J Clin Periodontol 2004; 31: 643–647 doi: 10.1111/j.1600-051X.2004.00555.x
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Journal of Clinical Periodontology

Baseline radiographic defect angle of the intrabony defect as a prognostic indicator in regenerative periodontal surgery with enamel matrix derivative

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Tsitoura E, Tucker R, Suvan J, Laurell L, Cortellini P, Tonetti M: Baseline radiographic defect angle of the intrabony defect as a prognostic indicator in regenerative periodontal surgery with enamel matrix derivative: J Clin Periodontol 2004; 31: 643–647. doi: 10.1111/j.1600-051X.2004.00555.x. © Blackwell Munksgaard, 2004.

Abstract

Introduction: The baseline radiographic defect angle has previously been correlated with the clinical outcomes of intrabony defects treated with access flap or guided tissue regeneration. The aim of this study was to investigate whether an association exists between baseline radiographic defect angle and treatment outcome when enamel matrix derivative (EMD) is used in periodontal regenerative surgery.
Materials and Methods: Baseline radiographs were collected from the test group of a previously published clinical trial using a population of 166 patients treated for chronic periodontitis. All intrabony defects were $\geqslant 3$ mm for inclusion in the original study. Either modified or simplified papilla preservation technique was used to access the defect. The roots were conditioned with an EDTA gel and the primary outcome measure was clinical attachment level (CAL) change, 1 year after surgery.
Results: Sixty-seven radiographs were measurable. The probability of obtaining CAL gain >3 mm was 2.46 times higher (95% confidence interval: 1.017–5.970) when the radiographic defect angle was $\leqslant 22^{\circ}$ than when it was $\geqslant 36^{\circ}$.
Conclusions: This study showed that there was a significant association between baseline radiographic defect angle and CAL gain at 1 year. The observed increased odds ratio of obtaining CAL gain of $\geqslant 4$ mm after regenerative surgery with EMD is used in narrow ($\leqslant 22^{\circ}$) intrabony defects, suggests that the baseline radiographic defect angle might be used as a prognostic indicator of treatment outcome.

Key words: clinical trial; enamel matrix derivative; periodontal therapy; prognosis; regeneration

Accepted for publication 26 October 2003

A correlation between radiographic changes in alveolar bone level (bone fill) occurring in intrabony defects after periodontal access flap surgery and the corresponding pre-treatment defect angles has been described, where greater potential for bone fill was found in defects with small angles (0–45°) compared with wide angles (45–90°, Steffensen & Weber 1989). Tonetti et al. (1993b) showed that, for guided tissue regeneration (GTR), the wider the radiographic defect angle, the lower the regenerated probing attachment level in intrabony defects. In a retrospective three-centre study, it was shown that clinical attachment level (CAL) gain and bone fill were positively correlated to the depth of the intrabony defect and that the less favourable results of one of these three centres were attributed to the fact that this centre had treated significantly wider defects compared with the other two centres (Falk et al. 1997).

Cortellini & Tonetti (1999) studied 242 intrabony defects treated with GTR and found a significant difference in the CAL outcomes when they compared narrow ($<25^{\circ}$) to wide ($>37^{\circ}$) defects. They concluded that the radiographic defect angle could represent a useful pre-surgical parameter to determine the potential of CAL gain in intrabony defects to be treated with GTR (Cortellini & Tonetti 1999).

Evidence indicates, therefore, that a correlation exists between the defect angle and the clinical outcome when periodontal access flap surgery and GTR are used in the treatment of intrabony defects. However, there is no such evidence when periodontal access flap surgery is combined with the application of enamel matrix derivative (EMD). The aim of this study was to investigate whether or not the baseline radiographic angle of an intrabony defect treated with access flap and the application of EMD was significantly associated with the observed changes in CAL, 1 year after treatment.

Materials and Methods

Study design

The radiographs obtained for this study, to measure the intrabony defect angles, were originally taken as part of a multicentre clinical trial that evaluated the clinical outcomes following treatment of intrabony defects with papilla preservation flap surgery with or without application of EMD. The clinical outcomes of this trial have been independently reported (Tonetti et al. 2002).

In brief, this was a parallel group, multi-centre, randomized, and controlled clinical trial that was designed to test the efficacy of access flap with or without EMD application in the treatment of intrabony defects. The control group received the same type of treatment as the test group, except for the omission of the EMD. A single defect was treated in each patient. Clinical outcomes were evaluated at 1 year.

A calibration exercise was carried out to obtain acceptable intra- and inter-examiner reproducibility for probing pocket depth (PPD), recession of the gingival margin (REC) and evaluation of the defect anatomy, as previously described by Tonetti et al. (1998).

Clinical measures

At study baseline and 1 year after treatment, the following parameters were evaluated: full-mouth plaque score (FMPS), full-mouth bleeding score (FMBS), PPD, REC and CAL.

Radiographic assessment

Routine diagnostic radiographs were taken with the long cone paralleling technique using Rinn holders (Updegrave 1951). Baseline radiographs were collected from the clinical centres and used for this study. All examinations were performed with the assessor blind to the treatment assignment or outcome and unaware of the defect morphology observed during the surgery. Radiographs were scanned with a purpose built high definition scanner (Digital Subtraction Radiography (DSR), Electro Medical Systems (EMS); Nyow, Switzerland); images were stored in a personal computer for analysis.

Measurement of the baseline defect angle

The radiographic angle of the intrabony component of the defect was measured with the assistance of DSR, which is a customized software program.

The following anatomical landmarks of the intrabony defect were identified on the scanned radiographs based on the criteria set by Bjorn et al. (1969) and Schei et al. (1959) (Fig. 1):

1. A1: The cemento-enamel junction (CEJ)of the tooth involved in the intrabony defect.
2. B1: The most coronal position of the alveolar bone crest of the intrabony defect when it touches the root surface of the adjacent tooth before treatment (the top of the crest).
3. D1: The most apical extension of the intrabony destruction where the periodontal ligament space still retained its normal width before treatment (the bottom of the defect).

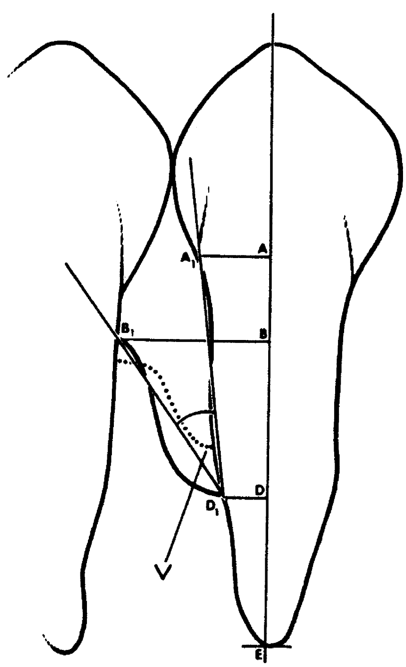

Fig. 1.

If restorations were present, the apical margin of the restoration was used to replace the CEJ as a fixed reference point.

The radiographic defect angle was then defined by the two lines that represent the root surface of the involved tooth and the bone defect surface, as described by Steffensen & Weber (1989) and Tonetti et al. (1993). These lines were expressed linearly as A1D1 and B1D1, respectively.

Calibration

The same examiner (Examiner A, E. T.) carried out all measurements of the radiographic defect angle. Examiner A was trained and calibrated in the measurement of the radiographic defect angle by another examiner (Examiner B, M. S. T.), who represented the ''gold standard''. Intra-examiner reproducibility was evaluated as the standard error of the mean difference of the duplicate measurements. This was 0.93° for Examiner A and 0.55° for Examiner B. Inter-examiner agreement was evaluated as the standard error of the mean difference of the measurements performed by Examiner A and those performed by Examiner B. This was 1.06°. Ninety percent of all the measurements carried out by the two examiners were within $\pm 3°$.

Data management and statistical analysis

The data from the control group of the clinical trail were not used in the analyses of this study. Data were entered into an excel database and proofread for entry errors. The database was subsequently locked, imported into SAS (Statistical Application Software, Version 8.0, SAS Institute, Cary, NC) format and analysed. After verification of the normality assumptions, numerical data were summarized as means and standard deviations; categorical data were summarized as frequency distributions. The correlation matrix between the various clinical and radiographic measurements of the defect was evaluated with the Spearman correlation coefficient. Multi-variate models predicting CAL gains at 1 year on the basis of baseline clinical and radiographic parameters were constructed using the

GLM SAS procedure and the Logistic SAS procedure with treatment, centre effect, and smoking status as classification variables, as previously described (Tonetti et al. 2002).

Results

Subject accountability

A total of 172 subjects were enrolled into the multi-centre clinical trial. Three subjects withdrew informed consent before surgery and 169 received treatment. Eighty-five were treated with access flap combined with EMD application (test group), while 84 were treated with access flap alone (control group).

During the 1-year period, three subjects failed to follow-up (two tests and one control), so complete observations were available for 166 subjects, 83 test and 83 controls. This represents 96.5% of the enrolled population.

Missing data

Periapical or bitewing radiographs of the intrabony defect to be treated were taken at baseline in each of the 166 patients. Twenty-six of the 166 radiographs could not be retrieved for measurement. In 10 of the available 140 radiographs, it was impossible to measure any defect angle, due to significant rotation of the tooth or excessive angulations of the radiographic beam. Therefore, measurement of the intrabony defect angle was possible in only 130 of the baseline radiographs for both test and controls, resulting in 67 available radiographs from the test group.

Subject characteristics at baseline

The baseline characteristics of the 67 individuals, who were treated with access flap and EMD application and for whom, the baseline radiographs of the intrabony defect angle were available, are displayed in Table 1.

The mean age of the patients was 49 ± 9 years. Females accounted for 55% of this group with 35.8% of the patient being smokers.

Oral hygiene

FMPS and FMBS at baseline are reported in Table 1. The mean FMPS was 14.5% at 12 months while the mean FMBS was 10.3%.

Table 1. Patient and defect characteristics at baseline (means ± SD)

Variable	Test
subject number	67
smokers (% <20 cigarettes/day)	35.8
FMPS (%)	10.4 ± 6.3
FMBS (%)	12.4 ± 6.3
PPD (mm)	8.1 ± 1.6
CAL (mm)	9.6 ± 2.2
CEJ-BD (mm)	10.3 ± 2.5
intrabony component (mm)	5.7 ± 2
radiographic defect angle range	12.8–54.4

SD, standard deviation; FMPS, full-mouth plaque score; FMBS, full-mouth bleeding score; PPD, probing pocket depth; CAL, clinical attachment level; CEJ-BD, cemento-enamel junction to the bottom of the defect.

Baseline defect characteristics

Mean PPD was 8.1 ± 1.6 mm. Mean CAL was 9.6 ± 2.2 mm (Table 1). The mean distance from the CEJ to the bottom of the defect (CEJ-BD) was 10.3 ± 2.5 mm, with an intrabony component of 5.7 ± 2 mm.

Clinical outcomes

The clinical outcome of papilla preservation flap with EMD application in terms of CAL gain and PPD reduction is described in Table 2. One year after therapy, the mean CAL gain was 3.2 ± 1.6 mm. The mean decrease in PPD was 4.1 ± 1.6 mm.

The significance of the treatment effect was also evaluated taking into account potential sources of variability such as centre effect, smoking status and radiographic defect angle. In order to construct multi-variate models, a correlation matrix was composed between the various estimates of defect morphology. A highly significant correlation was observed between the radiographic defect angle and the baseline PPD, the depth of the intrabony component of the defect as well as the distance between the CEJ and the bottom of the defect.

Table 2. Clinical outcome of access flap with EMD application at 1 year after therapy (means ± SD)

Outcome variable	Test, $N = 67$ (EMD)
gain in CAL	3.2 ± 1.6
decrease in PPD	4.1 ± 1.6

EMD, enamel matrix derivative; SD, standard deviation; CAL, clinical attachment level; PPD, probing pocket depth.

A multi-variate analysis based on the above-mentioned variables known before surgery was carried out to predict changes in CAL, 1 year after therapy. In this model, only variables known or measurable before surgery were used in order to evaluate their utility in predicting surgical outcomes.

An analysis was performed constructing a multi-variate model used to analyse the variables that might have an effect on the CAL gain in the subjects treated with papilla preservation flap combined with EMD application. This was statistically significant and explained 37% of the observed variability (Table 3). There was a statistically highly significant centre effect ($p = 0.0014$) and the difference between the centre with the largest CAL gain and the one with the smallest was 2.9 ± 0.9 mm. The radiographic defect angle also showed a statistically significant effect on CAL gain, with $p = 0.0477$. For each degree of increase in the radiographic defect angle the expected gain in CAL decreased by 0.04 ± 0.02 mm. Furthermore, in this subset, the effect of smoking on CAL gain did not appear to be statistically significant ($p = 0.8417$).

The factors that could significantly affect the probability of obtaining CAL gain >3 mm with the use of EMD were analysed using a logistic regression model (Table 4). The variables used in this model were centre effect, smoking and radiographic defect angle. The radiographic defect angle was categorized as narrow, intermediate and wide based upon inter-quartile ranges. Angles that were $\leqslant 22^{\circ}$ were defined as narrow, while angles $\geqslant 36^{\circ}$ were defined as wide based on observed inter-quartile ranges.

The probability of obtaining CAL gain >3 mm was 2.464 times higher (with a 95% confidence interval: 1.017–5.970) when the radiographic defect angle was $\leqslant 22^{\circ}$, than when the radiographic defect angle was $\geqslant 36^{\circ}$. The confidence interval of the odds ratio did not cross 1 and the values were greater than 1. Therefore, a defect with a narrow radiographic angle had significantly greater odds of gaining more than 3 mm in CAL than a defect with a wider radiographic angle (Table 4). A significant centre effect was also observed.

Table 3. Multi-variate analysis of CAL gain in subjects treated with EMD ($n = 67$)

Parameter	Estimate	Significance
centre effect (best versus worst)	2.9 ± 0.9	$p = 0.0014$
smoking (no versus yes)	-0.1 ± 0.4	$p = 0.8417$
radiographic defect angle (each degree)	-0.04 ± 0.02	$p = 0.0477$

Significance of model $p = 0.007$, adjusted $R^2 = 0.37$.
CAL, clinical attachment level; EMD, enamel matrix derivative.

Table 4. Logistic regression analysis of the factors that significantly affect the probability of obtaining CAL gain >3 mm with the use of papilla preservation flap and application of EMD

Parameter	Odds ratio	95% confidence interval
centre	1.198	1.004–1.428
smoking	0.888	0.283–2.791
radiographic defect angle (narrow versus wide*)	2.464	1.017–5.970

*Based upon inter-quartile ranges, when the radiographic defect angle was $\leqslant 22^\circ$ it was defined as narrow, while when it was $\geqslant 36^\circ$ it was defined as wide.
CAL, clinical attachment level; EMD, enamel matrix derivative.

Discussion

The results of this study indicated that the baseline radiographic angle of intrabony defects treated with papilla preservation flaps and EMD application was significantly associated with the CAL changes observed 1 year later. Moreover, the probability of obtaining CAL gains of $\geqslant 4$ mm was 2.5 times higher when the radiographic defect angle was $\leqslant 22^\circ$, than when it was $\geqslant 36^\circ$ (Odds Ratio = 2.464). The results of this study are in agreement with Tonetti et al. (1993a) and Cortellini & Tonetti (1999).

Tonetti et al. (1993a) have shown that the radiographic angle of an intrabony defect treated with GTR has a significant impact on the clinical outcome. Based on that, Cortellini & Tonetti (1999) tried to determine cut-off values that could help clinicians select the ideal cases for regeneration. Using the 25th and 75th percentiles, they defined the radiographic angle of 25° or less as narrow, while 37° or more was considered wide. When comparing wide with narrow intrabony defects, a significant difference ($p < 0.0001$) was observed, in that narrow defects gained 1.5 mm more CAL than wide defects. They concluded that, the radiographic defect angle could be used by a clinician as a useful pre-surgical parameter to determine the potential of CAL gain in intrabony defects treated with GTR. The extreme similarity with this study, therefore, indicates that the defect population treated in the two studies was similar in terms of radiographic defect angle. However, the fact that the cut-off values were quite similar in both studies seems to indicate that these ''universal'' cut-offs may be applicable in practice.

Intriguingly, this may indicate that wide and narrow defects have intrinsically different healing potentials. This could be due to the fact that wider defects may present a special healing challenge as more tissue is lost in a wide defect. In addition, the superficial component of a wide defect may be more exposed to the adverse effects of the oral environment (Tonetti et al. 1993b). In particular defects with wide radiographic angles may present a larger surface to the negative effects of the oral environment in terms of both bacterial contamination and microtrauma from chewing and oral hygiene manoeuvres. Relevant to this discussion may also be a potentially different aetiology and pathogenesis of narrow versus wide lesions. Waerhaug (1976) hypothesized that in periodontal lesions bone loss occurs within a radius of action from the pathogen-induced inflammatory reaction. A wider lesion somehow implies that the radius of resorption penetrates further. At present, however, there are no studies addressing this question both in terms of aetiology of the lesion and in terms of healing potential.

It was noteworthy that in this study, no measurement could be performed in 7% of the retrieved radiographs. This involves a potential bias, as we may doubt the quality of the images obtained by the centres that did not send us all of the radiographs. On the other hand, these data indicate that more than 90% of routine pre-operative radiographs taken with accepted minimal levels of standardization contain sufficient information to accurately assess the radiographic angle of the defect.

The limitations of radiographs as a diagnostic or prognostic tool should be taken into account when the radiographic angle of an intrabony defect is used to predict the clinical outcome of regenerative surgery with EMD. Lang & Hill (1977), in their review, discussed the technical and geometric variables that need to be considered when radiographs are used in periodontal diagnosis and research. Correct interpretation of radiographs is possible only if the object is well defined without too much contrast. Certain anatomical structures could mask the intrabony defect and make it radiographically invisible. These include the root, especially if the intrabony defect is primarily located buccally or lingually rather than interdentally, or if the defect wraps around the root when buccal or lingual bony walls of the defect are thick. These limitations also produced difficulties for study examiners and are most likely responsible for the observed values in the intra- and inter-examiner agreement calibration.

Tonetti et al. (1993) discussed the ability of radiographs to estimate the most apical extend of bone loss, i.e. the distance from the CEJ to the bottom of the defect before treatment (CEJ-BD distance), in intrabony defects treated with GTR. Their results showed that a mean of 1.1 mm of underestimation of bone loss was observed when using the radiographs to estimate the CEJ-BD distance. Therefore, they concluded that the radiographic linear measurements were poor estimates of the actual extend of bone loss in intrabony defects.

The combined use of EMD with papilla preservation flaps has already been shown to provide additional benefit in terms of CAL gain, PPD reduction and predictability of outcomes in the treatment of deep intrabony defects, when compared with papilla preservation flaps alone (Tonetti et al. 2002). This study has now shown that there is a significant association between the radiographic defect angle of an intrabony defect at baseline and the changes in CAL with this technique. However, it should be kept in mind that the data in this study was retrospective. The critical question is whether the knowledge of the radiographic width at the crest of an intrabony defect and its use in the baseline diagnosis would increase the extent and predictability of the clinical outcome. Future prospective studies could address this issue to see if there is any actual correlation between the baseline radiographic angle of the intrabony defect and the clinical outcome of the regenerative periodontal surgery.

Conclusions

This study revealed a significant association between the baseline radiographic defect angle of an intrabony defect and the changes in CAL after regenerative surgery utilizing the application of EMD. The observed increased odds ratio of obtaining CAL gain of $\geqslant 4$ mm in intrabony defects treated with EMD when the baseline radiographic defect angle is narrow, suggests that this parameter might be used to estimate the prognosis of treatment before performing the procedure. However, further clinical trials are needed to assess the utility and the actual outcomes of applying the width of the baseline radiographic defect angle in the case selection process.

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