doi:10.1111/j.1365-2591.2008.01513.x

Topographical evaluation of the major apical foramen in permanent human teeth

J. Martos[1], C. M. Ferrer-Luque[2], M. P. González-Rodríguez[2] & L. A. S. Castro[3]

[1]Department of Semiology and Clinics, School of Dentistry, Federal University of Pelotas, RS, Brazil; [2]Department of Dental Pathology and Therapeutics, School of Dentistry, University of Granada, Spain; and [3]Laboratory of Immunology and Microscopy, EMBRAPA-CPACT, Pelotas, RS, Brazil

Abstract

Martos J, Ferrer-Luque CM, González-Rodríguez MP, Castro LAS. Topographical evaluation of the major apical foramen in permanent human teeth. *International Endodontic Journal*, **42**, 329–334, 2009.

Aim To determine the distance from the anatomical root apex to the major apical foramen and the position of the major foramen on the root apex.

Methodology Crowns of 926 human teeth were sectioned at the cementum-enamel junction. Specimens were mounted on microscope slides for measurement parallel to the long axis of the teeth. The major foramen was identified as the largest-diameter opening at the root apex. A total of 1331 root specimens were evaluated using an optical stereomicroscope to an accuracy of 0.01 mm at $40 \times (\pm 10)$ magnification. The distance from the anatomical apex to the most apical point of the major foramen was measured, and its location (central, buccal, lingual, mesial and distal) was recorded.

Results The mean distance between the major foramen and the anatomical root apex was 0.69 mm; the mean distance was larger in posterior teeth (0.82 mm) and smaller in anterior teeth (0.39 mm). A wide range of anatomical apex to major foramen distances were observed in all tooth groups: the greatest distance was in maxillary molars (0.95 mm) followed by mandibular pre-molars (0.87 mm) and mandibular molars (0.80 mm). The major foramen was at the tip of the root in 40% of teeth. The most frequent deviations of the foramen were to the buccal (20%) and distal (14%).

Conclusion In this sample of teeth without apical resorption the distance between the major foramen and the anatomical root apex was always <1 mm. Deviation of the major foramen from the anatomic apex varied widely amongst tooth groups.

Keywords: anatomical root apex, apical foramen, dental anatomy, major foramen.

Received 8 February 2008; accepted 9 November 2008

Introduction

Knowledge of apical anatomy and accurate radiographical interpretation during root canal treatment are essential to avoid damage to the periodontal ligament (Dummer *et al.* 1984, Olson *et al.* 1991, Blasković-Subat *et al.* 1992). Two measurements are considered important for working length determination: distance from the apical foramen to the apical constriction; and distance from the apex to the apical foramen (Olson *et al.* 1991). An accurate clinical determination of the root canal terminus and its distance from the anatomical root apex is almost impossible (Gutierrez & Aguayo 1995).

Apical foramina can be asymmetrical under physiological and pathological conditions, for example as a consequence of tooth adaptation to functional activity (Kuttler 1955, Mizutani *et al.* 1992, Morfis *et al.* 1994). Constant remodelling of the root apex by external root resorption and cementum apposition appear to be the most common causes of deviation of the major foramen (Blasković-Subat *et al.* 1992).

The distance between the major foramen and anatomical root apex and the frequency of deviation of the major foramen have been studied in extracted teeth by

Correspondence: Josué Martos, Department of Semiology and Clinics, Pelotas Dental School, UFPel, R. Gonçalves Chaves, 457, 96.015-560, Pelotas, RS, Brazil (Tel.: 55 53 3222 4162; e-mail: josue.sul@terra.com.br).

stereomicroscopy (Kuttler 1955, Green 1960, Chapman 1969, Burch & Hulen 1972, Kerekes & Tronstad 1977, Dummer *et al.* 1984, Blasković-Subat *et al.* 1992, Mizutani *et al.* 1992, Brau Aguadé *et al.* 1997, Marroquín *et al.* 2004), dye injection into root canal (Kasahara *et al.* 1990, Martić *et al.* 1998), scanning electron microscopy (Morfis *et al.* 1994, Gutierrez & Aguayo 1995) and radiography (Palmer *et al.* 1971, Tamse *et al.* 1988, Basrani *et al.* 1997). Mean distances reported ranged from 0.2 to 3.8 mm and the frequency of major foramen deviation from the anatomic apex has been reported to be 34% to 92%.

Von der Lehr & Marsh (1973) reported that the point where the endodontic file exits the foramen can be visualized on X-ray when it opens mesially or distally. However, when the foramen opens buccally or lingually, the root structure is often superimposed, masking its radiographic visualization. Some authors reported that the most frequent location of the major foramen was on the buccal surface in anterior teeth (Chapman 1969, Burch & Hulen 1972, Kasahara *et al.* 1990, Blasković-Subat *et al.* 1992) and on the distal surface in posterior teeth (Burch & Hulen 1972, Tamse *et al.* 1988, Blasković-Subat *et al.* 1992).

The apical constriction is considered on the apical terminus of the root canal preparation. Nevertheless, further research is required to identify situations in which this is not the case (Dummer *et al.* 1984), e.g. in the presence of apical pathosis and root resorption (Simon 1994, Leonardo *et al.* 2007), when the apical foramen may be a more useful landmark. There have been relatively few reports to date based on large samples of teeth.

The aim of this study was to determine the distance from the apical foramen to the anatomical apex and the location of the foramen in relation to the apex.

Materials and methods

Nine hundred twenty-six nonrestored permanent maxillary and mandibular teeth (central and lateral incisors, canines, pre-molars and molars) with completely formed apices were used. The teeth were extracted during treatment of adult patients at the School of Dentistry, Federal University of Pelotas, Brazil. A total of 1331 roots were studied. Their distribution amongst tooth groups is shown in Table 1. The study was approved by the Ethics Committee of the University of Pelotas.

Before storage, calculus was removed from teeth by an ultrasonic scaler (Sonic Borden 2000N, Kavo Equipaments, Joinville, Brazil), using a 2% sodium hypochlorite solution to remove periodontal tissue remnants. Teeth were then kept in buffered formalin solution until analysis.

Teeth were cut transversely at the cementum-enamel junction using an Accutom-50 diamond cutter (Accutom Hard Tissue Microtome, Struers, Denmark) under copious water cooling. The apical area was stained with blue ink applied with a cotton swab to facilitate identification of the major foramen, i.e. the largest-diameter opening at and around the root apex (Fig. 1). Individually labelled bottles were used to keep roots separated, and each tooth was given a code number. Root sections were mounted on a microscope slide for measurements parallel to the long axis of the teeth.

The apices were examined with a Leitz optical stereomicroscope (Ernst Leitz GmbH, Wetzlar, Germany) at 40 × (±10) magnification. Numerical values were obtained from the micrometric scale on the ocular stage of the stereomicroscope. All measurements were made to an accuracy of 0.01 mm and evaluated by two examiners together under a direct light source. The criterium to characterize the major foramen as opposed to other minor foramina in this investigation was the opening of the largest diameter found at the apical level, previously observed under the stereomicroscope by the examiners. In cases of disagreement a size 6 K-file (DentsplyMaillefer, Ballaigues, Switzerland) especially trimmed for this purpose, was inserted into the canal until it emerged from the major apical foramen.

Table 1 Mean distance (mm) and standard deviation of the major apical foramen and the anatomical root apex

	Maxillary			Mandibular		
Tooth	*n*	x ± SD	Range	*n*	x ± SD	Range
Incisors	78	0.37 ± 0.27	0–1.20	183	0.32 ± 0.29	0–1.50
Canines	33	0.48 ± 0.39	0–1.70	87	0.42 ± 0.32	0–1.90
pre-molars	104	0.67 ± 0.40	0–1.20	164	0.87 ± 0.78	0–2.20
Molars	107	0.95 ± 0.79	0.10–1.70	170	0.80 ± 0.54	0–3.10

Mean apical foramen distance for all tooth types = 0.69 mm.

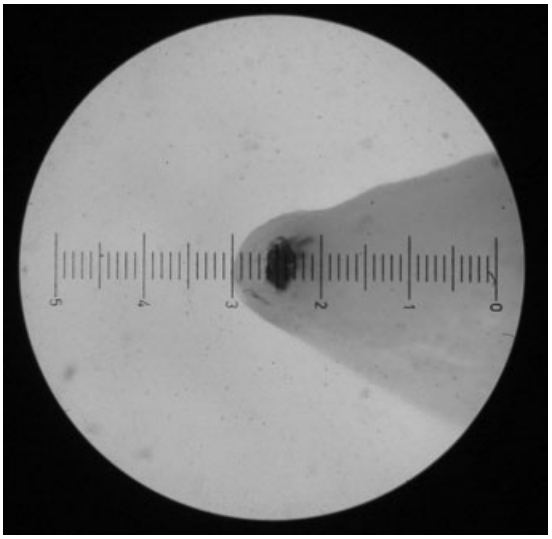

Figure 1 Root apex with a stained major foramen.

The standard file was used merely as a probe. Therefore, the major foramen was identified in two ways. It was the opening with the largest diameter found in the root apex confirmed by the visualization of the endodontic file tip. After identification of the major foramen, the instrument was removed and the root fragment was carefully mounted on a microscope slide for evaluation.

By this means, the distance from the apex to the most apical point of the major foramen and the position of the major foramen were determined (Fig. 2). The position of the major foramen was classified as central, buccal, lingual, mesial, or distal.

Additionally, the surface morphology of each two randomly selected specimens for group was qualitatively evaluated by SEM using a digital scanning microscope (Zeiss DSM 940A, Oberkochen, Germany).

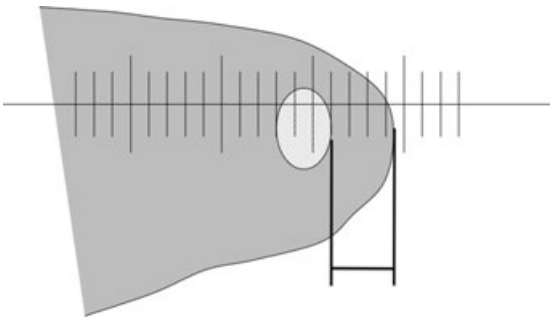

Figure 2 Schematic drawing of the measurements performed in the present investigation. The black lines under the rule represent the distance from the anatomic apex to the most apical point of the major foramen.

Using SPSS 8.0 software (SPSS Incorporated, Chicago, IL, USA) the mean values and standard deviations of the distances and frequencies of deviation of the major foramen with respect to the anatomical apex were calculated for each group of specimens.

Results

The mean distances from the major apical foramen to the anatomical apex are summarized in Table 1. The mean distance from the major foramen to the anatomical root apex was 0.69 mm; it was greater in posterior (0.82 mm) versus anterior (0.39 mm) teeth. The greatest mean distance was observed in the maxillar molar group (0.95 mm), followed by the mandibular pre-molar (0.87 mm) and mandibular molar (0.80 mm) groups.

The major foramen was in a central location on the root apex in 40% of specimens and deviated from the anatomical apex in 61%. The frequency of deviation was higher in posterior (43%) versus anterior (17%) teeth, and higher in mandibular (35%) versus maxillary (25%) teeth. The most frequent locations were buccal (20%) and distal (14%) surfaces, followed by lingual (13%) and mesial (13%) (Table 2).

Discussion

Anatomical knowledge of the root apex is essential for accurate determination of root canal working length because it contains the apical foramen, which is often the reference point for root canal treatment. In this study, 1331 roots from 926 adult teeth were examined. The measurements were performed by two different examiners; with respect to the tooth groups, one was not blinded whilst the other was. The results obtained by each examiner were compared and when differences were noted between them, the average of values found was calculated.

Data were collected on the distance from a perpendicular point of the anatomic apex to the most apical point of the major foramen (Gutierrez & Aguayo 1995). The most apical point of the major foramen was used for the measurement because of the difficulty in determining its midpoint. Globally, the mean distance from the apical point of major apical foramen to the anatomic apex in these roots was 0.69 mm. In agreement with previous reports (Kuttler 1955, Green 1956, 1960, Burch & Hulen 1972, Dummer *et al.*

Table 2 Position of major foramen in root apex: *n*(%)

	Maxillary(%)					Mandibular(%)				
Tooth	central	buccal	lingual	mesial	distal	central	buccal	lingual	mesial	distal
Incisors	23 (29.5)	18 (23.1)	1 (1.3)	17 (21.8)	19 (24.4)	84 (45.9)	54 (29.5)	11 (6)	20 (10.9)	14 (7.7)
Canines	9 (27.3)	12 (36.4)	6 (18.2)	5 (15.2)	1 (3)	33 (37.9)	21 (24.1)	13 (14.9)	15 (17.2	5 (5.7
pre-molars	86 (49.1)	17 (9.7)	27 (15.4)	24 (13.7)	21 (12)	74 (45.1)	20 (12.2)	15 (9.1)	33 (20.1)	22 (13.4)
Molars	103 (38)	52 (19.2)	57 (21)	30 (11.1)	29 (10.7)	114 (33.4)	69 (20.2)	40 (11.7)	41 (12)	76 22.3)

1984, Tamse *et al.* 1988, Kasahara *et al.* 1990, Blasković-Subat *et al.* 1992, Mizutani *et al.* 1992, Morfis *et al.* 1994), the distance never exceeded 1 mm in any root.

When resorption or eroded apical areas were observed, the specimen was excluded from the study because this would impair the accuracy during measurement. The areas of apical root cementum resorption in teeth with periapical lesion are generally extensive and deep and involve the entire surface of the root apex (Malueg *et al.* 1996, Leonardo *et al.* 2007). This resorption could occur both in a periforaminal and foraminal locations to different degrees (Vier & Figueiredo 2002).

Radiographical and morphological studies of different teeth groups have described mean distances between the apical foramen and the most apical end of the root in the range of 0.20–3.80 mm (Kuttler 1955, Green 1956, 1960, Burch & Hulen 1972, Dummer *et al.* 1984, Tamse *et al.* 1988, Kasahara *et al.* 1990, Blasković-Subat *et al.* 1992, Mizutani *et al.* 1992, Morfis *et al.* 1994, Gutierrez & Aguayo 1995, Martić *et al.* 1998). Variations amongst findings may be explained by differences in examination methods, number of teeth evaluated, racial differences and origin of samples.

In the maxillary and mandibular anterior teeth, the mean distance (0.33 mm) was similar to reports by Green (1960) and Dummer *et al.* (1984). It differed from the findings of 0.54 mm by Burch & Hulen (1972) and 0.65 mm by Blasković-Subat *et al.* (1992), although these authors used the most cervical point of the anatomical foramen as measurement reference and studied small numbers of roots. In maxillary and mandibular pre-molar groups, the mean distance was 0.76 mm. Blasković-Subat *et al.* (1992) described values of 1 mm in lingual and 1.3 mm in buccal roots of pre-molars, but in a sample of only 40 roots (from 20 teeth) compared with the 175 maxillary and 164 mandibular pre-molars in the present study. The mean distance was 0.95 mm in maxillary and 0.80 mm in mandibular molars. The more pronounced variations in posterior teeth may be explained by the higher chewing force applied, which would produce apical remodelling by resorption and cementum apposition (Palmer *et al.* 1971, Burch & Hulen 1972). Racial aspects (Martić *et al.* 1998) and pathological conditions such as hypercementosis (Malueg *et al.* 1996, Vier & Figueiredo 2002, Leonardo *et al.* 2007) may also be responsible.

In the present study, 60.5% of specimens showed deviation of the main foramen. Green (1960) found that the major foramen did not open directly to the apex in 69% of anterior teeth. Higher frequencies of 76% and even 92% were reported by Blasković-Subat *et al.* (1992) and Burch & Hulen (1972), respectively. Although there is a close relationship between the apical foramen and the root apex, they frequently do not coincide. Deviations ranging from 34 to 92% have been reported (Kuttler 1955, Chapman 1969, Burch & Hulen 1972, Kasahara *et al.* 1990, Blasković-Subat *et al.* 1992, Mizutani *et al.* 1992, Basrani *et al.* 1997, Brau Aguadé *et al.* 1997, Martić *et al.* 1998).

Gutierrez & Aguayo (1995) reported that foramen openings never coincided with the long axis of the root, defining apical deviation as the extension of a small portion of the foramen from the centre of the long axis. In the present study, because of the different shapes and peripheral contours of the apical foramen, deviation was only defined when a large (>50%) portion of the major foramen extended to the centre of the long axis.

Buccal deviation of the major foramen was observed in 25% of maxillary and 29% of mandibular incisors, similar to findings by other authors (Chapman 1969, Kasahara *et al.* 1990) but different from reports by Blasković-Subat *et al.* (1992) and Burch & Hulen (1972) of a predominantly lingual deviation in maxillary incisors.

In canine groups, the most frequent deviation was buccal (36%), as observed by others (Chapman 1969, Blasković-Subat *et al.* 1992). Burch & Hulen (1972) reported a predominance of buccal deviation in mandibular (41%) and distal deviation in maxillary (31%) canines.

A buccal location of the foramen has the potential to cause an incorrect clinical measurement of the canal. Radiographically, an apical foramen located buccally or lingually is superimposed over the root structure, making it difficult to view the exit point of the instrument (Von der Lehr & Marsh 1973, Olson *et al.* 1991).

The most frequent deviation of the major foramen was lingually in maxillary pre-molars (15.4%) and mesially in mandibular pre-molars (20.1%). In contrast, Burch & Hulen (1972) reported a predominance of distal deviation in both maxillary and mandibular pre-molars. Blasković-Subat *et al.* (1992) found a predominance of distal deviation in single-rooted pre-molars (60%) but of mesial in bifurcated pre-molars (45%), whilst a lingual location was most frequent in mandibular pre-molars (33%).

In the maxillary molars the most frequent deviations were to the buccal and lingual positions, as found by Blasković-Subat *et al.* 1992, whilst Burch & Hulen (1972) described a predominance of distal deviation in buccomesial and buccodistal maxillary molar roots. In the mandibular root, the most frequent deviation was distal, as also reported by Burch & Hulen (1972) and Tamse *et al.* (1988). Blasković-Subat *et al.* (1992) found a higher frequency of distal deviation in distal roots but lingual deviation in mesial roots.

A typical pattern of the apical foramen shape was not found. However, in the present study the greatest prevalence was of round and ovoid shapes (Figs 3 and 4). In most cases, the surface of the apical area was irregular or rough and in some others the apex appeared to have been eroded. All SEM observations enabled the identification of accessory foraminas (Fig. 5). Green (1956) observed in 400 anterior teeth, three types of apex configurations: infundibular, tapered and deflected. The differences in this case could have been due to nomenclature as the apex shapes were similar to those of the present study.

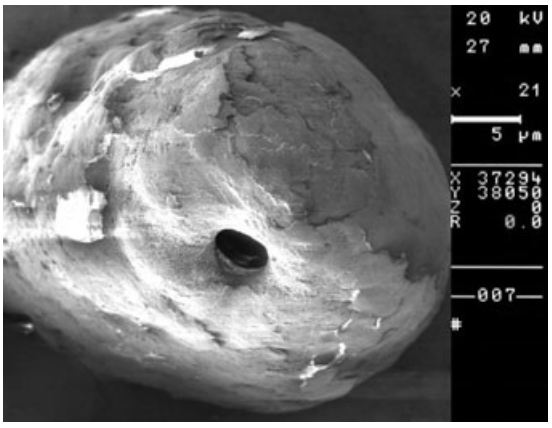

Figure 3 SEM micrograph of the deviation of the major apical foramen from the root apex (original magnification ×21).

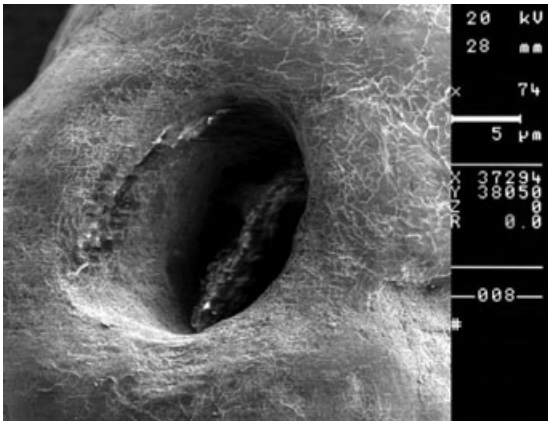

Figure 4 Typical ovoid shape of a foramen from a first maxillary molar (original magnification ×74).

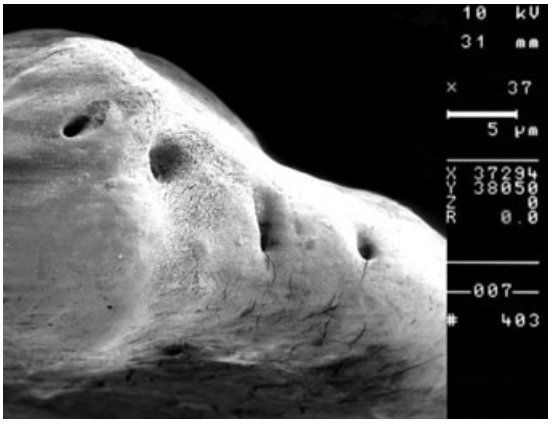

Figure 5 Appearance of accessory foramina around the apex of a maxillary pre-molar. (original magnification ×31).

Conclusion

The mean distance between the major apical foramen and the anatomical root apex was 0.69 mm. The frequency of deviation of the major foramen was 60% and varied amongst tooth groups.

Acknowledgements

This investigation was supported by the Coimbra Group Scholarship Program for Researchers from Latin

America Universities between the University of Granada (Spain) and Federal University of Pelotas (Brazil).

References

Basrani B, Revah S, Robinson C (1997) Ubicación del foramen apical. *Revista de la Asociación Odontológica Argentina* **85**, 230–2.

Blasković-Subat V, Maricic B, Sutalo J (1992) Asymmetry of the root canal foramen. *International Endodontic Journal* **25**, 158–64.

Brau Aguadé E, Roig Cayón M, Canalda Sahli C (1997) Estudio estereomicroscópico de la morfología apical. *Revista Operatoria Dental y Endodoncia* **1**, 1–2.

Burch JG, Hulen S (1972) The relationship of the apical foramen to the anatomic apex of the tooth root. *Oral Surgery, Oral Medicine and Oral Pathology* **34**, 262–8.

Chapman CE (1969) A microscopic study of the apical region of human anterior teeth. *Journal of the British Endodontic Society* **3**, 52–8.

Dummer PMH, McGinn JH, Rees DG (1984) The position and topography of the apical canal constriction and apical foramen. *International Endodontic Journal* **17**, 192–8.

Green D (1956) A stereomicroscopic study of the root apices of 400 maxillary and mandibular anterior teeth. *Oral Surgery, Oral Medicine and Oral Pathology* **9**, 1224–32.

Green D (1960) Stereomicroscopic study of 700 root apices of maxillary and mandibular posterior teeth. *Oral Surgery, Oral Medicine and Oral Pathology* **13**, 728–33.

Gutierrez JH, Aguayo P (1995) Apical foraminal openings in human teeth. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **79**, 769–77.

Kasahara E, Yasuda E, Yamamoto A, Anzai M (1990) Root canal system of the maxillary central incisor. *Journal of Endodontics* **16**, 158–61.

Kerekes K, Tronstad L (1977) Morphometric observations on root canals of human anterior teeth. *Journal of Endodontics* **3**, 24–9.

Kuttler Y (1955) Microscopic investigation of root apexes. *Journal of the American Dental Association* **50**, 544–52.

Leonardo MR, Rossi MA, Bonifacio KC, da Silva LA, Assed S (2007) Scanning electron microscopy of the apical structure of human teeth. *Ultrastructural Pathology* **31**, 321–5.

Malueg LA, Wilcox LR, Johnson W (1996) Examination of external apical root resorption with scanning electron microscopy. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **82**, 89–93.

Marroquín BB, El-Sayed MAA, Zönnchen BW (2004) Morphology of the physiological foramen: I. Maxillary and mandibular molars. *Journal of Endodontics* **30**, 321–8.

Martić D, Prpić-Mehičić G, Simeon P, Pevalek J (1998) Morphometrical analysis of main and accessory canals in apical root portion of frontal teeth. *Collegium Antropologicum* **22**, 153–9.

Mizutani T, Ohno N, Nakamura H (1992) Anatomic study of the root apex in the maxillary anterior teeth. *Journal of Endodontics* **18**, 344–7.

Morfis A, Sylaras SN, Georgopoulou M, Kernani M, Proutzos F (1994) Study of the apices of human permanent teeth with the use of scanning electron microscope. *Oral Surgery, Oral Medicine and Oral Pathology* **77**, 172–6.

Olson AK, Goerig AC, Cavataio RE, Luciano J (1991) The ability of the radiograph to determine the location of the apical foramen. *International Endodontic Journal* **24**, 28–35.

Palmer MJ, Weine FS, Healey HJ (1971) Position of the apical foramen in relation to endodontic therapy. *Journal Canadian Dental Association* **8**, 305–8.

Simon JHS (1994) The apex: how critical is it? *General Dentistry* **42**, 330–4.

Tamse A, Kaffe I, Littner MM, Moskona D, Gavish A (1988) Morphological and radiographic study of the apical foramen in distal roots of mandibular molars. Part II. The distance between the foramen and the root end. *International Endodontic Journal* **21**, 211–7.

Vier FV, Figueiredo JAP (2002) Prevalence of different periapical lesions associated with human teeth and their correlation with the presence and extension of apical external root resorption. *International Endodontic Journal* **35**, 710–9.

Von der Lehr WN, Marsh RA (1973) A radiographic study of the point of endodontic egress. *Oral Surgery, Oral Medicine and Oral Pathology* **35**, 105–9.

