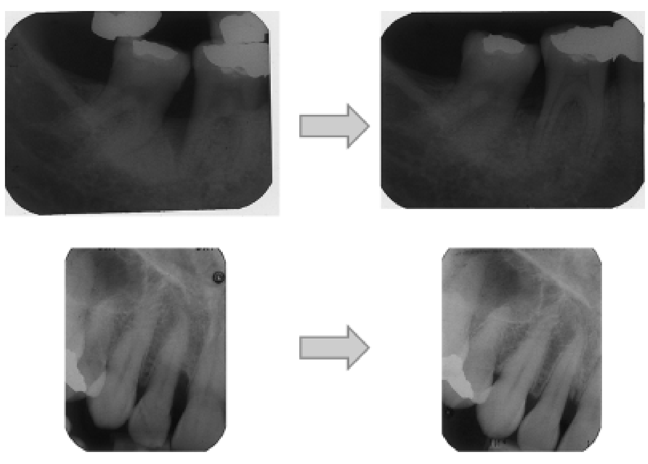

Fig. 2. Baseline and re-evaluation (12 months post-treatment) radiographs of two periodontal infrabony defects treated with non-surgical periodontal therapy, and exhibiting resolution of radiographic infrabony defect.

an increase in the defect angle, with a complete resolution of the infrabony defect in some instances (Figs 2 and 3).

The results from the multilevel analysis (Table 3) showed that greater radiographic defect depth reduction was found in sites with greater initial defect depth (0.28 mm, 95% CI = 0.08 to 0.48 mm, $p = 0.005$) and in patients with the use of adjunctive antibiotics (systemic $n = 11$, local $n = 1$) (1.10 mm, 95% CI = 0.29 to 1.90 mm, $p = 0.007$). Current smokers had less radiographic defect depth reduction (− 0.72 mm, 95% CI = − 1.39 to 0.05 mm, $p = 0.034$) than non-smokers. Defect angle changes (defined as re-evaluation minus baseline) were negatively associated with the initial defect angle (− 0.36°, 95% CI = − 0.71 to − 0.01°, $p = 0.045$), i.e. lesions with greater angles on average showed smaller increases in defect angles, and lesions adjacent to premolars (− 8.98°, 95% CI = − 15.86° to − 2.10°, $p = 0.011$) showed less increase in the defect angle than those adjacent to anterior teeth. Patients treated with adjunctive antibiotics showed greater increases in defect angles (10.25°, 95% CI = 1.79 to 18.70°, $p = 0.018$).

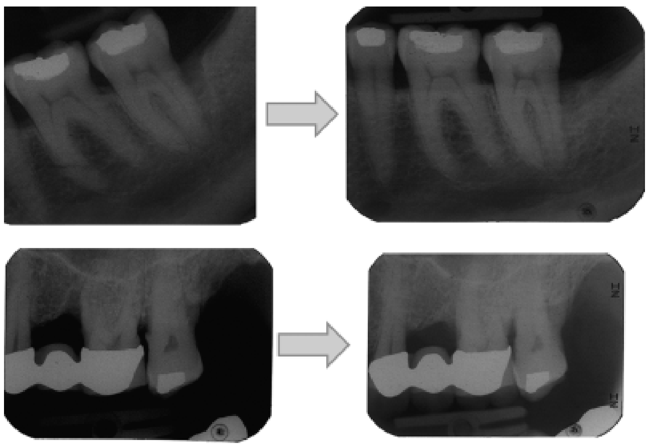

Fig. 3. Baseline and re-evaluation (12 months post-treatment) radiographs of two periodontal infrabony defects treated with non-surgical periodontal therapy, and exhibiting resolution of radiographic infrabony defect.

Discussion

Within the limitations of a retrospective design with no untreated controls, with possible residual radiographic measurement error, this study clearly indicates that bone fill can occur in periodontal infrabony defects (as assessed clinically and radiographically) following non-surgical periodontal therapy (NSPT) and oral hygiene instructions. Complete bone fill occurred in a small proportion of individuals. The bone fill was characterized by a reduction of defect depth associated with widening of the infrabony angle, likely to be due to the bone fill in the narrowest part of the defect (the deepest component). The reduction of defect depth was associated with the initial defect depth and the use of adjunctive antibiotics and was negatively associated with smoking.

Infrabony defects were identified at baseline in 68 of the 143 periodontitis patients treated non-surgically and re-assessed clinically and radiographically 12–18 months later. The presence of infrabony defects has been associated previously with local factors such as defective root cementum, interpoximal distance, food impaction, trauma and asynchronic propagation of subgingival plaque on two adjacent surfaces (Tal 1984, Papapanou & Tonetti 2000). Their aetiology is due to apical propagation of the subgingival plaque-induced lesion

Table 3. Results from multilevel linear regression for association with reduction in radiographic defect depth and defect angle

Outcome	Defect depth change			Defect angle change		
	coefficients	95% confidence interval	*p*-value	coefficients	95% confidence interval	*p*-value
Fixed effects						
Subject factors						
Smoking (current)	− 0.72	(− 1.39, − 0.05)	0.034	− 4.47	(− 11.62, 2.69)	0.221
Gender (male)	0.16	(− 0.57, 0.89)	0.673	2.19	(− 5.36, 9.74)	0.570
Age	0.002	(− 0.03, 0.03)	0.886	0.16	(− 0.18, 0.50)	0.357
AgP diagnosis (*versus* CP)	0.03	(− 1.17, 1.23)	0.962	− 1.65	(− 14.44, 11.14)	0.800
Site factors						
Previous endodontic treatment	− 0.24	(− 1.25, 0.77)	0.64	− 0.35	(− 10.11, 9.41)	0.944
Pre-molar (*versus* anterior)	− 0.73	(− 1.47, 0.14)	0.055	− 8.98	(− 15.86, − 2.10)	0.011
Molar (*versus* anterior)	− 0.47	(− 1.25, 0.30)	0.229	− 0.06	(− 7.21, 7.09)	0.986
Initial defect depth	0.28	(0.08, 0.48)	0.005	− 0.53	(− 2.38, 1.32)	0.575
Initial defect angle	0.01	(− 0.02, 0.05)	0.501	− 0.36	(− 0.71, − 0.01)	0.045
Visible calculus (on radiograph)	0.44	(− 0.55, 1.44)	0.382	7.80	(− 1.71, 17.31)	0.108
Treatment factors						
Multiple sessions (*versus* 1-day therapy)	0.48	(− 0.25, 1.21)	0.200	5.34	(− 2.40, 13.09)	0.176
Adjunctive antibiotics	1.10	(0.29, 1.90)	0.007	10.25	(1.79, 18.70)	0.018
Random effects						
Level-2 variance	0.39	(0.66–2.36)		7.49	(4.0–14.0)	
Level-1 variance	1.44	(1.21–1.71)		12.64	(10.42–14.34)	

Only the final model is reported (other subject and site factors were tested previously and discarded from the model as non-significant). The regression coefficients from multilevel linear regression analysis are reported in the first column, followed by confidence intervals and *p*-values for each investigated factor.

CP, chronic periodontitis; AgP, aggressive periodontitis.

with the concomitant resorption of bone within a couple of mm radius from the root surface (Papapanou & Tonetti 2000). Periodontal infrabony defects have traditionally been considered challenging from a management point of view and have been associated with a higher risk of periodontal progression and eventually tooth loss in the absence of systematic periodontal therapy (Papapanou & Wennstrom 1991), but not in periodontally well-maintained individuals (Pontoriero et al. 1988). Therefore, the presence of such vertical defects is generally considered as an indication for periodontal treatment (Papapanou & Tonetti 2000). In particular, periodontal infrabony defects have been considered suitable for periodontal regeneration with a variety of techniques (Nyman et al. 1982, Cortellini et al. 1994, Pagliaro et al. 2009).

Only a few studies have attempted previously to assess radiographic bone changes following non-surgical therapy (NSPT) in patients with periodontitis. Isidor et al. (1985) compared the radiographic changes in infrabony defects 12 months after treatment with three different modalities: modified Widman flap surgery, reverse bevel surgery and non-surgical therapy in 16 patients. The average PPD reduction in the 13 sites treated with NSPT was almost identical to the one in the present study (3.4 *versus* 3.2 mm in ≥ 7 mm PPD), while the CAL reduction was inferior (1.6 *versus* 2.3 mm). These authors reported that the radiographic bone level was essentially unchanged following non-surgical therapy. Renvert et al. (1985) followed up for 5 years 21 pairs of infrabony defects treated with either non-surgical therapy or flap surgery. All sites (average baseline PPD 6.6 mm) had an average 1.2 mm CAL gain and 0.3 mm probing bone level gain at 1 year. However, no radiographic data were presented. Other studies on combinations of periodontal defects (infrabony and suprabony) treated with NSPT showed minimal changes in bone height (Schmidt et al. 1988, Machtei et al. 1998). A review of such studies concluded that NSPT has minimal potential for osseous repair of infrabony defects (Greenstein 1992). However, studies where radiographs were analysed by digital subtraction radiography reported an increase of interproximal bone density following NSPT in periodontal defects (not specifically selected as infrabony defect) (Dubrez et al. 1990, Okano et al. 1990). Recently, Hwang et al. (2008) observed an increase in bone density in 39 sites presenting >3 mm vertical bone loss, treated with NSPT and re-assessed 12 months later. In agreement with the present study, they noted more bone density gain in sites with deeper initial PPD.

The present study is the first, to our knowledge, to examine radiographic bone changes with linear measurements in a large cohort of patients treated with NSPT, and where associations between defect depth reduction and site and subject factors were also evaluated. Multilevel analysis was used to account for the inherent hierarchical structure of periodontal data. This means that multiple defects within patients are taken into account in the same analysis, with a possible effect at different levels (subject, tooth and site) converging towards an overall model. The estimated reduction in radiographic defect depth was of approximately 0.7 mm (from 3.8 to 3.1 mm) overall. However, this value was approximately 1.0 mm in non-smokers, while virtually no change was observed in smokers (0.07 mm). The radiographic assessor was masked in relation to the time point of analysis, and this should have minimized the risk of bias. Studies comparing radiographic linear measurements and true (intra-surgical) bone levels have shown that radiographic measures underestimate bone loss and changes in alveolar bone (Tonetti et al. 1993, Toback et al. 1999, Zybutz et al. 2000).Therefore, true reductions in radiographic defect depth may actually be even larger than those shown in this study. The choice of linear measurements rather than subtraction radiography was mainly due to the lack of standardization between baseline and follow-up radiographs. The lack of standardization of radiographs is certainly a limitation due to potential random and systematic errors in taking and measuring radiographs. However, it should be noted that while the standardization of radiograph taking may reduce the random errors, it will not reduce the systematic errors. For example, with the help of individual stents and digital radiographs, the random errors in positioning periapical radiographs and image processing can be reduced, but the systematic distortion in the projective geometry between tooth and its images on the radiographs is simply replicated in the pair of pre- and post-treatment radiographs. The systemic errors may be estimated if the reference anatomic landmarks such as crown length were measured clinically for all teeth. We have shown elsewhere (Tu et al. 2010) that the latent variable method we used in this study is at least as efficient at correcting for random errors and biases in duplicate radiographic measurements as previously described methods (Linares et al. 2006).

Studies on periodontal regeneration have shown a 1-year reduction of radiographic defect depth generally ranging from just over 1 to 4 mm, often associated with some degree of crestal resorption (Cortellini et al. 1993, Klein et al. 2001, Eickholz et al. 2004, Francetti et al. 2004, Linares et al. 2006). More importantly, it is not clear whether in any published studies on periodontal regeneration results following NSPT had been re-assessed up to 12 months later, before proceeding to surgery. Based on the results of the present study, the observed bone gain results in those studies could partially be due to NSPT. Mechanisms of healing after non-surgical therapy involve the formation of a long junctional epithelium and the present study shows that this can be accompanied by changes in the hard tissues as well, although it is beyond the scope of this study to ascertain whether the radiographic changes are a sign of true bone apposition or of just an increase in bone mineralization (bone density). It could be speculated that complete bone fill was seen in cases where bone loss had occurred, but supra-crestal periodontal fibres were still attached to the cementum. The improvements in pocket depth and bone level observed in this study following NSPT might have drastically changed the prognosis of the affected teeth, because both factors have been associated with long-term tooth survival (McGuire & Nunn 1996). Among local factors, initial disease severity (expressed as PPD and CAL) was associated with a better clinical and radiographic response, in agreement with previous studies (Cobb 2002). A narrower baseline defect angle was associated with increased widening of the follow-up defect angle, in agreement with studies on periodontal regeneration (Linares et al. 2006), although this might partly be explained by the mathematical coupling between the changes and the initial values (Tu & Gilthorpe 2007). Infrabony defects on pre-molars seemed to respond less well to treatment than on other teeth, especially with regard to change in the defect angle. The finding that smoking was negatively associated with the extent of bone fill is in agreement with previous studies on healing following NSPT and GTR (Tonetti et al. 1995, Labriola et al. 2005) and stresses the negative influence of smoking on wound healing (Palmer et al. 2005) and tooth prognosis (Mc Guire & Nunn 1996).

Interestingly, we also observed an increase in radiographic defect depth reduction in patients treated with adjunctive antibiotics. This is in agreement with a study with a split-mouth design that showed ''positive changes'' (no linear measurements performed) to alveolar bone levels when NSPT was associated with topical subgingival antimicrobial treatment in periodontitis patients (Rosling et al. 1983). This observation needs to be assessed cautiously, as the present study was not a randomized trial, and despite the adjustments in the analysis, factors influencing the decision to use antimicrobials, rather than their actual use, might be associated with this reduction. If confirmed, this effect would be in agreement with reports of increased CAL reduction following the adjunctive use of antimicrobials, especially in deep pockets and patients with AgP (Guerrero et al. 2005). In this study, adjunctive antimicrobials were only used in a subset of patients, starting on the day of non-surgical debridement completion, as suggested by recent guidelines (Herrera et al. 2008). The possible side effects linked with antibiotic usage were not systematically recorded, although no major adverse events were reported by any of the patients at reassessment. A few of the treated cases presented here ($n = 6$) have received selective grinding as part of the therapy owing to the presence of interferences. Because of the small number of such cases, it is unlikely that this occlusal therapy might have a major impact on the conclusion of the present study. Prospective randomized-controlled trials should be performed to confirm which factors are associated with a reduction of defect depth and resolution of periodontal infrabony defects following NSPT, in order to maximize its clinical benefits. Furthermore, these results may not be generalizable as the treatment was provided by just one clinician (L. N.). If the results from this investigation are confirmed by larger prospective and controlled studies, this might have implications for both periodontal research and clinical practice.

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Clinical Relevance

Scientific rationale for the study: There is a paucity of data on the clinical and radiographic response of periodontal infrabony defect following non-surgical therapy only.

Principal findings: Infrabony defects can be consistently reduced following NSPT. The use of adjunctive antimicrobials showed some association with reduction of defect depth, while smoking was negatively associated with it.

Practical implications: NSPT can be effective in determining favourable clinical and radiographic outcomes in infrabony defects, sometimes giving rise to complete defect resolution.