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Retrospective radiological assessment of root canal treatment in young permanent dentition in a Turkish subpopulation

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Abstract

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Aim To determine the technical quality of root fillings as well as the periapical status of root filled teeth and non-root filled teeth in young permanent dentitions using a retrospective analysis of orthopantomographs (OPTGs) in a Turkish subpopulation.

Methodology Included in this study were the digital OPTGs taken as a part of diagnostic and planning procedures for all 19-year-old adolescents who attended the Faculty of Dentistry, Marmara University (Istanbul, Turkey) for the first time during the period from June 2007 to May 2009. The periapical status of all teeth and the technical quality of the root fillings were assessed by radiographic criteria. Statistical analysis was performed by the Mann–Whitney *U*, chi-squared, Fisher's exact and Cohen's kappa tests.

Results The survey involved OPTGs of 1077 19-year-old adolescents: 663 (61.6%) women and 414 (38.4%) men. Of the 28974 teeth examined, 459 (1.6%) were root filled, of which 193 (42.0%) had radiological signs of apical periodontitis (AP), and 454 (1.6%) were non-root filled teeth with AP. No significant difference was found between women and men regarding the number of teeth present, the number of root filled teeth and the number of non-root filled teeth with AP ($P > 0.05$). The most commonly treated teeth were molars (54.2%), followed by pre-molars (27.0%) and incisors (18.8%). Length was adequate in 57.3%, and homogeneity was adequate in 50.5% of the root fillings. Statistically, both the length and the homogeneity of the root fillings were significantly associated with periapical status individually ($P < 0.01$). The overall technical quality was inadequate in 60.1% of the root fillings, and 67.0% of these were associated with signs of AP. Amongst root filled teeth, the frequency of AP in connection with molars was significantly higher (57.0%) than that for incisors (27.9%) and pre-molars (21.8%) ($P < 0.01$).

Conclusions The results of this study indicated that the frequency of root filled teeth with AP, non-root filled teeth with AP and of technically inadequate root fillings amongst all root filled teeth was high in this selected adolescent Turkish population.

Keywords: apical periodontitis, endodontics, epidemiology, radiology, root canal treatment.

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Introduction

The frequency of root filled teeth and the technical quality of root fillings are usually studied in cross-sectional surveys and mainly in adults. Most studies originate from the Scandinavian and European populations (Ödesjö *et al.* 1990, Eriksen *et al.* 1995, Weiger

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et al. 1997, Marques *et al.* 1998, Schulte *et al.* 1998, De Moor *et al.* 2000, Kirkevang *et al.* 2000, 2001, Boucher *et al.* 2002, Lupi-Pegurier *et al.* 2002, Jiménéz-Pinzón *et al.* 2004, Segura-Egea *et al.* 2004, Georgopoulou *et al.* 2005, Loftus *et al.* 2005). However, more recently such information has also been collected from other parts of the world (Buckley & Spångberg 1995, Dugas *et al.* 2003, Kabak & Abbott 2005, Siqueira *et al.* 2005, Tsuneishi *et al.* 2005, Touré *et al.* 2008, Da Silva *et al.* 2009). Although the frequency of root filled teeth and the technical quality of the treatments varied amongst these epidemiological studies, they all revealed an association between the quality of root fillings and the periapical status and emphasize that improvement in the quality of root fillings is required to promote periapical health. The variation in the these parameters could originate from different study populations, different age groups, types of teeth included and different time periods for data collection.

Studies reporting on the presence of root canal treatment in young permanent dentition are limited. Only a few studies from Sweden were found in the literature on the presence of root filled young permanent teeth and the treatment quality (Ridell *et al.* 2003, 2006, 2007, Ridell 2008).

Studies which attempt to analyse the prevalence of patients with root filled teeth and the frequency and quality of treatment in Turkey are scarce, and none of them have concerned young permanent teeth exclusively (Sunay *et al.* 2007, Gulsahi *et al.* 2008, Kayahan *et al.* 2008). Data on dental health focus on caries (prevalence and distribution of decayed and filled teeth/surfaces) in young permanent teeth in Turkey. Root canal treatment that cannot be distinguished by clinical examination and that requires radiographic examination has not previously been investigated.

The aim of this study was to investigate the technical quality of root fillings and the periapical status of root filled and non-root filled teeth in the young permanent dentition in a Turkish subpopulation, based on radiographic examination.

Material and methods

Selection of the radiographs

The patient file pool at the Faculty of Dentistry, Marmara University (Istanbul, Turkey), was screened for digital orthopantomographs (OPTGs) taken as a part of diagnostic and planning procedures between June 2007 and May 2009. Amongst these, the OPTGs of all 19-year-old patients who came to the dental school for initial screening examinations in this period were selected. The search resulted in 1077 OPTGs to be examined. All the radiographs were taken by the same trained assistant radiographer, using a digital OPTG unit (Veraviewpocs; J. Morita MFG. Corp., Kyoto, Japan). The design of this retrospective study was approved by the Clinical Research Ethics Committee of the Istanbul University School of Medicine, and patient anonymity was strictly respected.

Examination of the radiographs

For each patient, the following information was recorded on a customized form: (i) gender, (ii) number of teeth present, (iii) number and location of root filled teeth with and without apical periodontitis (AP), and (iv) number of non-root filled teeth with AP. Impacted teeth were excluded, as well as third molars, giving a maximum of 28 teeth per dentition.

Teeth were categorized as endodontically treated if they had been filled with a radiopaque material in the pulp chamber and/or in the root canal(s). In the root filled teeth, the parameters listed in Table 1 were assessed.

The 'Periapical Index' (PAI) proposed by Ørstavik *et al.* (1986) was used to assess the periapical status of root filled teeth. PAI is a visual 5-point index, representing categories on an ordinal scale from healthy periapical bone to severe AP with exacerbating features. The five PAI scores were dichotomized so that 1 and 2 represented healthy periapical status, and 3, 4 and 5 represented AP. For multi-rooted teeth, the root exhibiting the highest PAI score and the quality of the corresponding root filling were considered.

The overall technical quality of the root fillings was classified as either adequate or inadequate on the basis of the guidelines published by the European Society of Endodontology (2006).

Observer

All radiographs were evaluated by one endodontist with more than 10 years of clinical experience, who was calibrated before the start of the study Bilge Tarcin (BT). Intra-observer agreement for PAI and other radiographic parameters were assessed by calculating Cohen's kappa by a double scoring of randomly selected 50 individuals' radiographs at 3-month intervals. All kappa values exceeded 0.80.

Table 1 Parameters recorded in root filled teeth

Parameters	Criteria
Length of root filling	1. Root filling terminating 0–2 mm from the radiographic apex (adequate) 2. Root filling terminating >2 mm from the radiographic apex (underfilling) 3. Root filling extending beyond the radiographic apex (overfilling) 4. Root filling limited to the pulp chamber (pulpotomy)
Homogeneity of root filling	1. Homogeneous root filling, no voids visible (adequate) 2. Inhomogeneous root filling, voids visible (inadequate)
Technical quality of root filling (European Society of Endodontology, 2006)	Adequate: No voids or defects along the walls of the canal, the filling terminated between 0 and 2 mm from the radiographic apex Inadequate: Voids or defects along the walls of the canal, filling ending more than 2 mm short of the radiographic apex or overfilled
Apical periodontitis (PAI scores) (Ørstavik *et al.* 1986)	1. Normal periapical structures } Absent 2. Small changes in bone structure } 3. Changes in bone structure with some mineral loss } Present 4. Periodontitis with well-defined radiolucent area } 5. Severe periodontitis with exacerbating features }

PAI, Periapical Index.

Statistical analysis

Statistical analysis was performed using NCSS 2007 (Number Cruncher Statistical System) and PASS 2008 (Power Analysis and Sample Size Software; NCSS LLC Inc., Utah, Kaysville, USA). The Mann–Whitney *U* test was used to determine the significance of differences in frequencies by gender for the following parameters: the number of teeth present, the number of root filled teeth and the number of non-root filled teeth with AP. The association between the quality of the root fillings, and periapical status and tooth groups was studied with the chi-squared and Fisher's exact tests. A P value of <0.05 was considered statistically significant.

Results

The survey involved OPTGs of 1077 19-year-old patients: 663 (61.6%) women, and 414 (38.4%) men. The total number of teeth present was 28974, with an average number of 26.90 ± 1.43 teeth per patient and a range from 19 to 28. Of the 1077 patients, 263 (24.4%) had at least one root filled tooth (range 1–11), and 314 (29.2%) had at least one non-root filled tooth with AP (range 1–8). A majority of the patients had one root filled tooth (61.2%). No significant difference between women and men was found regarding the number of teeth present, the number of root filled teeth and the number of non-root filled teeth with AP ($P > 0.05$).

Amongst the 28974 teeth examined in the survey, 459 (1.6%) were root filled teeth, of which 193 (42.0%) had radiographic signs of AP (Table 2), and 454 (1.6%) were non-root filled teeth with AP. The most commonly treated teeth were the permanent first molars (54.2%), followed by the second pre-molars (27.0%). Homogeneity of the root fillings was adequate in 50.5% of the teeth. The length of the root fillings was adequate in 57.3% of the teeth. The numbers of root filled teeth that were adequately filled, underfilled, overfilled and filled in the pulp chamber were 263 (57.3%), 149 (32.5%), 38 (8.3%) and 9 (1.9%), respectively.

The relationship between the parameters recorded for root filled teeth and the radiographic sign of AP is presented in Table 3. Statistically, both the length and the homogeneity of the root fillings were significantly related to periapical status individually ($P < 0.01$). AP

Table 2 Distribution of the radiographically examined teeth according to periapical status

Periapical status	Root filled teeth *n* (%)	Non-root filled teeth *n* (%)	Total *n* (%)
With apical periodontitis	193 (0.7)	454 (1.6)	647 (2.2)
Without apical periodontitis	266 (0.9)	28061 (96.8)	28327 (97.8)
Total	459 (1.6)	28515 (98.4)	28974 (100)

Table 3 The relationship between parameters recorded on root filled teeth and radiographic signs of AP

			Apical Periodontitis (AP)		
			Absent	Present	
			n (%)	*n* (%)	*P*
Length of root filling	Adequate		214 (81.4)	49 (18.6)	
	Inadequate	Underfilled	37 (24.8)	112 (75.2)	0.001**
		Overfilled	14 (36.8)	24 (63.2)	
		Pulpotomy	1 (11.1)	8 (88.9)	
Homogeneity of root filling	Adequate		194 (83.6)	38 (16.4)	
	Inadequate		72 (31.7)	155 (68.3)	0.001**
Technical quality of root filling	Adequate		175 (95.6)	8 (4.4)	
	Inadequate		91 (33.0)	185 (67.0)	0.001**
Type of teeth	Incisors		62 (72.1)	24 (27.9)	
	Pre-molars		97 (78.2)	27 (21.8)	0.001**
	Molars		107 (43.0)	142 (57.0)	

Chi-squared test or Fisher's exact test $^{**}P < 0.01$.

was observed most often in teeth with root filling limited to the pulp chamber (88.9%), followed by underfilled (75.2%), overfilled (63.2%) and, finally, adequately filled teeth (18.6%). When overall technical quality was considered, only 183 (39.9%) of the root filled teeth fulfilled the criteria for an adequate root filling, whilst 4.4% of these were associated with signs of AP. In teeth with inadequate root fillings, 67.0% had periapical pathosis. Inadequate root fillings were associated with a higher frequency of AP ($P < 0.01$).

In Table 4, the relationship between the parameters recorded in root filled teeth and the type of teeth is shown. Statistically significant differences in the frequency of inadequate homogeneity, inadequate length and inadequate technical quality were found between different types of teeth. Compared with incisors and pre-molars, significantly more molars had inadequate root fillings for all the three parameters recorded ($P < 0.01$). Amongst root filled teeth, the frequency of AP in connection with molars was higher (57.0%) than that for incisors (27.9%) and pre-molars (21.8%) ($P < 0.01$).

Discussion

The material used in this study consisted of the OPTGs of 19-year-old patients who visited the clinic of the Oral Diagnosis and Radiology Department at the Faculty of Dentistry, Marmara University (Istanbul, Turkey), where all the patients visiting the faculty for the first time are examined. The dental faculty attracts a patient population from numerous parts of the city and its surroundings, which eliminates the risk of including only patients previously treated by a limited number of practitioners. However, the sample does not represent a random sample of the Turkish population; therefore, extrapolation of the results to the general population

Table 4 The relationship between the parameters recorded on root filled teeth and the type of teeth

			Incisors	Pre-molars	Molars	
			n (%)	*n* (%)	*n* (%)	*P*
Length of root filling	Adequate		72 (83.7)	89 (71.8)	102 (41.0)	0.001**
	Inadequate	Underfilled	10 (11.6)	24 (19.4)	115 (46.2)	
		Overfilled	4 (4.7)	11 (8.9)	23 (9.2)	
		Pulpotomy	0 (0)	0 (0)	9 (3.6)	
Homogeneity of root filling	Adequate		54 (62.8)	80 (64.5)	98 (39.4)	0.001**
	Inadequate		32 (37.2)	44 (35.5)	151 (60.6)	
Technical quality of root filling	Adequate		51 (59.3)	69 (55.6)	63 (25.3)	0.001**
	Inadequate		35 (40.7)	55 (44.4)	186 (74.7)	

Chi-squared test $^{**}P < 0.01$.

cannot be carried out. It is known that some patients sought care from the dental faculty because treatment costs are lower than in the private sector, whilst others did so because of the reputation of the faculty.

Evaluation of apical conditions in root filled teeth is achieved mainly through radiographic examination because the absence of clinical symptoms can be misleading, and histological evaluation, which could be the ideal test, is not realistic. In Turkey, full mouth periapical films are taken only in special situations, such as severe periodontal problems, because of the higher radiation doses. OPTGs are preferred as general screening radiographs, and they were the radiograph of choice for this study because of their availability. Some studies comparing OPTGs and periapical radiographs have concluded that the accuracy of these two techniques was similar and have supported the use of OPTGs in epidemiological studies because all teeth can be seen on one radiograph and because the method provides relatively lower patient radiation doses (Muhammed *et al.* 1982, Ahlqwist *et al.* 1986, Molander *et al.* 1995a,b). However, it is acknowledged that this method is not ideal for the precise analysis of periapical status.

Three different indices have been used to examine and assess periapical tissue conditions (Strindberg 1956, Reit & Gröndahl 1983, Ørstavik *et al.* 1986). PAI was first described for periapical radiographs (Ørstavik *et al.* 1986); however, some epidemiological studies have used PAI for OPTGs (Schulte *et al.* 1998, De Moor *et al.* 2000, Lupi-Pegurier *et al.* 2002, Kabak & Abbott 2005, Loftus *et al.* 2005, Da Silva *et al.* 2009), or for a combination of OPTGs and periapical radiographs (Weiger *et al.* 1997, Dugas *et al.* 2003). In this study, the use of PAI – an index based on the radiographic image of maxillary incisors in periapical radiographs – for OPTGs, which provide a poor quality image of the anterior teeth, can be criticized. The main reason for choosing the PAI scoring system was to facilitate the comparison of results with other epidemiological studies, as in recent years studies have increasingly used the PAI to assess periapical status. Also, the use of this index improves intra- and inter-observer agreement. The dividing line between healthy and diseased periapical tissues was set between PAI scores 2 and 3. It is arguable, however, whether this dichotomization does, in fact, represent the borderline between healthy and pathologic periapical status. Comparability with other studies have favoured a dividing line between scores 2 and 3.

Different thresholds have been used for evaluating the quality of root fillings and periapical status in previous studies. Some researchers have concentrated merely on the length of the root fillings (De Moor *et al.* 2000, Kabak & Abbott 2005, Tsuneishi *et al.* 2005, Sunay *et al.* 2007); others have used both length and homogeneity of root filling without combining the two (Eriksen *et al.* 1995), and some have used both length and homogeneity and a combination of the two recordings (Ödesjö *et al.* 1990, Buckley & Spångberg 1995, Marques *et al.* 1998, Kirkevang *et al.* 2000, Boucher *et al.* 2002, Lupi-Pegurier *et al.* 2002, Dugas *et al.* 2003, Segura-Egea *et al.* 2004, Da Silva *et al.* 2009). Agreement exists in the literature that the length of the root filling is an important factor in the success of non-surgical root canal treatment (De Moor *et al.* 2000, Kirkevang *et al.* 2000, Dugas *et al.* 2003, Segura-Egea *et al.* 2004, Kabak & Abbott 2005, Sunay *et al.* 2007), and this is confirmed by the results of the present study. Determining the length of the root filling in relation to the radiographic apex is less of a problem than assessing its density. As the radiographic image is just a two-dimensional reproduction of three-dimensional structures, it is difficult to reach a proper assessment of the root canal obturation. There is still some disagreement, however, about the effect of the homogeneity of the root filling on the periapical status. Ödesjö *et al.* (1990) and Eriksen *et al.* (1995) found no difference between compact and poorly compacted root fillings in relation to periapical lesions. In the current study, it is found that the homogeneity of the root filling has a statistically significant influence on the frequency of AP. This finding has been supported by others (Petersson *et al.* 1991, Kirkevang *et al.* 2000, Da Silva *et al.* 2009).

The comparison of the results of this study with previous prevalence studies conducted on adult populations seems controversial, because in these studies, even the youngest age group was composed of older individuals (20–29 years) (Kirkevang *et al.* 2001, Lupi-Pegurier *et al.* 2002, Tsuneishi *et al.* 2005), whereas this study focused specifically on 19-year-olds. On the other hand, in a Swedish study by Hugoson *et al.* (1995) and in a North American study by Buckley & Spångberg (1995), the youngest age groups studied were relatively closer to the one in this study. The frequency of root filled teeth in 20-year-olds was reported as 0.3% by Hugoson *et al.* (1995). Buckley & Spångberg (1995) reported a frequency of 0.5% in individuals under the age of 20.

Conclusion

Within the limitations of this study, the high frequency of root filled and non-root filled teeth with AP, along with the poor technical quality of the root fillings in young permanent dentition, highlights the importance of caries preventive measures and the need to improve the standards of root canal treatment for this highly selected adolescent Turkish population.

References

Ahlqwist M, Halling A, Hollender L (1986) Rotational panoramic radiography in epidemiological studies of dental health. Comparison between panoramic radiographs and intraoral full mouth surveys. *Swedish Dental Journal* **10**, 73–84.

Boucher Y, Matossian L, Rilliard F, Machtou P (2002) Radiographic evaluation of the prevalence and technical quality of root canal treatment in a French subpopulation. *International Endodontic Journal* **35**, 229–38.

Buckley M, Spångberg LSW (1995) The prevalence and technical quality of endodontic treatment in an American subpopulation. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **79**, 92–100.

Da Silva K, Lam JM, Wu N, Duckmanton P (2009) Cross-sectional study of endodontic treatment in an Australian population. *Australian Endodontic Journal* **35**, 140–6.

De Moor RJ, Hommez GM, De Boever JG, Delmé KI, Martens GE (2000) Periapical health related to the quality of root canal treatment in a Belgian population. *International Endodontic Journal* **33**, 113–20.

Dugas NN, Lawrence HP, Teplitsky PE, Pharoah MJ, Friedman S (2003) Periapical health and treatment quality assessment of root-filled teeth in two Canadian populations. *International Endodontic Journal* **36**, 181–92.

Eriksen HM, Berset GP, Hansen BF, Bjertness E (1995) Changes in endodontic status 1973–1993 among 35-year-olds in Oslo, Norway. *International Endodontic Journal* **28**, 129–32.

European Society of Endodontology (2006) Quality guidelines for endodontic treatment: consensus report of the European Society of Endodontology. *International Endodontic Journal* **39**, 921–30.

Georgopoulou MK, Spanaki-Voreadi AP, Pantazis N, Kontakiotis EG (2005) Frequency and distribution of root filled teeth and apical periodontitis in a Greek population. *International Endodontic Journal* **38**, 105–11.

Gulsahi K, Gulsahi A, Ungor M, Genc Y (2008) Frequency of root-filled teeth and prevalence of apical periodontitis in an adult Turkish population. *International Endodontic Journal* **41**, 78–85.

Hugoson A, Koch G, Bergendal T *et al.* (1995) Oral health of individuals aged 3–80 years in Jönköping, Sweden in 1973, 1983, and 1993. II. Review of clinical and radiographic findings. *Swedish Dental Journal* **19**, 243–60.

Jiménéz-Pinzón A, Segura-Egea JJ, Poyato-Ferrera M, Velasco-Ortega E, Ríos-Santos JV (2004) Prevalence of apical periodontitis and frequency of root-filled teeth in an adult Spanish population. *International Endodontic Journal* **37**, 167–73.

Kabak Y, Abbott PV (2005) Prevalence of apical periodontitis and the quality of endodontic treatment in an adult Belarusian population. *International Endodontic Journal* **38**, 238–45.

Kayahan MB, Malkondu O, Canpolat C, Kaptan F, Bayirli G, Kazazoglu E (2008) Periapical health related to the type of coronal restorations and quality of root canal fillings in a Turkish subpopulation. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **105**, e58–62.

Kirkevang LL, Ørstavik D, Hörsted-Bindslev P, Wenzel A (2000) Periapical status and quality of root fillings and coronal restorations in a Danish population. *International Endodontic Journal* **33**, 509–15.

Kirkevang LL, Hörsted-Bindslev P, Ørstavik D, Wenzel A (2001) Frequency and distribution of endodontically treated teeth and apical periodontitis in an urban Danish population. *International Endodontic Journal* **34**, 198–205.

Loftus JJ, Keating AP, McCartan BE (2005) Periapical status and quality of endodontic treatment in an adult Irish population. *International Endodontic Journal* **38**, 81–6.

Lupi-Pegurier L, Bertrand MF, Muller-Bolla M, Rocca JP, Bolla M (2002) Periapical status, prevalence and quality of endodontic treatment in an adult French population. *International Endodontic Journal* **35**, 690–7.

Marques MD, Moreira B, Eriksen HM (1998) Prevalence of apical periodontitis and results of endodontic treatment in an adult, Portuguese population. *International Endodontic Journal* **31**, 161–5.

Molander B, Ahlqwist M, Gröndahl HG (1995a) Image quality in panoramic radiography. *Dentomaxillofacial Radiology* **24**, 17–22.

Molander B, Ahlqwist M, Gröndahl HG (1995b) Panoramic and restrictive intraoral radiography in comprehensive oral radiographic diagnosis. *European Journal of Oral Sciences* **103**, 191–8.

Muhammed AH, Manson-Hing LR, Ala B (1982) A comparison of panoramic and intraoral radiographic surveys in evaluating a dental clinic population. *Oral Surgery, Oral Medicine, and Oral Pathology* **54**, 108–17.

Ödesjö B, Helldén L, Salonen L, Langeland K (1990) Prevalence of previous endodontic treatment, technical standard and occurrence of periapical lesions in a randomly selected adult, general population. *Endodontics and Dental Traumatology* **6**, 265–72.

Ørstavik D, Kerekes K, Eriksen HM (1986) The periapical index: a scoring system for radiographic assessment of apical periodontitis. *Endodontics and Dental Traumatology* **2**, 20–34.

Petersson K, Håkansson R, Håkansson J, Olsson B, Wennberg A (1991) Follow-up study of endodontic status in an adult Swedish population. *Endodontics and Dental Traumatology* **7**, 221–5.

Reit C, Gröndahl HG (1983) Application of statistical decision theory to radiographic diagnosis of endodontically treated teeth. *Scandinavian Journal of Dental Research* **91**, 213–8.

Ridell K (2008) Endodontic treatment in young permanent teeth. Prevalence, quality and potential risk factors. *Swedish Dental Journal Supplement* **193**, 9–58.

Ridell K, Sundin B, Matsson L (2003) Endodontic treatment during childhood and adolescence. A survey of 19-year-olds living in the city of Malmö, Sweden. *Swedish Dental Journal* **27**, 83–9.

Ridell K, Petersson A, Matsson L, Mejàre I (2006) Periapical status and technical quality of root-filled teeth in Swedish adolescents and young adults. A retrospective study. *Acta Odontologica Scandinavica* **64**, 104–10.

Ridell K, Matsson L, Mejàre I (2007) Background factors associated with endodontic treatment due to caries in young permanent teeth. *Acta Odontologica Scandinavica* **65**, 219–23.

Schulte A, Pieper K, Charalabidou O, Stoll R, Stachniss V (1998) Prevalence and quality of root canal fillings in a German adult population. A survey of orthopantomograms taken in 1983 and 1992. *Clinical Oral Investigations* **2**, 67–72.

Segura-Egea JJ, Jiménéz-Pinzón A, Poyato-Ferrera M, Velasco-Ortega E, Ríos-Santos JV (2004) Periapical status and quality of root fillings and coronal restorations in an adult Spanish population. *International Endodontic Journal* **37**, 525–30.

Siqueira JF Jr, Rôças IN, Alves FR, Campos LC (2005) Periradicular status related to the quality of coronal restorations and root canal fillings in a Brazilian population. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **100**, 369–74.

Strindberg L (1956) The dependence of the results of pulp therapy on certain factors. An analytic study based on radiographic and clinical follow-up examinations. *Acta Odontologica Scandinavica* **14**(Suppl. 21), 1–175.

Sunay H, Tanalp J, Dikbas I, Bayirli G (2007) Cross-sectional evaluation of the periapical status and quality of root canal treatment in a selected population of urban Turkish adults. *International Endodontic Journal* **40**, 139–45.

Touré B, Kane AW, Sarr M, Ngom CT, Boucher Y (2008) Prevalence and technical quality of root fillings in Dakar, Senegal. *International Endodontic Journal* **41**, 41–9.

Tsuneishi M, Yamamoto T, Yamanaka R *et al.* (2005) Radiographic evaluation of periapical status and prevalence of endodontic treatment in an adult Japanese population. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontics* **100**, 631–5.

Weiger R, Hitzler S, Hermle G, Löst C (1997) Periapical status, quality of root canal fillings and estimated endodontic treatment needs in an urban German population. *Endodontics and Dental Traumatology* **13**, 69–74.