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Patterns of bone loss around teeth restored with endodontic posts

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Abstract

Objectives: This retrospective study described the pattern of bone loss around teeth with endodontic posts in periodontitis patients, and compared it with contra-lateral teeth without posts.

Material and Methods: From full-mouth radiographic surveys of 146 periodontitis patients (⩾35 years), 194 roots with endodontic posts and contra-laterals without posts were selected. Upper molars, pre-molars with two posts and roots of lower molars with two posts were excluded. Technical parameters of the post space preparation, endodontic and restorative status were evaluated. The level of alveolar bone measured in millimetre from the cemento-enamel junction (CEJ)/restoration margin and the pattern of bone loss (angular/horizontal) were evaluated on both mesial and distal aspects of roots with posts and contra-laterals, but not on the furcal areas of lower molars.

Results: The distance from the bone level to the CEJ/restoration margin was similar for teeth with posts and contra-laterals. However, teeth with posts had more angular defects mesially (18.8% *versus* 7.3%) as compared with their contra-laterals without posts. The defects around teeth with posts appeared to be typical in the sense that their apical level approximated the tip of the endodontic post.

Conclusion: In periodontitis patients, teeth restored by an endodontic post had angular bony defects on the mesial aspect more frequently in comparison with their contra-laterals.

Key words: alveolar bone loss; angular bone defect; periodontitis; post and core; restoration

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Dental materials and technologies evolve constantly, offering a wide range of options. Post and core techniques remain very popular among dental clinicians, with metal posts still representing the vast majority of endodontic posts provided (Eckerbom & Magnusson 2001).

This may seem surprising, considering that for some decades, the theoretical basis for this technique has been proven invalid. This technique initially aimed to strengthen the remaining tooth structure (Rosen 1961, Baraban 1970, Perel & Muroff 1972), which is no longer considered possible (Bravin 1976, Trope et al. 1985). The scientific literature describes a series of disadvantages and merits of this technique. Posts concentrate tension in relatively small areas of the root surface (Reinhardt et al. 1983), carrying the potential to induce root fractures. Furthermore, an additional disadvantage is the possibility of metal corrosion (Dérand 1971, Glantz & Nilner 1986, Sorensen et al. 1990). The release of corrosive products inside the root may increase root susceptibility to fractures (Angmar-Månsson et al. 1969). These products include agents with known cellular toxicity (Arvidson et al. 1980, Wataha et al. 1995, Garhammer et al. 2003) that can reach the root surface and potentially be released into the periodontal ligament (Dérand 1971, Arvidson & Wróblewski 1978). It is expected that such phenomena will have a detrimental effect on the adjacent periodontal tissues.

In a radiographic study of a Swedish population with high standards of oral hygiene and low levels of gingival inflammation, Eliasson et al. (1995) found that the presence of root posts was associated with a lower marginal bone height

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when compared with contra-lateral teeth without posts. Furthermore, bone loss appeared to be positively correlated with the length of the post. This indicated a possible association of alveolar bone with post length, length of the remaining root canal filling or both. These results are interesting, considering that they were observed in a periodontally healthy population and that the mean difference in bone level between test and control teeth reached approximately 1 mm.

Another retrospective study on the clinical performance of teeth restored specifically by means of carbon fibre-reinforced epoxy resin posts bonded with resin cement included clinical and radiographic periodontal measurements (Fredriksson et al. 1998). Teeth with resin posts were compared with their contra-laterals. The mean periodontal bone height was lower (both mesially and distally) in teeth with posts, but this difference reached significance only at the mesial sites (Fredriksson et al. 1998).

The results of these two studies are, however, subject to certain limitations. The quality of the preparation technique for the post or the endodontic treatment and the periapical status of the test teeth were not considered in the analysis. Endodontic infection could have had a negative impact on the periodontal tissues (Jansson et al. 1993, 1995). Furthermore, post space preparation has been described as an important factor for apical gutta-percha seal and fracture resistance, especially when it is not subjected to dimensional limitations that have been well defined (Bravin 1976, Shillingburg et al. 1982, Mattison et al. 1984, de Cleen 1993, Moshonov et al. 2005). As a result, teeth with posts are more often associated with periapical pathologic radiographic signs than root-treated teeth without posts (Eckerbom et al. 1991, de Cleen 1993). Another potential factor affecting the periodontal condition that was not evaluated by the two studies mentioned previously involves the type and quality of the restorative suprastructure. There is sufficient evidence that endodontically treated teeth included in fixed partial dentures do not perform as well in the clinic as vital teeth (Roberts 1970, Silness & Gustavsen 1985, Reichen-Graden & Lang 1989), especially in cantilever bridges (Randow et al. 1986, Decock et al. 1996, Hämmerle et al. 2000). The majority of teeth restored with posts exhibit a crown or a restoration extending into the inter-dental space, creating inter-proximal margins. The effect of poorly fitting restoration margins in inducing periodontal inflammation has been well described (Björn et al. 1970, Lang et al. 1983, Sorensen et al. 1986, Brunsvold & Lane 1989, Jansson et al. 1994). The two studies mentioned above (Eliasson et al. 1995, Fredriksson et al. 1998) described a negative influence of endodontic posts on the periodontal tissues of general dental patients. This effect may differ in periodontitis patients, who are prone to alveolar bone loss.

A recent study (Timmerman & Van der Weijden 2006) involving periodontitis patients from a specialist clinic compared endodontically treated teeth with their contra-laterals. More bone loss was observed around the endodontically treated teeth. This study sample also included 38 endodontically treated teeth with posts. The presence of a post, when analysing the total sample, did not seem to have a significant effect on the outcome. When analysed separately, the subgroup of 38 teeth with posts showed a statistically significant difference of 1 mm in the mean bone level mesially when compared with the mean of the non-endodontically treated contra-laterals (4.3 mm *versus* 3.3 mm respectively). However, in that study, the bone level was not specifically redorded around the root treated with the post. Bone measurements included the mesial and distal aspects of the tooth along the respective root surfaces as extensions of the mesial and distal surfaces of the crown. It would therefore be interesting (particularly for multi-rooted teeth) to study the effect of a post on the bone level, specifically around the root that bears the post. In addition, it seems relevant to assess the influence of variables such as type and quality of restoration, quality of root canal filling/post space preparation and periapical condition. The purpose of the current study was thus to investigate the amount and pattern of bone loss around teeth restored by the post and core technique and to compare these results with those obtained for contra-lateral teeth in referred periodontitis patients.

Material and Methods

Study population

This retrospective radiographic study was performed in a population of consecutive referrals in a specialist periodontal clinic in Utrecht, the Netherlands. According to the treatment protocol of the practice, all new patients had a full set of intra-oral radiographs taken as part of their first consultation. The radiographic status consisted of periapical exposures of all teeth (16 radiographs for a full dentition), acquired with the help of commercially available bite blocks and aiming instruments (XCP, DentsplyRinn, Elgin, IL, USA) and supplemented by four vertical bitewing exposures. These were taken bilaterally with the help of an aiming instrument (Paro-Bite, KerrHawe, Biogio, Switzerland). In all cases, radiographs were acquired by means of a commercially available dental X-ray tube (Satelec Aminal AC, 70 kV, 8 mA, Satelec, Bordeaux, France). The radiographs were taken by different operators, following a standardized procedure regarding the choice of areas and technique of film placement. For the lateral segments, eight exposures were made (two in each distal-canine region of the quadrant) with commercially available intra-oral films (Kodak Insight IP-22, Rochester, NY, USA). For the distal exposure, the bite block was placed distal to the mesial surface of the first molar. For the mesial radiograph, the bite block was placed mesially on the distal part of the molar. The films were exposed for 0.32 s in the upper jaw and for 0.25 s in the lower jaw. In the anterior segments, another eight periapical radiographs were obtained (two in each quadrant to include canine and incisors, using Kodak Insight IP-12). For exposures of the canine teeth, the bite blocks were placed with their centres at the cusp of the canine. The incisor radiographs were made with the long axis of the central incisor passing through the centre of the bite block. The exposure times were 0.25 s for the upper jaw and 0.16 s for the lower jaw. For the four vertical bitewing radiographs, the exposure time of the film (Kodak Insight IP-22, 31 × 41 mm) was 0.32 s. The two distal exposures were taken with the centre of the bite block at the inter-dental space between the first and the second molars. The two mesial exposures were taken with the bite block placed mesially from the distal part of the first molar.

All films were processed using a commercially available daylight processor (Periomat Plus, Dürr Dental, Bietigheim-Bissingen, Germany), with the use of a developer and a fixer (Periomat-Intra, Dürr Dental) that were replaced every 5

days. All intake radiographs of each patient were mounted on a commercially available frame for dental radiographs (Pocketmount PM620V, Adamount®, Milwaukee, WI, USA). Consecutively, frames with a full set of radiographs were scanned using a commercially available, high-resolution device (Epson Expression 1680 Pro, Seiko Epson Corporation, Suwa, Nagano, Japan) at a standard setting of 360 dpi. Scans were entered in the dental patient management software (Visiquick V3, Thomas Monitor Systems, Amsterdam, the Netherlands) for analysis.

Selection criteria

From this referral population, the new patients who received their initial consultation (including a full radiographic set) in the period between January 2004 and December 2005 and were diagnosed with adult periodontitis ($\geqslant$35 years of age and having radiographic evidence of bone loss) (Van der Velden 2000) had their radiographic records screened for the presence of at least one tooth bearing an endodontic post.

Following this initial screening, teeth/roots with posts were excluded from the study depending on aspects that were considered to limit the reliability of the radiographic analysis, namely:

- upper molars;
- upper pre-molars with two endodontic posts; and
- mesial or distal roots of lower molars bearing two posts.

Furthermore, teeth were excluded if they had:

- a radiographically detectable root fracture;
- an iatrogenic root perforation; and
- irregular inclination or rotation of the tooth.

Radiographs of teeth with posts were excluded whenever:

- the image quality was poor;
- the apex and the proximal periapical tissues were not included; and
- the margin of the coronal restoration was not visible.

Of the remaining teeth, those possessing contra-laterals without endodontic posts were selected for subsequent radiographic analysis.

Radiographic assessments

After entry into the electronic database of the practice, the radiographs of the selected teeth were subjected to linear and angular measurements using the integrated measuring tools of the software (Visiquick V3, Thomas Monitor Systems). Calibration of the measuring tool was performed by measuring the known dimensions of the radiograph's mounting frame on the scanned image. Thereafter, linear distances could be estimated with an accuracy of 1/10 of a millimetre. Intra-observer reproducibility was evaluated by re-measurement of 20 randomly chosen pairs of teeth with posts and contra-laterals, with an interval of 6 months between assessments. The following assessments were performed by one of the authors (S. K.) on the radiographs included for each selected tooth/root with endodontic post and its contra-lateral tooth/root:

(1) The marginal alveolar bone: The level was measured as the distance between the most coronal level with normal periodontal ligament width (Schei et al. 1959) and the cemento-enamel junction (CEJ) or margin of the coronal restoration. The pattern of loss was characterized as angular if there was a difference of $\geqslant$2 mm between the most coronal and the most apical part of the oblique defect and a $\geqslant$1 mm horizontal difference between the most coronal part of the crest and the root surface (Jansson et al. 1993). The vertical distance between the apical end of the post and the marginal bone level was also measured. The measurements for alveolar bone were performed on both mesial and distal sites. Exceptions were the roots of lower molars with posts. In these cases, the furcation area was not evaluated. Bone-level measurements were included only from the distal aspect of a distal root with a post and only from the mesial aspect of a mesial root with a post. Similarly, only the corresponding aspects of the contra-lateral teeth were measured.

(2) Periapical condition and quality of endodontic treatment: Periapical condition was registered as healthy or pathologic after an evaluation of the width of the periodontal ligament space and the presence or absence of a lamina dura (Jansson et al. 1995). The presence of periapical radiolucency was recorded if the width of the periodontal ligament apically was double or more than the lateral measurement (Hommez et al. 2002). In addition, the presence of apicoectomy with or without retrograde filling and the root length from the CEJ/restoration margin to the apex were scored. The presence, material and quality of root filling were also registered. The root filling was scored as acceptable when its apical end was 0–2 mm shorter than the radiographic apex (Wu et al. 2000, Hommez et al. 2002) and lacked visible lateral voids.

(3) The endodontic post (for the teeth/roots bearing one): The quality of post space preparation was scored as acceptable if there was a minimum of 5 mm of root filling apical to the post (Mattison et al. 1984), the mesio-distal root diameter at the apical end of the post was at least 1.5 mm greater than the post diameter (Shillingburg et al. 1982) and the distance (space) between the tip of the post and the most coronal part of the root filling was $<$2 mm (Moshonov et al. 2005). The preparation was characterized as ''non-acceptable'' whenever those requirements were not fulfilled or when it was in an eccentric direction. The length of the post was measured by the distance between the most apical part of the post and the margin of the coronal restoration. Whenever it was possible to deduct from the radiographs, the type of post was categorized into one of the following categories: cast, prefabricated parallel smooth, prefabricated parallel threaded, prefabricated tapered and prefabricated screwpost.

(4) The coronal restoration: The prosthodontic status and abutment function of the teeth were recorded. Margin quality of the coronal restoration was also registered. Restoration margin was characterized as deficient when it was poorly fitting (short) or overhanging; 0.5 mm was used as the level of acceptability (Lang et al. 1988).

Data Analysis

Bone level (the distance of marginal bone from the CEJ/restoration margin) and the presence or absence of angular bone loss were used as principal outcome variables. The site (mesial or distal) was used as the unit for statistical analysis. For the inferential statistics of the continuous outcome variable ''bone level'', when the independent variable was also continuous, the correlation was tested using Pearson's coefficient. In the case of a dichotomous grouping variable, the independent (non-paired)

samples *t*-test was used. The associations of the dichotomous outcome variable of presence or absence of an angular bony defect with independent variables were expressed by calculating the corresponding odds ratios. For this calculation, in the case of continuous independent variables, a binary logistic regression model was used. For dichotomous variables, it was performed using the χ^2-test after constructing 2×2 tables (crosstabs). The comparison of teeth with posts with their contra-laterals was performed using a paired samples *t*-test for the continuous outcome variables (the distance from the CEJ/restoration margin to marginal bone level or root apex) and the McNemar test for the dichotomous outcome of the presence or absence of an angular bony defect. In order to tackle the clustering of multiple teeth with posts within patients, this comparison was also carried out on a subject level. For the continuous outcome variable, a mean was calculated separately for all mesial and distal sites in each patient. The comparison was then carried out by a paired samples *t*-test. *p*-values <0.05 were considered statistically significant. For the dichotomous outcome variable and in order to nest the sites into the upper level ''patient'', a data transformation had to be performed. For every angular bony defect around a tooth with a post, a positive value of $+1$ was assigned. For every defect around a contra-lateral tooth, the value was a negative unit (-1). When no angular defect was present, the value was 0. This was carried out independently for mesial and distal sites. Consequently, the values were summed up for every pair (tooth with post-contra-lateral). There were three possibilities (-1, 0 or $+1$) for the value of the pair. Finally, the values of all pairs of teeth (tooth with post-contra-lateral) within a subject were summed and the outcome was divided by the number of pairs for that individual. This resulted in a new set of data, where each patient contributed a value ranging from -1 (in every selected pair of teeth of this patient, the contra-lateral tooth had an angular defect, whereas the tooth with a post did not) to $+1$ (all included teeth with posts had a defect, while their contra-laterals did not). This value was indicative of whether, within an individual, more defects were present around teeth with posts (positive values) or their contra-laterals (negative values). The null value supported the null hypothesis in that there was no difference in the frequency of angular defects between teeth with posts and contra-laterals without posts. These values were used to calculate a sample mean and a confidence interval (CI) separately for mesial and distal sites. If the null value was beyond the margins of the 95% CI, the null hypothesis was rejected. Analysis of the data was performed with SPSS 14 statistical software (SPSS Inc., Chicago, IL, USA).

The reliability of the bone-level measurements in relation to the CEJ/restoration margin was expressed as an intra-class correlation coefficient, reaching a value of 0.95 for the mesial surfaces and 0.96 for the distal. The reliability of the presence or absence of an angular defect was 0.75 for the mesial radiographic aspect of the teeth and 0.95 for the distal (intra-class correlation coefficient) showing ''good'' (Cohen 1988) reproducibility overall.

Results

Subject-level characteristics

One thousand and three hundred patients and their full sets of radiographs were screened. In total, 208 patients had at least one tooth with an endodontic post. Of this sample, 146 patients who met the inclusion criteria were selected for the study (mean age 53 years, range: 35–79 years); 63.7% of the patients were female and 36.3% were male. The mean number of teeth per patient was 25 (range 15–32), with a mean of two teeth with posts (ranging from one to seven per patient) (Table 1). From the 146 study-subjects, 194 roots with endodontic posts and contra-lateral teeth without posts were included in the analysis. The selected roots ranged from one to four per patient (Table 2). Thirty-three per cent of the studied posts were placed in the anterior (incisors and canines) teeth, while 47.4% were placed in the pre-molars and 19.6% in the molars. Correspondingly, 194 contra-lateral teeth without endodontic posts (by selection) were included. These could be classified into two groups based on their endodontic status: 166 did not show radiographic signs of an endodontic filling, while 28 did show such signs and were considered to be endodontically treated.

Table 1. Subject ($n = 146$) characteristics

	Mean (SD)	Range
Number of teeth	25 (3)	15–32
Number of teeth with post	2 (1.42)	1–7

Full-mouth condition of the subjects, before application of inclusion and exclusion criteria at the tooth level.

Teeth with posts

In Fig. 1, the radiographic mean dimensional characteristics of teeth with posts are illustrated. The mean distance from the reference level of the CEJ or restoration margin to the alveolar bone was 3.93 mm on the mesial and 3.94 mm on the distal aspects of the teeth with posts (Fig. 1). The mean length of the residual root canal filling was 4.31 mm and its distance to the apex was 1.76 mm, while a void of 0.94 mm interfered between the tip of the post and the root filling. Gutta-percha was the most frequent filling material, although one out of four root canals was not filled or filled with other materials such as pastes or silver points (Table 3). In this study, 36.6% of teeth with posts presented with radiographic signs of apical periodontitis.

For the endodontic posts, the mean length was 6.60 mm and the diameter at the tip was 0.98 mm. The majority of these were cast in metal. The corresponding mean root diameter at the level of the post tip was 4.33 mm (Fig. 1), meaning that the mean thickness of residual dentine at the same level was 3.35 mm. More than 90% of teeth with posts were restored by means of a crown, and considerably fewer by filling material. The margins of the coronal suprastructures were evaluated as deficient twice as frequently on the distal surface in comparison with the mesial surface ($\pm$ 10.0% *versus* 5.0%, respectively). Eleven per cent of the test teeth served as an abutment for fixed dental prosthesis (Table 3).

The next step in the analysis was to investigate the possible influence of endodontic and restorative parameters on the bone-level outcome variables (Table 4) and the presence of angular

Table 2. Distribution of the included posts in patients

No. of posts/patient	Frequency (number of patients)
1	107
2	31
3	7
4	1
Total	146

bony defects (Table 5) for the 194 teeth with posts. The latter analysis was separately performed for the mesial and distal surfaces. The mean bone level relative to the CEJ/restoration margin on both mesial and distal surfaces was not significantly different between teeth with or without periapical radiolucencies. Neither was it related to the quality of the endodontic treatment or of root preparation for the post. Bone level was not statistically correlated with the thickness of the residual dentine (mean: 3.35 mm) at the level of the post tip or with the void space between post tip and residual root canal filling (Table 4). In 18.8% of the mesial surfaces of teeth with posts, an angular bone defect was observed; the corresponding figure for the distal surface was 11.1%. The presence of an angular bony defect on any of the mesial or distal aspects was not related to the periapical status of those teeth. It was related, however, to the quality of the endodontic treatment for the mesial but not the distal sites. Despite the lack of a statistical association between root preparation for the post and the thickness of remaining dentine at the level of the post tip (both mesially and distally), the presence of angular defects was associated with the distance between post tip and root canal filling – but only for the distal sites (Table 5). In addition, the correlation between the length of the endodontic post and the amount of bone loss was not significant on either the mesial or the distal surface (correlation coefficients $r = 0.023$ and 0.064, respectively).

Figure 2 shows the mean distance of the bone level (mesial and distal) from the reference line (drawn parallel to the CEJ/restoration margin level and tangent to the post tip), indicating the level of the post tip. These values are displayed separately for teeth presenting with angular or horizontal patterns of bone loss. When an angular defect was present, the corresponding bone level approximated (within a limit of ± 0.50 mm) the tip of the post (both mesially and distally), while in cases of horizontal bone loss, the mean distance was about 3.00 mm (Fig. 2). This difference was significant for both mesial and distal surfaces ($p < 0.0001$, independent samples *t*-test).

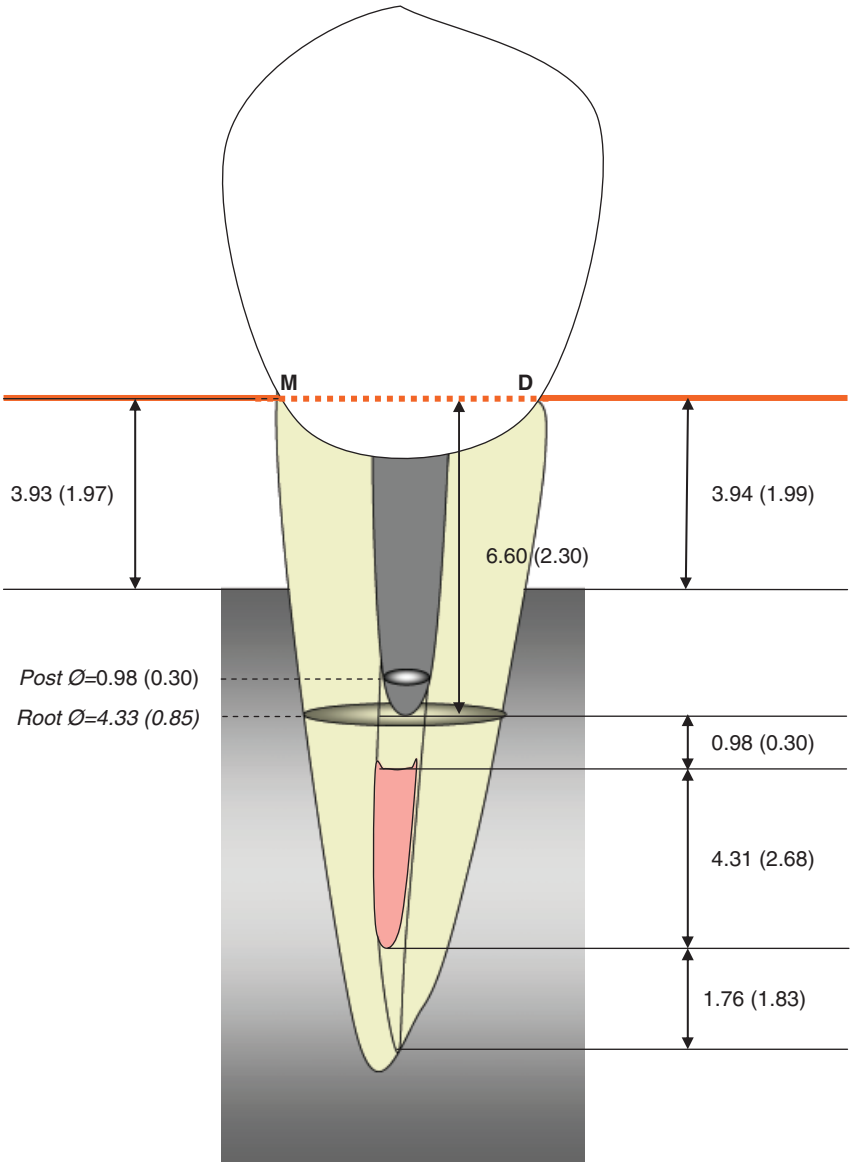

Fig. 1. Mean characteristics of the selected teeth with posts regarding endodontic treatment, root preparations for post and bone levels relative to the cemento-enamel junction (CEJ)/restoration margin (all mean dimensions in mm, standard deviations in parentheses).

Contra-lateral teeth

Contra-lateral teeth without endodontic treatment showed a mean distance of the marginal bone from the CEJ or the restoration margin of 4.06 mm on the mesial and 4.20 mm on the distal surface. The

Table 3. Description of teeth/roots with endodontic posts ($n = 194$)

Characteristics	Percentage of teeth with posts
Root-filling material	
None	11.9
Gutta-percha	74.7
Paste	10.8
Silver points	2.6
Post type	
Cast	66.5
Pre-fabricated parallel smooth	15.5
Pre-fabricated parallel threaded	8.2
Screwpost	8.2
Pre-fabricated tapered	1.5
Coronal restoration	
Crown	92.8
Filling	6.2
None	1.0
Abutment	
For FPD	10.8
Non-abutment	89.2
Deficient margin mesially	
Yes	4.6
No	95.4
Deficient margin distally	
Yes	10.3
No	89.7

Table 4. Relationship between the mean amount of bone loss in relation to the CEJ/restoration margin and various characteristics of teeth with posts

Mean bone level (SD)	Quality of apical root canal filling*	Periapical condition*	Quality of post space preparation*	Thickness of the remaining dentine at the post tip†	Distance from the tip of the post to the root canal filling†
Mesial					
3.93 (1.97)	NS	NS	NS	$r = 0.15$ ($p = 0.056$)	$r = -0.12$ ($p = 0.164$)
Distal					
3.94 (1.99)	NS	NS	NS	$r = 0.13$ ($p = 0.069$)	$r = 0.03$ ($p = 0.66$)

Bone level measured in millimetre from the CEJ/restoration margin.
*Independent sample *t*-test, comparing bone-level means after dividing the teeth with posts among two groups according to dichotomous characteristics.
†Pearson correlation, for amount of bone loss and the thickness of the remaining dentine at the level of the post tip.
r, correlation coefficient; CEJ, cemento-enamel junction.

Table 5. Odds ratios (95% confidence interval) for the presence of an angular bony defect in the presence of certain characteristics of teeth with posts

Frequency of angular bone defect	Quality of the apical root filling†	Periapical condition†	Quality of the root preparation for post†	Thickness of the remaining dentine at the post tip‡	Distance from the tip of the post to the root canal filling‡
Mesial					
18.8%	2.4* (1.02–5.65)	1.06 (0.46–2.41)	1.06 (0.46–2.45)	1.00 (0.60–1.67)	0.90 (0.65–1.24)
Distal					
11.1%	0.71 (0.29–1.79)	0.68 (0.25–1.85)	2.36 (0.76–7.34)	1.37 (0.81–2.30)	1.43* (1.08–1.89)

†Fisher's exact test, based on a 2 × 2 table.
‡Binary logistic regression analysis.
*$p < 0.05$.

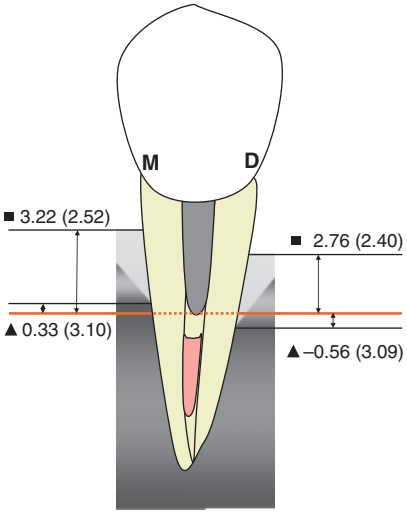

Fig. 2. Mean bone level of the selected teeth with posts relative to the post tip in cases of horizontal ■ ($n = 130$ mesial and $n = 168$ distal) and angular ▲ ($n = 30$ mesial and $n = 21$ distal) patterns of bone loss (mean distances in mm, standard deviations in parentheses).

frequency of angular bone defects was 6.7% for the mesial surfaces and 9.7% for the distal surfaces. Eight of the teeth had periapical radiolucencies (4.8%) and the majority of teeth were restored: 75 (45.2%) by means of a filling and 60 (36.1%) by crowns; only 31 (18.7%) were not restored and had intact clinical crowns. The mean bone level for the 28 endodontically treated contra-lateral teeth was 3.91 mm on the mesial surface and 4.30 mm on the distal surface. The frequency of angular bone defects was 10.7% for both mesial and distal sites. The radiographic appearance of the endodontic filling was suggestive of gutta-percha in 27 teeth and of paste in one (3.6%). The mean length of the endodontic filling was 10.45 mm, ending 2.24 mm from the radiographic apex; periapical radiolucency was found in six cases (21.4%). There was a relative balance in the type of coronal restorations between crowns (15/28, 53.6%) and fillings (46.4%).

Table 6. Mean bone level and frequency of angular bone defects in 194 teeth with posts and their contra-laterals without posts

	Mean bone level (SD)*		Presence of angular bone defect (%)†	
	Mesial	Distal	Mesial	Distal
Contra-lateral teeth	4.04 (2.05)	4.22 (1.98)	7.3%	9.8%
	NS	NS	$p = 0.007$	NS
Endodontically treated teeth with posts	3.93 (1.98)	3.94 (2.00)	18.8%	11.1%

Bone level measured in millimetre from the CEJ/restoration margin.
*Paired samples *t*-test.
†McNemar test, based on a 2 × 2 table.
CEJ, cemento-enamel junction.

Comparison of teeth with posts with contra-laterals

Because of the small number of contra-lateral teeth with endodontic treatment and the lack of a significant difference in the outcome variables between contra-lateral teeth with endodontic treatment and the non-endodontically treated contra-laterals (data not shown), it was considered appropriate to pool these samples for comparison with the teeth with posts. Table 6 shows the mean bone level in relation to the CEJ/restoration margin and the frequency of angular bony defects in both mesial and distal aspects of teeth with posts, as well as the comparison with the corresponding characteristics of the contra-lateral teeth without posts. Table 6 shows that despite the lack of a significant difference in the mean radiographic bone levels, the mesial surfaces of teeth with posts presented significantly more frequently (18.8% *versus* 7.3%) with angular bone

Table 7. Mean root length for teeth with posts and their contra-lateral teeth

	Mean root length (SD)[†]	
	Contra-lateral teeth with crowns ($N = 64$)	Contra-lateral teeth without crowns ($N = 106$)
Teeth with post and crown	13.85 (2.75)*	14.31 (2.52)***
Contra-lateral teeth	14.51 (2.74)	15.75 (2.39)

Root length measured in millimetre from the CEJ/restoration margin to the root apex.
Teeth with apicoectomy ($N = 10$ for teeth with posts and $N = 0$ for the contra-lateral teeth) and their contra-laterals were excluded.
Contra-lateral teeth were divided into two subgroups on the basis of coronal restoration.
[†]Paired samples *t*-test.
*$p < 0.05$; ***$p < 0.001$.
CEJ, cemento-enamel junction.

defects in comparison with contra-lateral teeth. Such a difference was not present on the distal surfaces. The data analysis for subject level was in accordance with the above-mentioned findings. The mean distance from the bone level to the CEJ/restoration margin (mesially) was not statistically different (p value > 0.05, paired samples *t*-test) between teeth with posts (mean: 3.93 mm) and their contra-laterals (mean: 3.95 mm). For distal sites, the distance between teeth with posts (mean: 3.93 mm) and contra-laterals (mean: 4.19 mm) was not statistically different. For the angular defects, the value representing the coincidence of angular/horizontal bone loss between teeth with posts and their contra-laterals within every patient ($N = 146$) was > 0 for both mesial (mean: 0.12, 95% CI: 0.03–0.21) and distal locations (mean: 0.01, 95% CI: -0.06 to 0.09). The 95% CI support the rejection of the null hypothesis for only the mesial sites. The fact that the marginal values of the CI are > 0 indicates that on the subject level, teeth with posts had more frequent angular defects on the mesial aspect than their contra-laterals. Teeth with posts and contra-laterals were also compared with respect to the mean root length, after excluding teeth with apicoectomy. This was measured as the distance from the CEJ/restoration margin to the radiographic apex in millimetre. The results are presented in Table 7. Teeth with posts had significantly shorter roots than their contra-laterals. The difference was significant, irrespective of the coronal restoration of teeth without posts. There was, however, a tendency for contra-lateral teeth with crowns to have a lower mean root length value (14.51 mm) than teeth without crowns (unrestored or restored by fillings, mean = 15.75 mm, Table 7).

Discussion

The main focus of this study was the radiographic appearance of periodontal tissues around endodontically treated teeth restored with endodontic posts in referred periodontitis patients. We specifically attempted to describe the patterns of horizontal and vertical bone loss around these teeth and compare them with the corresponding characteristics of their contra-laterals. Teeth with posts presented more frequently than contra-laterals with an angular bony defect on the mesial aspect of the root. The apical end of the angular defect was found to approximate the tip of the post. None of the parameters tested as possible confounders could predict this phenomenon. Investigated parameters involved periapical condition, endodontic treatment, post dimensions (Tables 4 and 5) and the type and quality of marginal adaptation for the coronal restoration (data not shown). The relevant parameter of interdental space width (Tal 1984) and its association with angular defects was, however, not considered in this study.

With respect to the mean bone level, this study did not show a statistically significant difference between teeth with posts and their contra-laterals in periodontitis patients. This finding conflicts with previous studies (Eliasson et al. 1995, Fredriksson et al 1998) in general dental patients. Our study also contradicts the findings of a recent study on a similar population (Timmerman & Van der Weijden 2006). That study was performed on an earlier referral population from the same clinic for periodontology. The reason for the discrepancy is unclear; however, there are profound methodological differences between the present and the above-mentioned investigations. The study of Timmerman & Van der Weijden (2006) investigated the influences of endodontic treatment and periapical condition on the mean bone level. Endodontically treated teeth were found to present with significantly more bone loss than their non-endodontically treated contra-laterals, while the presence of a post was not found to have any further effect. There were also differences in the selection and analysis of the subgroup of teeth with a post (N = 38). For the molars (12/38), the bone level was not scored specifically for the root bearing the post but rather for the mesial and distal aspects of the entire tooth. The present study did not include any maxillary molars, which formed 13.1% (5 of 38) of the subsample in the study by Timmerman & Van der Weijden (2006). In contrast to the 2006 investigation, the present study digitally analysed the radiographs with a higher-precision measurement tool.

Unlike previous studies on teeth with posts (Eliasson et al. 1995, Fredriksson et al. 1998, Timmerman & Van der Weijden 2006), the present study investigated and reported on the frequency of angular bony defects (using the definition found in the majority of the periodontal literature – Papapanou et al. 1988, Jansson et al. 1993), in addition to the mean bone level. Angular bony defects around teeth with endodontic posts were observed more frequently on the mesial (18.8%) as compared with the distal aspect (11.1%), with a ratio of 1.7:1. This is in agreement with observations of full dentitions from a large-scale, cross-sectional radiographic study on dental patients referred to the radiology department for a full radiographic status, which revealed a very similar ratio of 1.6:1 (respective frequencies 10.0%: 6.0%) (Papapanou et al. 1988, confirmed by Wouters et al. 1989, Baljoon et al. 2003 in general dental care patients). In another radiographic study carried out on referral periodontitis patients and not including molar teeth, this difference was reduced, with angular bone defect frequencies of 15.1% mesially and 11.2% distally (Ehnevid et al. 1997). Overall, it appears that the prevalence and distribution of angular bony defects around teeth with endodontic posts in the present study correspond to trends found in the existing literature.

The presence of periapical radiolucency has been associated with angular bony destruction around single-rooted teeth in periodontitis patients (age range

30–79) (Jansson et al. 1993). In the present study, the frequency of radiographic signs of apical periodontitis around teeth with posts was 36.6%, corresponding well with the respective data from previous studies on endodontically treated teeth (34.0% from Jansson et al. 1993, 38.0% from Miyashita et al. 1998 and 39.0% from De Cleen et al. 1993). In this study, radiolucencies were not found to be associated with the presence of an angular bone defect, despite the use of criteria that are comparable to those used by Jansson et al. (1993), for both variables. The reason for this discrepancy remains unclear.

The difference between teeth with posts and their contra-laterals in the frequency of angular bony defects coupled with the lack of a difference in the mean bone level appears to be counterintuitive, since, by definition, an angular defect represents a site-specific periodontal breakdown (Papapanou & Tonetti 2000). However, the methodological difference in the evaluation of the two parameters should not be overlooked. The presence of an angular bone defect is a dichotomous (yes/no) variable that involves only bone tissue (length and width of the infrabony component). On the other hand, bone level in this study was a continuous variable, measured in millimetre from a level of reference, in this case the CEJ/restoration margin. Alteration of the reference directly influences the bone measurements. This effect can be evaluated by measuring the distance from the reference level to a ''fixed'' anatomic point that is symmetric for contra-lateral teeth, such as the radiographic root apex. In the present study, this distance was expressed as root length. Contra-lateral teeth with crowns exhibited a decrease in root length of 1.24 mm as compared with unrestored and filled contra-laterals (Table 7). Although tooth type was not evenly distributed between the two groups, this difference may be considered as an indication that a crown preparation ending apical to the CEJ shifts the reference level in the same direction. The apical shift in the preparation margin for the teeth with posts (restored in 92.8% of the cases by crowns) may have thus masked a possible difference between teeth with posts and their contra-laterals in radiographic periodontal support (restored by crowns in only 38.7% of cases). Root length measurements revealed that teeth with posts presented with shorter roots than their contra-laterals, even when the latter were restored by crowns (Table 7). An explanation might be offered by the difference in the frequency of endodontic treatment between teeth with posts (100%) and their contra-laterals with crowns (18.8%). It has been shown that endodontically treated teeth present more frequently with apical root resorption than their contra-lateral teeth with vital pulp (Malueg et al. 1996). More root resorption may have occurred in teeth with posts, resulting in further root length reduction. Another explanation might be offered by the clinical conditions that indicated the use of a post and core-retained crown. The indication is often insufficient mechanical retention for the crown, due to extensive loss of tooth substance. In order to increase the retention, in addition to the post, the crown preparation, in many cases, has to be extended apically to create the desirable ferrule (Stankiewicz & Wilson 2002). This results in shorter roots and correspondingly longer crowns for compromised teeth, restored by this technique.

In the case of an angular pattern of bone loss around teeth with posts, the level of the marginal bone approximated the level of the post tip on both the mesial and the distal aspects of the investigated teeth. This statistical association implies that a link exists between the presence of an endodontic post and the chance for an angular defect in the directly adjacent periodontal tissues. This possible link is further supported by the comparison of endodontically treated teeth with posts and their contra-lateral teeth. On the mesial surface, teeth with posts more frequently showed angular patterns of bone loss (18.8%) as compared with their contra-laterals (7.3%). The incidence of angular defects for the contra-lateral teeth without posts appeared to be much lower than expected (particularly on the mesial surface with a frequency of 7.3%) according to previous studies (Ehnevid et al. 1997). This may be partly explained by inclusion criteria that resulted in the exclusion from the patient sample of a number of maxillary first pre-molars with posts in both roots. It has been shown that maxillary first pre-molars are the teeth that most frequently present angular bone defects, with a frequency of 13.9% (Papapanou et al. 1988; a similar trend was also found by Wouters et al. 1989). Also, the present sample did not contain maxillary molars. Excluding these particular teeth may have caused an underestimation of the frequency of angular defects. As mentioned, no association was found between the tested confounders and the presence of angular defects around teeth with posts. Regarding the comparison between these teeth and their contra-laterals, the considerable difference in the type of coronal restoration between the two groups of teeth has to be considered. The possible influence of the type of restoration on the frequency of infrabony defects cannot be excluded. However, the subsample of both teeth with posts and contra-laterals bearing a crown ($N = 51$) followed trends similar to the whole sample. Specifically, teeth with posts presented more often with a mesial angular bony defect in comparison with contra-laterals with crowns (19.6% *versus* 9.8%). This difference did not reach significance due to the low number of defects in this subsample. Despite this, this finding is suggestive of an association between endodontic posts and angular defects independent of the type of coronal restoration.

This retrospective study does not provide an explanation for the possible mechanisms that may be involved in the increased frequency of this characteristic pattern of angular bone defects on the mesial surfaces of teeth with posts. However, the existing evidence on this subject may lead to certain assumptions. More specifically, in vitro studies have shown that dentine stresses and functional forces during mastication of teeth with posts are concentrated on a relatively small area around the post tip (Davy et al. 1981, Reinhardt et al. 1983). Furthermore, endodontic posts have been associated in the clinic with vertical root fractures (Morfis 1990, Mullally & Ahmed 2000). Particularly, cast posts have been associated with more vertical root fractures than other post types (Pontius & Hutter 2002). This study sample (66.5% cast metal posts) may have run a high risk for vertical root fracture. The radiographic appearance of a complete vertical root fracture is characteristic (Nicopoulou-Karayianni et al. 1997). In the present study, no such teeth were included. The possibility remains that the concentration of tensions on a relatively small root surface may have resulted in longitudinal or oblique (Angmar-Månsson et al. 1969) micro-fractures or cracks, without separation of the fractured parts. In such cases, the line of the micro-fracture may serve as a potent pathway for bacteria

(Walton et al. 1984) to bypass natural barriers and immunological mechanisms of the periodontal tissues. Additionally, irrespective of the mechanism that resulted in the fracture line [mechanical stresses during root canal obturation (Gher et al. 1987, Boyarsky & Davis 1992), post cementation or corrosion of the post], it is likely that the fracture line facilitates more rapid and intense corrosion of the post alloy, due to contact with oral fluids (Angmar-Månsson et al. 1969, Meister et al. 1980). Subsequently, products with known cellular toxicity may be released into the periodontal tissues (Arvidson et al. 1980, Wataha et al. 1995, Garhammer et al. 2003), resulting in an infrabony periodontal defect. Indeed, one of the typical radiographic characteristics of a vertical root fracture is an isolated osseous defect that is clinically or radiographically diagnosed (Meister et al. 1980, Testori et al. 1993), ending at the apical extent of the fracture line (Lommel et al. 1978). This defect may eventually play a role in the local progression of periodontal disease (Pontoriero et al. 1988, Papapanou & Wennström 1991).

An intervention study could be used to further investigate the role of endodontic posts in the pattern of periodontal breakdown. Particularly for teeth with posts that present with an angular bony defect, it would be interesting to study the effect on the periodontal tissues of removal of the post, endodontic retreatment and core build-up by means of an adhesive restoration material.

In conclusion, in periodontitis patients, teeth restored by means of an endodontic post had an angular bony defect on the mesial surface more frequently in comparison with their contra-lateral teeth. The angular pattern of bone loss appeared to be typical in the sense that the apical level approximated the tip of the endodontic post. The exact mechanism for the development of such defects and their clinical course remain to be investigated.

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Clinical Relevance

Scientific rationale for the study: Studies in non-periodontitis populations showed reduced bone levels for teeth restored by the post and core technique in comparison with contra-laterals without posts. This study examined periodontitis patients in order to investigate the size of this effect and its possible interactions with relevant cofactors.

Principal findings: In periodontitis patients, mesial angular bony defects were more frequent in teeth restored by endodontic posts than in their contra-laterals. In teeth with posts that exhibited an angular pattern of bone loss, the alveolar bone approximated the level of the post tip. Teeth with posts had shorter roots than the contra-lateral teeth, irrespective of the coronal restoration.

Practical implications: In periodontitis patients, the presence of an infrabony defect around a tooth with an endodontic post may be at least partly associated with the post.