J Clin Periodontol 2015; 42: 853–859 doi: 10.1111/jcpe.12443

Journal of Clinical Periodontology

Minimally invasive non-surgical approach for the treatment of periodontal intrabony defects: a retrospective analysis

Luigi Nibali[1,2], Daniela Pometti[2], Tzu-Ting Chen[3] and Yu-Kang Tu[3]

[1]Periodontology Unit and Department of Clinical Research, UCL Eastman Dental Institute, London, UK; [2]Private practice, London and Bishop's Stortford, UK; [3]Graduate Institute of Epidemiology and Preventive Medicine, College of Public Health, National Taiwan University, Taipei, Taiwan

Nibali L, Pometti D, Chen T-T, Tu Y-K. Minimally invasive non-surgical approach for the treatment of periodontal intrabony defects: a retrospective analysis. J Clin Periodontol 2015; 42: 853–859. doi: 10.1111/jcpe.12443

Abstract

Aim: The aim of this retrospective analysis was to assess healing of intrabony defects treated with minimally invasive non-surgical therapy (MINST).

Methods: A retrospective analysis was carried out in 35 consecutive intrabony defects treated by MINST (without any adjuncts) in 23 non-smoking patients. All defects had a radiographic intrabony component > 3 mm and had clinical and radiographic data available at baseline and 12 after treatment. Pre- and post-treatment radiographs were analysed and bone levels were compared by multilevel linear regression adjusted by latent variable method.

Results: Following MINST, the average PPD and CAL reduction in the intrabony defects were 3.12 mm and 2.78 mm respectively ($p < 0.001$). The average radiographic intrabony vertical defect depth was reduced by 2.93 mm (from 6.74 mm to 3.81 mm) ($p < 0.001$), whereas the average defect angle changed from and 28.5° at baseline to 44.4° at re-evaluation ($p < 0.001$). Smaller initial defect angles and deeper initial defect depths were associated with greater defect depth reduction. Greater initial defect angles were associated with less defect angle change.

Conclusions: This paper shows considerable clinical and radiographic improvements after MINST, therefore bringing evidence to support its efficacy for the treatment of intrabony defects in non-smokers.

Key words: healing; intrabony defects; non-surgical therapy; periodontitis; radiographic bone gain

Accepted for publication 27 July 2015

Untreated periodontal vertical bony defects (intrabony defects) are believed to have a high risk of further progression and eventually tooth loss (Papapanou & Wennstrom 1991). Therefore, they are considered sites requiring therapy, often beyond non-surgical debridement. Advisable therapy has moved from surgical elimination of the defect (Friedman 1955) to more conservative open flap approaches avoiding bone resection (Rosling et al. 1976) to the even more conservative periodontal regeneration, aiming to regenerate the lost periodontal attachment and bone (Nyman et al. 1982). Robust evidence shows that periodontal regenerative surgery results in clinical radiographic improvements in intrabony defects (Nyman et al. 1982, Cortellini & Tonetti 2000). However, this is associated with potential morbidity and high costs due to the use of bone graft and barrier materials and is not always predictable (Needleman et al. 2006).

A recent retrospective study from our group has shown that non-surgical periodontal treatment of intrabony defects results in clinical improvements (measured as PPD reductions and CAL gain) but also

Conflict of interest and source of funding statement

The authors declare no conflicts of interest. No specific funding was obtained for the analysis reported in this paper.

in bone fill of the bony defects, measurable radiographically. The extent of the radiographic resolution of the defect was positively associated with initial defect depth and use of adjunctive antibiotics, whereas smoking seemed to negatively influence this outcome (Nibali et al. 2011). More recently, MINST (minimally invasive non-surgical periodontal therapy) has been introduced as a concept aiming to obtain extensive subgingival debridement with minimal tissue trauma. Interestingly, no clinical differences were detected in the healing of intrabony defects in a study comparing minimally invasive surgical regenerative and non-surgical interventions (Ribeiro et al. 2011). These authors observed a CAL gain of 2.8 mm with a surgical approach and 2.6 mm with a non-surgical approach in intrabony defects at the 6 months follow-up, not observing any differences in gingival recessions between the two groups. Therefore, minimally invasive non-surgical periodontal therapy (MINST) is emerging not just as a pre-requisite but also as a potential treatment alternative for the intrabony defects. However, no studies, to our knowledge, have been published on radiographic healing of periodontal intrabony defects following MINST. Hence, the aim of this study was to perform a retrospective analysis to assess the healing of intrabony defects in non-smoking individuals following the use of MINST.

Materials and Methods

Clinical and radiographic data were retrieved from periodontal patients under care by the same operator (L. Nibali) in three different private clinics in London and Hertfordshire (UK). All patients had been referred by their general dental practitioners for periodontal assessment and treatment. The London City & East NHS Research Committee gave a favourable opinion for the analysis to be carried out as service evaluation. Inclusion criteria for patients to be included in the analysis were: (i) not pregnant, (ii) non-smokers (or smokers who had given up at least 2 years before the baseline visit) (iii) a diagnosis of 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, (iv) presenting with at least 1 intrabony defect, with a radiographic intrabony component ≥3 mm as previously defined (Eickholz et al. 2004) not in a furcation-involved area, (v) judged not to have periodontal-endodontic pathology requiring endodontic therapy, (vi) treated non-surgically by one periodontist (L. Nibali) without any adjuncts (antimicrobial or host-modulating agents) and re-assessed clinically and radiographically at least 12 months after the completion of MINST. A total of 23 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.

Clinical examination

Full-mouth clinical measurements of the distance from the free gingival margin (FGM) to the base of the sulcus (PPD, rounded up to the next millimetre) and of the distance from the cement-enamel junction (CEJ) to the FGM (recession, REC) were collected using a manual UNC-15 periodontal probe. The clinical attachment level (CAL) was calculated as 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. A dichotomous full-mouth bleeding score (FMBS) was recorded as the percentage of total bleeding surfaces upon probing. A full-mouth dichotomous plaque score was obtained as described previously (Nibali et al. 2011). Tooth mobility (Laster et al. 1975) and furcation involvement (Hamp et al. 1975) were also recorded. One single examiner (L. Nibali) carried out all the measurements. The examiner had previously been calibrated to >99% agreement of CAL within 2 mm in double measurements of 10 periodontitis patients with at least a 15-min. gap. All clinical measurements were re-taken at re-evaluation (at least 12 months later) along with a new radiographic assessment of the intrabony defect sites, for clinical purposes.

Radiographic examination

At first visit, routine long cone periapical radiographs with the parallel technique were obtained using Rinn holders (Updegrave 1951) from all intrabony defects for treatment planning purposes. Follow-up radiographs for further treatment planning were obtained with the same technique on the same teeth after active periodontal therapy (at least 12 months after the baseline examination). To clarify inclusion for this analysis, potentially suitable radiographs were screened as previously described (Nibali et al. 2011). 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 the midpoint of its occlusal surface (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). Whenever the distance between points B and C was found to be ≥3 mm, with radiographic signs of bone resorption in the lateral boundary of the defect detected as previously described

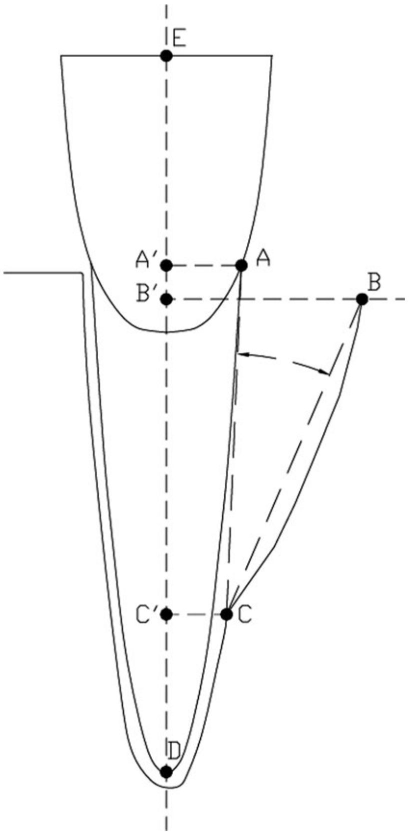

Fig. 1. Representation of reference points for radiographic analysis: A1–B1, horizontal (suprabony) component; B1–C1, vertical (intrabony) component of the defect.

(Papapanou et al. 1988), and associated to PPD ≥ 5 mm in at least one of the inter-poximal aspects of the tooth (buccal or lingual), the defect was considered suitable for the analysis.

Radiographic analysis

All radiographs of selected sites were digitized using an EPSON expression 1600 professional scanner (Long Beach, CA, USA), imported and analysed using a specific software (AutoCAD 2014, Autodesk, Inc., San Rafael, CA, USA). 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. Pometti). A calibration exercise was carried out for the radiographic assessments, including 20 duplicate measurements of bone levels and defect angles performed in separate days. The intra-class correlation coefficients were between 0.96 and 0.98 for linear and angle measurements, indicating a very good reproducibility in radiographic measurements.

Periodontal treatment

All patients included in this study had received cause- related periodontal treatment by the same therapist (LN), including oral hygiene instructions and supra- and subgingival tooth debridement under local anaesthesia. This was performed following the concepts of minimally-invasive non-surgical periodontal therapy (MINST) (Ribeiro et al. 2011). In the absence of a universally accepted protocol for MINST, the following principles were followed:

1 Thorough debridement of the root surface up to the bottom of the periodontal pocket under local anaesthesia.
2 Attempt to minimize the trauma to the soft tissues with the use of prevalently piezo-electric devices with specific thin and delicate tips (Hu-Friedy after five plus 25K straight insert UI25KSF10S, Hu Friedy, Rotterdam, the Netherlands; Siroperio 1, 2, 3 and 7, Sirona, Salzburg, Austria; Woodpecker P3 tip, Guilin Woodpecker, Guilin, China), complemented by Gracey minicurettes including the range of “after five” and “micro mini five” curettes (Hu Friedy, Rotterdam, the Netherlands). It was deliberately avoided to “smooth” the root surface or to perform gingival curettage.
3 Use of 3.4× magnification loupes.
4 Attempt to stimulate the formation of a stable blood clot, by natural filling of the intrabony defect with blood following debridement (the use of subgingival rinses was avoided).

All subjects were first reviewed approximately 3 months 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 up to 12 months after baseline, when new clinical and radiographic measurements were taken for treatment planning purposes.

Statistical analysis

Clinical data from all patients were entered in an Excel file. Continuous, normally distributed variables are reported as means ± standard deviations. The one-sample *t*-test was used to assess the changes between baseline and re-evaluation for probing pocket depth, recessions, clinical attachment loss, defect depth, and defect angle measures. Reduction in the intrabony component was the primary outcome and the change angle was the secondary outcome. Therefore, two regression analysis were performed. As some patients contributed more than one intrabony defect, further statistical analysis took the clustering of observations into account by using multilevel modelling. 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). In this study, multilevel linear regression analyses were performed to analyse the effects of baseline radiographic, clinical and subject variables on the changes in intrabony defect depths and angles using statistical package Stata version 13 (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 mixed was used for the multilevel analyses using the restricted maximum likelihood estimation method. Since the before and after-treatment radiographs were not taken in a standardized way, a latent variable factor analysis approach (Brown 2006) was used to correct for the potential variations in radiographic images due to positioning. This method had been shown to achieve a better correction for measurement error in a simulation study (Tu et al. 2010) and used in a previous clinical study (Nibali et al. 2011). The statistical significance level was set to 5% throughout the analysis.

Results

Baseline presentation

The demographic and clinical characteristics of the 23 subjects included in the study are presented in Table 1. The great majority of patients (83%) were Caucasians and fifty-seven per cent were females. The average age was 51 years. The patients had an average of nearly 27 teeth present, with an average of 29 PPDs >4 mm detected. Nine of these patients had more than one radiographic intrabony defect. The intrabony defects were located mainly on molars ($n = 23$), followed by premolars ($n = 7$), incisors ($n = 4$) and canines ($n = 1$). Twenty-six defects were located in the mandible and 9 in the maxilla. Table 2 shows the characteristics of the 35 intrabony defects included in this study. The defects had a baseline average PPD of 7.08 mm (7.4 mm buccal and 6.8 lingual), with average 0.6 mm gingival recession (0.6 mm buccal and 0.5 lingual). The average CAL was 7.64 mm (8.0 mm buccal and 7.3 lingual). Radiographically, a 6.7 mm intrabony defect was detected, with a 28.5° average defect angle. The average suprabony component of the defects was 2.1 mm, for a total bony defect (CEJ to bottom of the defect) of 8.9 mm. Last follow-up clinical and radiographic measurements were taken 12–24 months after MINST (average 17 months).

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

	Patients	
	($n = 23$)	%
Age	51 ± 10	–
Gender		
Male	10	43.5
Female	13	56.5
Ethnicity		
Caucasian	19	82.6
Other	4	17.4
No. teeth present	27.2 ± 3	–
No. PPD > 4 mm	28.8 ± 21.9	–
FMPS	–	24.7 ± 19.2
FMBS	–	25 ± 17.1

FMPS, full-mouth plaque score; FMBS, full-mouth bleeding on probing score; PPD, probing pocket depth.

Table 2. Comparison between baseline and re-evaluation (following non-surgical periodontal treatment) of intrabony defects. *T*-test values for differences between the two time-points are presented in the last column

	intrabony defects ($n = 35$)		*t*-test
	Baseline (mean ± SD)	Re-evaluation (mean ± SD)	
PPD (mesio- or distobuccal) (mm)	7.4 ± 1.9	3.9 ± 1.5	$p < 0.0001$
PPD (mesio- or distolingual) (mm)	6.8 ± 2.4	4.1 ± 1.4	$p < 0.0001$
REC (mesio- or distobuccal) (mm)	0.7 ± 0.8	1.0 ± 1.2	$p = 0.1328$
REC (mesio- or distolingual) (mm)	0.5 ± 0.7	0.8 ± 0.9	$p = 0.0831$
CAL (mesio- or distobuccal) (mm)	8.1 ± 1.9	4.9 ± 1.7	$p < 0.0001$
CAL (mesio- or distolingual) (mm)	7.3 ± 2.6	4.9 ± 1.5	$p < 0.0001$
PPD (deepest site)	7.8 ± 2.0	4.5 ± 1.4	$p < 0.0001$
CAL (worst site)	8.6 ± 2.2	5.4 ± 1.5	$p < 0.0001$
Total radiographic defect (mm)	8.9 ± 0.5	6.5 ± 0.4	$p < 0.0001$
CEJ to bone crest (mm)	2.1 ± 0.3	2.7 ± 0.3	$p = 0.0005$
Intrabony defect depth (mm)	6.7 ± 3.4	3.8 ± 2.7	$p < 0.0001$
Defect angle (°)	28.5 ± 11.1	44.4 ± 15.0	$p < 0.0001$

CAL, clinical attachment loss; REC, recessions; PPD, probing pocket depth.

Clinical outcomes

Across the 35 intrabony defects, the average PPD reduction from baseline to re-evaluation was 3.5 mm and 2.8 mm, respectively, for the buccal ($p < 0.0001$) and lingual ($p < 0.0001$) inter-proximal aspects (overall average 3.1 mm) (see Table 2). The average CAL gain from baseline to re-evaluation was 3.1 mm ($p < 0.0001$) and 2.4 mm ($p < 0.0001$), respectively, for the buccal and lingual inter-proximal aspects of the intrabony defect (overall average 2.8 mm). The average gingival recession increased from 0.6 mm to 0.8 mm (not statistically significant).

Radiographic outcomes

Figures 2 and 3 show examples of radiographic outcomes at 1 year of two of the cases included in the analysis. Following MINST, the average radiographic vertical defect depth and average defect angle changed from 6.74 mm and 28.49° at baseline to 3.8 mm and 44.3° at re-evaluation respectively ($p < 0.0001$ for both parameters). The overall intrabony defect depth reduction was 2.93 mm. The suprabony defect increased from 2.1 mm to 2.6 mm ($p = 0.0005$). The overall defect depth (distance CEJ-bottom of bony defect) went down from 8.9 mm to 6.5 mm ($p < 0.0001$) (see Table 2).

The results of univariate analysis from the multilevel linear regression (Table 3) showed that smaller initial defect angles and deeper initial defect depths were associated with greater defect depth reduction (−0.12 mm per one degree increase in defect angle, 95% CI = −0.18 to −0.06, $p < 0.001$, and 0.39 mm per 1 mm increase in baseline defect depth, 95% CI = 0.17 to 0.61 mm, $p = 0.001$ respectively). When both baseline defect depth and defect

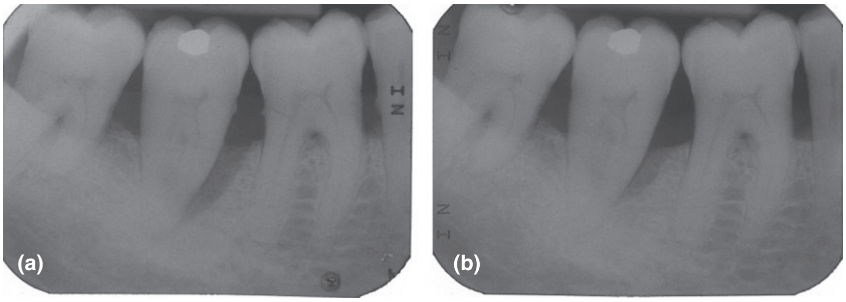

Fig. 2. Baseline (a) and re-evaluation (b) (1-year review) radiographic images of the mesial defect on lower right second molar (one of the cases included in the analysis).

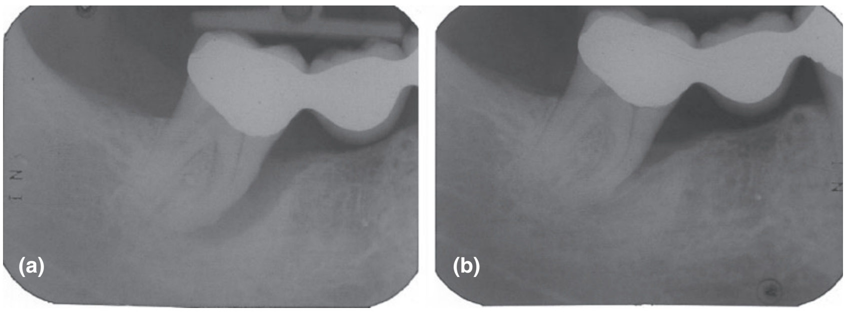

Fig. 3. Baseline (a) and re-evaluation (b) (1-year review) radiographic images of the mesial defect on lower right second molar (one of the cases included in the analysis).

angle were included in the model, only the baseline defect angle remained statistically significant. For the outcome of defect angle change, the greater initial defect angle (−0.45° per one degree increase in baseline defect angle, 95% CI = −0.87 to −0.03°, $p = 0.036$) was associated with less defect angle change.

Discussion

This is the first study, to our knowledge, to analyse clinical and radiographic response of intrabony defects treated with minimally invasive non-surgical periodontal therapy (MINST).

The use of minimally invasive procedures has recently been advocated for the treatment of periodontitis, to minimize patient discomfort and maximize the healing potential. These techniques usually involve the use of magnification lenses or microscopes and small instruments which reduce the risk of tissue trauma compared with traditional instruments. The application of MINST stems from a line of research which has recently suggested the use of small split-thickness incisions, a single flap approach with minimal suturing, and preservation of the inter-dental papilla (Cortellini & Tonetti 2007, 2011, Harrel et al. 2014). These techniques aim at the preservation of the blood supply to the periodontal tissues and can aided by the use of a microscope and/or a videoscope with a small digital camera (Harrel et al. 2014). The MINST protocol used in this study has the same objective, with the difference of completely avoiding incisions and suturing, with consequent reduction in chair-time and potentially morbidity. In support of the favourable response to MINST, no clinical outcome differences were detected in the healing of intrabony defects in a study comparing minimally invasive surgical and non-surgical interventions (Ribeiro et al. 2011). The average pocket reduction in this study was almost identical to that observed in the study by Ribeiro and co-workers (3.12 mm *versus* 3.13 mm), while the CAL in this study was slightly higher (2.78 mm *versus* 2.56 mm), due to a smaller degree of gingival recession (0.28 mm *versus* 0.45 mm).

The observation of the healing of intrabony defects reported here is in agreement with a previous study on patients treated with non-surgical periodontal therapy by the same author (Nibali et al. 2011), reporting a 2.3 mm PPD reduction, a 1.5 mm CAL gain and 0.7 mm infrabony defect gain. This is also supported by a significant increase in bone density by subtraction radiography observed in 39 periodontal vertical osseous defects following NSPT (Hwang et al. 2008).

The radiographic intrabony defect reduction in this study was close to 3 mm. An indirect comparison with our previous retrospective analysis (Nibali et al. 2011) shows improved clinical and radiographic gains, potentially attributable to the exclusion of smokers, to increased initial disease severity but also possibly to the use of MINST rather than

Table 3. Results of univariate analysis 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
Gender (Male)	0.69	−1.14, 2.51	0.461	6.46	−4.13, 17.05	0.232
Age	0.07	−0.02, 0.16	0.113	0.14	−0.42, 0.71	0.621
Previous endodontic treatment	−0.15	−3.77, 3.48	0.937	3.58	−17.33, 24.49	0.737
Premolar (*versus* anterior)	0.80	−2.00, 3.61	0.574	10.38	−3.79, 24.55	0.151
Molar (*versus* anterior)	−0.68	−3.03, 1.67	0.571	−6.63	−18.49, 5.24	0.274
Initial defect depth	0.39	0.17, 0.61	0.001	0.66	−0.89, 2.21	0.403
Initial defect angle	−0.12	−0.18, −0.06	<0.001	−0.45	−0.87, −0.03	0.036

traditional subgingival debridement. This is suggested by a smaller recession increase (0.28 mm) compared to that obtained with traditional subgingival debridement (0.8 mm) (Nibali et al. 2011), although no data are available on the possible aesthetic impact of this change. The clinical and radiographic improvements in the intrabony defects in this study are in the same range of those observed in studies on periodontal regeneration (median 4.1 mm PPD reductions, median 3.2 mm CAL reductions and median 3.3 mm radiographic intrabony defect gains as observed in a recent review) (Nibali et al. 2015). It is interesting to notice that the reduction in intrabony defects was accompanied by a widening of the defect angle and by a 0.5 mm increase in suprabony defect depth. The increase in the defect angle may also be partially a mathematical function of defect depth, since it has been shown that narrow defect angles are related to deep intrabony defects (Kim et al. 2006). The suprabony defect depth increase is of a smaller magnitude than the crestal bone resorption observed after periodontal surgical treatment, generally shown to range from 0.8 mm to 1.7 mm (Persson et al. 2000, Kyriazis et al. 2012), although smaller values have also been observed (Joly et al. 2002). Both widening of the defect angle and increase in suprabony defect depth are probably expressions of the significant bone remodelling which clearly takes placed in intrabony defects after MINST. Out of the initial 35 defects, five presented with PPD > 5 mm and bleeding on probing at the last follow-up visit, hence could be considered candidate for further treatment (Tonetti & Claffey 2005), possibly regenerative surgery.

This study also brings further confirmation that smaller initial defect angles and deeper initial defect depths were associated with greater defect depth reduction, as observed in studies on periodontal regeneration (Tsitoura et al. 2004). This is likely to be due to the bone fill in the narrowest part of the defect (the deepest component) (Nibali et al. 2011).

We previously speculated that mechanisms of healing after non-surgical therapy including the formation of a long junctional epithelium may be accompanied by bone apposition or an increase in bone mineralization (bone density) following non-surgical periodontal therapy. This could have happened mainly where bone loss had occurred, but supracrestal periodontal fibres were still attached to the cementum (Nibali et al. 2011). The limitations of this study are inherent to its retrospective nature, with the risk of recruitment bias and the lack of standardization of the radiograph. However, the possible distortion of the radiographic images was corrected for with the validated method of latent variable analysis. Within these limitations, this study brings forward evidence for the efficacy of minimally invasive non-surgical periodontal therapy in inducing clinical and radiographic gains in intrabony defects. Longitudinal studies should be performed to validate the results of this study and to compare MINST with "traditional" subgingival root debridement.

References

Bjorn, H., Halling, A. & Thyberg, H. (1969) Radiographic assessment of marginal bone loss. *Odontologisk Revy* **20**, 165–179.

Brown, T. A. (2006) *Confirmatory Factor Analysis*. New York: Guilford; 40–102.

Cortellini, P. & Tonetti, M. S. (2000) Focus on infrabony defects: guided tissue re generation. *Periodontology 2000* **22**, 104–132.

Cortellini, P. & Tonetti, M. S. (2007) Minimally invasive surgical technique and enamel matrix derivative in intra-bony defects. I: Clinical outcomes and morbidity. *Journal of Clinical Periodontology* **34**, 1082–1088.

Cortellini, P. & Tonetti, M. S. (2011) Clinical and radiographic outcomes of the modified minimally invasive surgical technique with and without regenerative materials: a randomized-controlled trial in intra-bony defects. *Journal of Clinical Periodontology* **38**, 365–373.

Eickholz, P., Krigar, D. M., Pretzl, B., Steinbrenner, H., Dorfer, C. & Kim, T. S. (2004) Guided tissue regeneration with bioabsorbable barriers. II. Longterm results in infrabony defects. *Journal of Periodontology* **75**, 957–965.

Friedman, N. (1955) Periodontal osseous surgery. The apically repositioned flap. *Journal of Periodontology* **33**, 328–340.

Gilthorpe, M. S., Griffiths, G. S., Maddick, I. H. & Zamzuri, A. T. (2000) The application of multilevel modelling to periodontal research data. *Community Dental Health* **17**, 227–235.

Goldstein, H. (1995) *Multilevel Statistical Models*, 2nd edition. New York: John Wiley.

Hamp, S. E., Nyman, S. & Lindhe, J. (1975) Periodontal treatment of multirooted teeth. Results after 5 years. *Journal of Clinical Periodontology* **2**, 126–135.

Harrel, S. K., Abraham, C. M., Rivera-Hidalgo, F., Shulman, J. D. & Nunn, M. E. (2014) Videoscope-assisted minimally invasive periodontal surgery (V-MIS). *Journal of Clinical Periodontology* **41**, 900–907.

Hox, J. (2002) *Multilevel Analysis*. Mahwah, NJ: Laurence Erlbaum Associates.

Hwang, Y. J., Fien, M. J., Lee, S. S., Kim, T. I., Seol, Y. J., Lee, Y. M., Ku, Y., Rhyu, I. C., Chung, C. P. & Han, S. B. (2008) Effect of scaling and root planing on alveolar bone as measured by subtraction radiography. *Journal of Periodontology* **79**, 1663–1669.

Joly, J. C., Palioto, D. B., de Lima, A. F., Mota, L. F. & Caffesse, R. (2002) Clinical and radiographic evaluation of periodontal intrabony defects treated with guided tissue regeneration. A pilot study. *Journal of Periodontology* **73**, 353–359.

Kim, C. K., Choi, S. H., Kim, T. S., Kaltschmitt, J. & Eickholz, P. (2006) The infrabony defect and its determinants. *Journal of Periodontal Research* **41**, 498–502.

Kyriazis, T., Gkrizioti, S., Mikrogeorgis, G., Tsalikis, L., Sakellari, D., Lyroudia, K. & Konstantinides, A. (2012) Crestal bone resorption after the application of two periodontal surgical techniques: a randomized, controlled clinical trial. *Journal of Clinical Periodontology* **39**, 971–978.

Lang, N. P., Bartold, P. M. & Cullinan, M. (1999) Consensus report: aggressive periodontitis. *Annals Periodontology* **4**, 53.

Laster, L., Laudenbach, K. W. & Stoller, N. H. (1975) Evaluation of clinical tooth mobility measurements. *Journal of Periodontology* **46**, 603–607.

Linares, A., Cortellini, P., Lang, N. P., Suvan, J. & Tonetti, M. S. (2006) Guided tissue regeneration/deproteinized bovine bone mineral or papilla preservation flaps alone for treatment of intrabony defects. II: radiographic predictors and outcomes. *Journal of Clinical Periodontology* **33**, 351–358.

Needleman, I. G., Worthington, H. V., Giedrys-Leeper, E. & Tucker, R. J. (2006) Guided tissue regeneration for periodontal infra-bony defects. *Cochrane Database Systematic Reviews* CD001724.

Nibali, L., Pelekos, G., Onabolu, O. & Donos, N. (2015) Effect and timing of non-surgical treatment prior to periodontal regeneration: a systematic review. *Clinical Oral Investigations*. [Epub ahead of print].

Nibali, L., Pometti, D., Tu, Y. K. & Donos, N. (2011) Clinical and radiographic outcomes following non-surgical therapy of periodontal infrabony defects: a retrospective study. *Journal of Clinical Periodontology* **38**, 50–57.

Nyman, S., Lindhe, J., Karring, T. & Rylander, H. (1982) New attachment following surgical treatment of human periodontal disease. *Journal of Clinical Periodontology* **9**, 290–296.

Papapanou, P. N. & Wennstrom, J. L. (1991) The angular bony defect as indicator of further alveolar bone loss. *Journal of Clinical Periodontology* **18**, 317–322.

Papapanou, P. N., Wennstrom, J. L. & Grondahl, K. (1988) Periodontal status in relation to age and tooth type – a cross-sectional radiographic study. *Journal of Clinical Periodontology* **15**, 469–478.

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.

Ribeiro, F. V., Casarin, R. C., Palma, M. A., Junior, F. H., Sallum, E. A. & Casati, M. Z. (2011) Clinical and patient-centered outcomes after minimally invasive non-surgical or surgical approaches for the treatment of intrabony defects: a randomized clinical trial. *Journal of Periodontology* **82**, 1256–1266.

Rosling, B., Nyman, S. & Lindhe, J. (1976) The effect of systematic plaque control on bone regeneration in infrabony pockets. *Journal of Clinical Periodontology* **3**, 38–53.

Schei, O., Waerhaug, J., Lovdal, A. & Arno, A. (1959) Alveolar bone loss as related to oral hygiene and age. *Journal of Periodontology* **30**, 7–16.

Steffensen, B. & Weber, H. P. (1989) Relationship between the radiographic periodontal defect angle and healing after treatment. *Journal of Periodontology* **60**, 248–254.

Tonetti, M. S. & Claffey, N. (2005) Advances in the progression of periodontitis and proposal of definitions of a periodontitis case and disease progression for use in risk factor research. Group C consensus report of the 5th European Workshop in Periodontology. European Workshop in Periodontology group C. *Journal of Clinical Periodontology* **32** (Suppl 6), 210–213.

Tsitoura, E., Tucker, R., Suvan, J., Laurell, L., Cortellini, P. & Tonetti, M. (2004) Baseline radiographic defect angle of the intrabony defect as a prognostic indicator in regenerative periodontal surgery with enamel matrix derivative. *Journal of Clinical Periodontology* **31**, 643–647.

Tu, Y. K., Donos, N., Pometti, D. & Nibali, L. (2010) Latent variable approach to correct errors in radiographic measurements. *European Journal of Oral Sciences* **118**, 642–648.

Updegrave, W. J. (1951) The paralleling extension-cone technique in intraoral dental radiography. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology and Endodontics* **4**, 1250–1261.

Address:
Luigi Nibali
Periodontology Unit and Department of Clinical Research
UCL Eastman Dental Institute
University College London
256 Gray's Inn Road
London WC1X 8LD
UK
E-mail: l.nibali@ucl.ac.uk

Clinical Relevance

Scientific rationale for the study: Evidence is starting to emerge about the favourable response of intrabony defect to non-surgical therapy.

Principal findings: Minimally invasive non-surgical therapy led to considerable clinical and radiographic improvement in intrabony defects.

Practical implications: The role of minimally invasive non-surgical therapy in the healing of intrabony defects should be emphasized.