Prevalence of persistent pain after endodontic treatment and factors affecting its occurrence in cases with complete radiographic healing

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Abstract

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Aims To (i) determine the prevalence of persistent dento-alveolar pain following nonsurgical and/or surgical endodontic treatment conducted in a teaching dental hospital and (ii) identify the risk factors associated with persistent pain after apparently successful root canal treatment.

Study design A total of 175 patients/teeth were reviewed 12–59 months following treatment. The patients were examined clinically and radiographically and a detailed pain history obtained. Multiple logistic regression analysis was used to investigate the association between potential risk factors and persistent pain after successful endodontic treatment.

Results The prevalence of persistent pain after successful root canal treatment was 12% (21/175). Treatment success was determined by the absence of clinical and radiographic signs of dental disease. The factors that were significantly ($P < 0.05$) associated with persistent pain following endodontic treatment were: 'duration of preoperative pain' [odds ratio (OR) = 8.6], 'preoperative pain from the tooth' (OR = 7.8), 'preoperative tenderness to percussion' (OR = 7.8), 'previous chronic pain problems' (OR = 4.5), 'gender' (OR = 4.5) and 'history of painful treatment in the orofacial region' (OR = 3.8). 'Type of treatment received (surgical or nonsurgical treatment)' showed borderline significance at the 10% level.

Conclusions The presence and duration of preoperative pain from the tooth site, lasting at least 3 months, a positive history of previous chronic pain experience or painful treatment in the orofacial region, and female gender were important risk factors associated with persistent pain after successful endodontic treatment.

Keywords: endodontic treatment, persistent pain.

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Introduction

Persistent pain associated with teeth after nonsurgical or surgical endodontic treatment has been used as an indicator of treatment failure (Rahbaran *et al.* 2001, Hoskinson *et al.* 2002). However, pain may be experienced in a tooth or adjacent site in the absence of clinical or radiographic signs of dental disease. Such diagnostic dilemmas in decision-making during treatment planning were highlighted by Hunter (1778). Failure to detect pathological change on periapical radiographs may reflect limitations of the diagnostic method rather than an absence of an osteolytic lesion (Bender & Seltzer 1961, Shoha *et al.* 1974). Superimposition of adjacent anatomical structures over the suspect tooth may further obscure the view. Conversely, residual periapical disease may be truly absent and the pain may be nonodontogenic.

Pain in a tooth site of neurogenic origin has been reported in the literature (Marbach *et al.* 1982, Campbell *et al.* 1990) but only a few published studies

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(Marbach 1978, Marbach *et al.* 1982, Campbell *et al.* 1990, Schnurr & Brooke 1992, Vicker *et al.* 1998, Berge 2002) have investigated the occurrence of neuropathic pain after dental treatment. Evidence of the association between dental treatment and chronic neuropathic pain has been presented by Marbach (1978), Schnurr & Brooke (1992) and Vicker *et al.* (1998), who reported that most patients diagnosed with atypical odontalgia related the onset of the pain to dental treatment, dental infection or dental trauma.

Only three epidemiological studies (Marbach *et al.* 1982, Campbell *et al.* 1990, Berge 2002) have investigated the prevalence of chronic neuropathic pain after dental treatment. The study by Marbach *et al.* (1982) was conducted by a single endodontist, who mailed questionnaires to patients 1 month following nonsurgical endodontic treatment. Only female patients were included in their analyses because the male sample was considered too small. Of the 256 female patients assessed, 20 (9%) reported persistent pain during the period of survey but only 11 female patients attended for clinical and radiographic examination to exclude an odontogenic cause of pain. Of the 11 patients, eight (3% of 256 female patients) were diagnosed with 'phantom toothache'. Campbell *et al.* (1990) carried out a similar survey of patients who had undergone surgical endodontic treatment 2 years previously and found that 59 (5%) of the 118 patients suffered from chronic pain that divided equally into two groups; post-traumatic stress dysaesthesia (absence of pain preoperatively) (PTD) and phantom tooth pain (PTP) (presence of pain preoperatively). In contrast, Berge (2002) found none of the 1035 patients in their survey suffered from chronic neuropathic pain following surgical removal of third molars 5–6 years previously. None of these studies extended their investigation to include risk factors affecting prevalence of persistent pain after dental treatment.

The aims of this study were therefore to: (i) determine the prevalence of persistent pain following endodontic treatment, and (ii) evaluate the association between prevalence of persistent pain after 'successful' endodontic treatment and potential risk factors.

Materials and methods

Inclusion criteria

The sample population of this study comprised all patients ($n = 400$) who had received nonsurgical or surgical endodontic treatment during a defined period (October 1997 to May 2001) in the Unit of Endodontology, Eastman Dental Hospital, London, UK. The patients were referred from general dental practice, secondary referral centres and other units within the dental hospital. All patients had endodontic treatment completed at least 1 year previously.

Data gathering

Pre- and intra-operative data extraction from prospective data collection forms

Comprehensive prospective pre- and intra-operative data for each patient were meticulously recorded by clinicians on a custom designed proforma from October 1997. Relevant demographic data, medical history, preoperative pain history, diagnostic and treatment details of the tooth were extracted and entered onto a database (SPSS 11.0 for Windows; SPSS Inc., Chicago, IL, USA, 2002).

Follow-up clinical examination data

Follow-up examination consisted of history taking, clinical and radiographic examination. All subjects were interviewed and examined by two operators (NP and YLN). During the interview, the patient's personal, medical and dental details as well as the preoperative pain history were confirmed. A detailed pain interview was conducted on patients presenting with pain on review. Extra-oral examination included palpation of masticatory, neck and shoulder muscles for comparative tenderness, auscultation and palpation of the temporomandibular joint and assessment of the range of mandibular movement. Clinical details of the treated tooth recorded were: tenderness to percussion, tenderness to palpation of adjacent soft tissues, presence of an associated sinus tract, mobility, periodontal probing depths and the presence of an adequate coronal seal. The teeth adjacent and opposing the tooth under investigation were also examined in order to exclude them as causes of pain.

Radiographic data

All the preoperative, immediate postoperative and follow-up periapical radiographs were taken reproducing the same angulation; facilitated by a beam-aiming device (Rinn; Dentsply Ltd, Weybridge, UK) and a customized stent. The immediate postoperative and follow-up radiographs, mounted side by side, were examined blindly by two observers, both endodontists, independently under controlled conditions in a darkened room using a fluorescent light box (Rinn; Dentsply Ltd) and a magnifying viewer (Brynolf, ×2.5 magnifi-

cation; Trycare Ltd, Bradford, UK). The observers were precalibrated using reference radiographs representing the four categories of radiographic healing pattern:

1. Complete – a normal periodontal ligament space (periodontal ligament space widened to twice that of normal adjacent to the root-end filling was tolerated in surgical cases only).

2. Incomplete – a reduction in size of the lesion, but no return to normal periodontal ligament space width.

3. Uncertain – radiographically impossible to make definitive decision on status of postoperative healing.

4. Failure – a previously existing periapical lesion had increased or remained at the same size or a previously normal periodontal ligament space had increased in width or developed into a radiolucent area.

In multi-rooted teeth the worst outcome by root decided the overall healing pattern for the tooth. In the event of disagreement, the two observers discussed their findings and agreed on the outcome. In absence of unanimity, a decision was arbitrated by another author (KG).

Both observers re-examined 30% of the radiographs from randomly selected cases after a 6-week interval, to determine intra-observer reliability of radiographic interpretation.

Assessment of overall treatment outcome

For 'successful' cases to be included in this study, the patient/tooth had to demonstrate an absence of clinical and radiographic evidence of periapical disease. As persistent pain was the dependent variable under analysis in this study it was not used as the sole arbiter of treatment failure.

Collation, summary and analysis of data

Statistical analyses were performed with a computer statistics package (SPSS 11.0 for Windows). The Cohen's κ coefficient was calculated to assess both intra- and inter-observer agreement. Good agreement was taken as >0.8, substantial as 0.61–0.8 and moderate as 0.4–0.6 (Petrie & Watson 1999). Chi-square tests and logistic regression analyses were employed to investigate the association of possible influencing factors and their odds in the development of persistent pain following endodontic treatment and complete periapical healing.

Results

In total 175 patients (253 teeth) were reviewed, representing a recall rate of 43.8%. Failure of patients to attend ($n = 225$) was attributed to loss of contact (30%), loss of tooth (15% extracted), lack of compliance to attend (9%) or death (2%). Only one tooth per patient was selected randomly for this study, therefore the final total sample number was 175 patients/teeth. The characteristics of the samples are presented in Table 1. The proportions of males (42%) and females (58%) were similar. The subjects were predominantly within the 31–51 years age bracket (72%) and belonged to the white ethnicity group (84%). Teeth included were incisors/canines (29.1%), premolars (19.4%) and molars (51.4%). Most of these teeth had nonsurgical treatment only (85%) and 15% had surgical treatment. Treatment on most teeth had been completed 1–2 years (49.5%) previously.

The κ coefficient performed to determine the degree of agreement revealed 0.43 (moderate) inter-observer reliability. The intra-observer reliability could not be calculated in this study due to asymmetry of the contingency table required to perform this statistical analysis.

Persistent pain was detected in 37 (21.1%) of the 175 patients/teeth. Out of the group judged to have successful treatment ($n = 103$, 58.9%), 21 (20.4%) of the patients presented with pain specifically related to the tooth (Table 2). This represents 12.0% (21/175) of the total sample. The majority of the patients presented with preoperative pain (62.1%) and 37.9% of the patients did not. Most of the patients ($n = 19$, 95%), regardless of treatment outcome had been suffering from the pain at review for at least 3 months, except two patients in the incomplete healing group. By definition, all these patients were suffering from chronic pain; defined as 'persistent pain after signs of disease have subsided or pain extending over a period of at least 3 months' (IASP; Merskey 1986).

Only those cases in the complete healing group ($n = 103$) were included for further statistical analyses to identify potential risk factors for persistent pain after endodontic treatment. The frequency distribution of the key explanatory variables and the proportion of patients that presented with chronic pain on review within the complete healing group are presented in Table 3. Chi-square tests identified nine factors that had significant ($P < 0.05$) association with the prevalence of chronic pain on review (Table 3). These were: gender, ethnicity, history of previous chronic pain problems and previous painful treatment in the orofacial region, presence and duration of preoperative pain from the treated tooth, tenderness of the treated tooth preoperatively, type of treatment and inter-appointment pain.

Table 1 Frequency distribution of sample ($n = 175$ patients/teeth) with regards to gender, age, ethnicity, tooth type, treatment received and review period

	Number (%)
Gender	
Male	73 (41.8)
Female	102 (58.2)
Age range	
≥11 and >21	5 (2.9)
≥21 and >31	21 (12)
≥31 and >41	41 (23.4)
≥41 and >51	45 (25.7)
≥51 and >61	40 (22.8)
≥61 and >71	17 (9.7)
≥71	6 (3.4)
Ethnicity	
White (British or Irish)	111 (63.4)
White other (non-British and non-Irish)	36 (20.6)
Black Caribbean	8 (4.6)
Black other	6 (3.5)
Indian	3 (1.8)
Pakistani	1 (0.7)
Bangladeshi	1 (0.7)
Chinese	4 (2.4)
Asian other	5 (2.8)
Tooth type	
Incisors/canines	51 (29.1)
Premolars	34 (19.4)
Molars	90 (51.4)
Tooth location	
Upper arch	100 (57.1)
Lower arch	75 (42.9)
Treatment received	
Primary root canal treatment (vital pulp)	16 (9.1)
Primary RCT (nonvital pulp)	49 (27.8)
Root canal re-treatment	84 (47.7)
Primary RCT or root canal re-treatment followed by periapical surgery	17 (9.7)
Periapical surgery	7 (4)
Periapical re-surgery	2 (1.14)
Review period (months)	
≥12 and >23	86 (49.5)
≥24 and >35	48 (27.4)
≥36 and >47	31 (17.7)
≥48 and >59	10 (5.8)

Table 2 Prevalence of pain complaint associated with the treated tooth on review by overall treatment outcome ($n = 175$)

Complaint of pain on review	Overall outcome of treatment				
	Complete (%)	Incomplete (%)	Uncertain (%)	Failure (%)	Total (%)
Yes	21 (12.0)	6 (3.4)	5 (2.9)	5 (2.9)	37 (21.1)
No	82 (46.9)	41 (23.4)	7 (4.0)	8 (4.6)	138 (78.9)
Total	103 (58.9)	47 (26.9)	12 (6.9)	13 (7.4)	175 (100)

Each of these factors was analysed separately in single logistic regression models with the odds of 'persistent pain after endodontic treatment' as the dependent variable (Table 4). No further logistic regression analysis for ethnicity was conducted as each of the nine groups was poorly represented and the significance of each was impossible to ascertain. The odds ratios of occurrence of persistent pain after successful endodontic treatment by each explanatory variable, with the reference category in bracket as the baseline, are presented in Table 4.

Some of these potential predictive factors were highly correlated to each other ($P < 0.05$) (Table 5) and therefore could not be included in a multiple regression model simultaneously. The variable 'inter-appointment pain' failed to retain significance at the 10% level when it was tested in multiple regression models, therefore it is absent in the final models presented in Table 6.

In Table 6, models 1, 2 and 3 illustrate the effect of attempting to enter 'gender' and 'type of treatment received' together with 'preoperative pain persistent for 3 months or more', 'previous chronic pain problems' or 'preoperative pain from the tooth', respectively. All the factors retained their significance at the 5% level except 'type of treatment received' which achieved significance at the 5% level in model 2 but only at 10% level in models 1 and 3.

Model 4 explored three variables: 'preoperative TTP of the tooth', 'history of painful treatment in orofacial region' and 'type of treatment received' simultaneously. 'Type of treatment received' again attained significance only at the 10% level. These results show that 'type of treatment received' only demonstrated borderline significance in multiple regression models.

Factors not significantly affecting the occurrence of chronic nonodontogenic pain after successful endodontic treatment were age; tooth type; history of trauma or surgery generally in orofacial region; history of psychological problems; history of employment; intensity of preoperative pain from the tooth; preoperative tenderness to palpation of adjacent soft tissue; effectiveness of anaesthesia during treatment and experience of inter-appointment pain.

Discussion

The Eastman Dental Hospital is a tertiary referral centre where patients with complex or recalcitrant problems tend to be referred; therefore patients included in this study represent a biased population sample. The recall rate (43.8%) was comparable with previous endodontic

Table 3 Frequency distribution of data and presence of pain on review of patients within the complete healing group (based on criteria for overall outcome of treatment) for key explanatory variables

Variables	Total ($n = 103$)	Presence of pain on review ($n = 21$)	χ^2 test (P-value)
Male	38 (36.9)	3 (14.3)	0.031*
Female	65 (63.1)	18 (85.7)	
11–20	5 (4.9)	1 (4.8)	0.064
21–30	13 (12.6)	2 (9.5)	
31–40	20 (19.4)	0 (0)	
41–50	24 (23.3)	6 (28.6)	
51–60	28 (27.2)	8 (38.1)	
61–70	8 (7.8)	3 (14.3)	
>70	5 (4.9)	1 (4.8)	
White	68 (66)	9 (42.9)	0.007*
White other	22 (21.4)	8 (38.1)	
Black Caribbean	4 (3.9)	0 (0)	
Black other	3 (2.9)	0 (0)	
Indian	2 (1.9)	1 (4.8)	
Pakistani	1 (1.0)	1 (4.8)	
Bangladeshi	0 (0)	0 (0)	
Chinese	1 (1.0)	0 (0)	
Asian other	2 (1.9)	2 (9.5)	
Upper incisor/canine	24 (23.3)	5 (23.8)	0.729
Upper premolars	13 (12.6)	3 (14.3)	
Upper molars	24 (23.3)	6 (28.6)	
Lower incisor/canine	4 (3.9)	0 (0)	
Lower premolar	7 (6.8)	2 (9.5)	
Lower molar	31 (30.1)	5 (23.8)	
Previous chronic pain problems[a]	50 (48.5)	16 (76.2)	0.009*
No previous chronic pain problems	53 (51.5)	5 (23.8)	
Painful treatment in the orofacial region[b]	47 (46.1)	15 (71.4)	0.018*
No painful treatment in the orofacial region	55 (53.9)	6 (28.6)	
History of trauma	27 (26.2)	7 (33.3)	0.580
No history of trauma	76 (73.8)	14 (66.7)	
History of surgery in orofacial region	47 (45.6)	10 (47.6)	1.000
No history of surgery in orofacial region	56 (54.4)	11 (52.4)	
History of psychological problems	18 (17.5)	5 (23.8)	0.593
No history of psychological problems	85 (82.5)	16 (76.2)	
Unemployed	18 (17.5)	3 (14.3)	0.604
Employed	67 (66)	13 (61.9)	
N/A	17 (16.5)	5 (23.8)	
Presence of preoperative pain from the tooth	64 (62.1)	19 (90.5)	0.006*
No preoperative pain from the tooth	39 (37.9)	2 (9.5)	
TTP preoperatively	64 (62.1)	19 (90.5)	0.006*
No TTP preoperatively	39 (37.9)	2 (9.5)	
TTPL of adjacent soft tissues preoperatively	46 (44.7)	11 (52.4)	0.581
No TTPL of adjacent soft tissues preoperatively	57 (55.3)	10 (47.6)	
Preoperative pain persistent for <3 months	41 (39.8)	2 (9.5)	0.003*
Preoperative pain persistent for ≥3 months	62 (60.2)	19 (90.5)	
Intensity of pain (0–5) preoperatively	36 (56.3)	14 (73.7)	0.121
Intensity of pain (6–10) preoperatively	28 (43.8)	5 (26.3)	
Presence of periapical lesion preoperatively	80 (77.7)	15 (71.4)	0.634
No periapical lesion preoperatively	23 (22.3)	6 (28.6)	
Satisfactory anaesthesia during treatment	99 (96.1)	19 (90.5)	0.170

Table 3 continued

Variables	Total ($n = 103$)	Presence of pain on review ($n = 21$)	χ^2 test (P-value)
Unsatisfactory anaesthesia during treatment	4 (3.9)	2 (9.6)	
Inter-appointment pain	66 (64.1)	8 (38.1)	0.012*
No inter-appointment pain	37 (35.9)	13 (61.9)	
Surgical treatment received	11 (10.7)	5 (23.8)	0.029*
Nonsurgical treatment received	92 (89.3)	16 (72.6)	

Values are expressed as n (%). TTP, tenderness to percussion; TTPL, tenderness to palpation of associated soft tissues. *P-value indicates significance at a 5% level.
[a]Chronic pain problem = patient reported a history of neck, shoulder or back pain, TMD or headache.
[b]Painful treatment in orofacial region = patient experienced severe pain during or immediately after general restorative or surgical treatment.

Table 4 Logistic regression (LR) models for each explanatory variable given individually

Explanatory variable (test category/reference category)	LR analyses		
	Odds ratio	95% CI	P-value
Preoperative pain persistent for ≥3 months (yes/no)	8.60	1.88–39.29	0.005
Previous chronic pain problems (yes/no)	4.52	1.51–13.52	0.007
Inter-appointment pain (yes/no)	3.93	1.44–10.69	0.007
Preoperative pain from the tooth (yes/no)	7.80	1.71–35.66	0.008
Preoperative TTP of the tooth (yes/no)	7.80	1.71–35.66	0.008
History of painful treatment in the orofacial region (yes/no)	3.83	1.35–10.90	0.012
Gender (female/male)	4.47	1.22–16.37	0.024
Surgical treatment received (yes/no)	3.96	1.08–14.57	0.039

P-value indicates significance at a 5% level. TTP, tenderness to percussion; odds ratio, odds of pain with test category/odds of pain with reference category.

Table 5 Results of chi-square tests (P-values) between the potential explanatory variables (binary variables)

	Variables	2	3	4	5	6	7	8
1	Gender	0.128	0.005*	0.665	0.990	0.183	0.720	0.151
2	Preoperative pain from the tooth		<0.001*	0.042*	0.444	<0.001*	<0.001*	0.610
3	Preoperative TTP of the tooth			0.302	0.914	<0.001*	<0.001*	0.610
4	Previous painful treatment in orofacial region				0.060	0.002*	0.017*	0.416
5	Type of treatment received					0.854	0.349	0.630
6	Previous chronic pain problems						<0.001*	0.388
7	Preoperative pain persistent for ≥3 months							0.582
8	Presence of inter-appointment pain							

TTP, tenderness to percussion.
*P-value indicates significance at 5% level.

outcome studies (Swartz *et al.* 1983, Sjögren *et al.* 1990, Rahbaran *et al.* 2001, Hoskinson *et al.* 2002). In order to avoid bias due to asymptomatic patients not returning for review, all the patients were contacted by post and followed-up by telephone to explain the purpose of the study. However, a relatively large proportion of the patients who had treatment completed more than 3 years previously were not contactable because of the mobile nature of the population. Only 6% of the patients had treatment completed at least 4 years previously.

Although a 4-year review period is regarded as the gold standard for assessing the long-term outcome of endodontic treatment (Strindberg 1956), the requirements for a pain study are different. Assessment of postoperative pain is reliant upon an accurate pain history which is more likely to be obtained over shorter review intervals. A balance therefore had to be realized

Table 6 Multiple logistic regression (LR) models incorporating combination of several explanatory variables

Explanatory variable (test category/reference category)	LR analyses		
	Odds ratio	95% CI	*P*-value
Model 1			
Preoperative pain persistent for ≥3 months (yes/no)	7.27	1.54–34.29	0.012*
Gender (female/male)	3.99	1.01–15.66	0.048*
Surgical treatment received (yes/no)	3.93	0.89–17.37	0.071
Model 2			
Previous chronic pain problems (yes/no)	4.94	1.49–16.30	0.009*
Gender (female/male)	4.59	1.13–18.65	0.033*
Surgical treatment received (yes/no)	5.93	1.32–26.66	0.020*
Model 3			
Preoperative pain from the tooth (yes/no)	6.69	1.42–31.63	0.016*
Gender (female/male)	4.06	1.04–15.86	0.044*
Surgical treatment received (yes/no)	4.06	0.92–17.85	0.064
Model 4			
Preoperative TTP of the tooth (yes/no)	8.28	1.68–40.92	0.010*
History of painful treatment in orofacial region (yes/no)	3.27	1.08–9.93	0.037*
Surgical treatment received (yes/no)	3.78	0.85–16.83	0.081

TTP, tenderness to percussion; odds ratio, odds of pain with test category/odds of pain with reference category. **P*-value indicates significance at 5% level.

in allowing complete periapical healing against a review period short enough not to compromise the memory of pain history. Previous surveys on chronic pain after endodontic treatment used either 1 month (Marbach *et al.* 1982) or 2–3 years (Campbell *et al.* 1990) post-treatment recall periods. A 12-month review period was decided upon in the present study because the majority of periapical lesions are likely to be healed within this time-frame (Eriksen *et al.* 1988, Ørstavik 1988) and yet may be short enough to yield accurate pain histories.

Only one tooth per patient was selected randomly for this study because multiple teeth in the same patient could not be assumed to behave independently.

In contrast to previous studies (Marbach *et al.* 1982, Campbell *et al.* 1990), all patients were reviewed both clinically and radiographically. This part of the data collection was adapted from various pain questionnaires to encompass the multi-dimensional aspects of pain. These included the visual analogue scale (Huskisson 1974), the McGill pain questionnaire (Melzack 1975) and the graded chronic pain scale (Von Korff *et al.* 1992). Factors that may have influenced the development of chronic postoperative pain were researched through reviews of epidemiology studies on chronic benign pain (Verhaak *et al.* 1988) and orofacial pain (McFarlane *et al.* 2001).

All the teeth were classified into one of the four radiographic periapical healing patterns but given the well documented problem of observer variability, an attempt was made to calibrate the observers using standard reference radiographs. The initial inter-observer κ correlation was 0.43, which is within the range of agreement found for initial agreement in other studies (Goldman *et al.* 1972, 1974, Lambriandis 1985). Cases on which there was disagreement were reviewed by the observers and an agreed decision negotiated (Sjögren *et al.* 1990); a third observer arbitrated on the five cases that required a decision. The initial low κ value in this study was therefore unlikely to influence the quality of the final outcomes. The previous epidemiological studies (Marbach *et al.* 1982, Campbell *et al.* 1990) had not addressed the issue of observer bias.

Of the total sample of 175 patients/teeth, 21 (12%) patients presented with persistent pain at review despite successful endodontic treatment. By definition, all these 21 patients (12%) were suffering from chronic pain after endodontic treatment, a prevalence much higher than that reported by Marbach *et al.* (1982) (3%) and Campbell *et al.* (1990) (5%). This discrepancy could be attributed to the difference in characteristics of sample and method of survey. Most of the patients in this study may have been consulted and treated by several dentists before being referred to the hospital for repeat nonsurgical or surgical treatment. In addition to this, there was a long waiting list for consultation and treatment at the hospital therefore potentially prolonging the duration of preoperative pain from the tooth: a factor found to be a significant ($P = 0.005$) risk factor

for development of chronic pain. A relatively large proportion of patients in the successful group had preoperative pain that continued after treatment, interestingly all these patients reported that either the intensity or the characteristics of pain at review had changed after treatment. The treatment procedure itself could provide sufficient peripheral stimulation to alter the characteristics of a chronic nonodontogenic pain complaint. On the other hand, the presence of a cracked tooth or undetected periapical lesion could not be completely ruled out given the known limitations of current clinical and radiographic assessment.

Significant risk factors leading to the development of chronic pain after endodontic treatment in this study were 'presence and duration of preoperative pain from the tooth', 'tenderness to percussion of the tooth preoperatively', 'female gender', 'previous painful treatment in the orofacial region', 'previous chronic pain problems' and 'type of treatment received (nonsurgical or surgical treatment)'.

All chronic pain patients, by definition, have suffered from an episode of acute pain that did not resolve (Dworkin 1997). A converse view is that acute pain is a risk factor for the development of phantom pain (Jensen *et al.* 1985). Measures of presence, intensity and duration of acute preoperative pain have been reported to predict phantom pain after mastectomies (Krøner *et al.* 1989) and limb amputations (Jensen *et al.* 1985). Many of the measures of pain used in the present study are also used to gauge acute pain in the dental setting. However, only three of them (presence and duration of preoperative pain; tenderness to percussion of the tooth preoperatively) were found to have a significant association with persistent pain after 'successful' endodontic treatment. Interestingly, intensity of preoperative pain had no significant influence on the prevalence of chronic pain after endodontic treatment. Whilst there are a number of possible explanations for this observation, it might simply reflect a lack of sensitivity in the methods used to record pain intensity.

Although it has been well defined, phantom tooth pain is sometimes referred to as atypical odontalgia, a condition which is assumed to be a variant of atypical facial pain (Schnurr & Brooke 1992). Only 5% ($n = 2$) of the patients with no preoperative pain developed chronic pain following endodontic treatment. This could be due to undetected odontogenic problems such as root fracture or persistent inflammation due to infection. On the other hand, the persistent pain may be of a nonodontogenic origin with a neuropathic basis. Marbach (1993) has suggested that a deafferentation pain syndrome may be triggered by pulp amputation (Marbach 1993). Support for this theory comes from the work of Hu & Sessle (1989) who showed that somato-sensory pathways alter as a result of removal of pulp tissue in cats.

This study found that patients with a history of previous chronic pain problems (e.g. neck, shoulder and back pain, TMD and headache) were approximately 4.5 times ($P = 0.007$) more likely to have chronic pain despite successful endodontic treatment. This is in agreement with other studies (Helkimo 1974, Tervonen & Knuuttila 1988, Andersson *et al.* 1996) that reported co-morbidities such as headache and pain elsewhere in the body to be significantly associated with chronic orofacial pain.

Patients that had previously experienced painful treatment in the orofacial region (general restorative and surgical) were approximately 3.8 times ($P = 0.012$) more likely to have chronic pain after endodontic treatment. Although no previous research has investigated or commented on this factor, it may be hypothesized that prior episodes of painful treatment in the orofacial region may have induced central or peripheral changes in patients with subsequent increased vulnerability to chronic orofacial pain.

Women were found to be approximately four times more likely than men to develop chronic pain following endodontic treatment. This finding is in agreement with some epidemiological studies of chronic orofacial pain (Von Korff *et al.* 1988, Lipton *et al.* 1993, Goulet *et al.* 1995, Riley & Gilbert 2001). In contrast, other studies (Locker & Grushka 1987, Andersson *et al.* 1993, MacEntee *et al.* 1993) did not find gender differences in prevalence across various measures of orofacial pain. Various hypotheses have been proposed to explain female predominance with regards to pain prevalence. The dominant argument is that women tend to seek and accept treatment more willingly, as the presence of symptoms is readily perceived as indicators of disease (Unruh 1996). Hence women are perhaps more likely to attend for review if pain is persistent. A misconception, which has been highlighted in the literature (Colemeco *et al.* 1983), is that many clinicians believe that women are more likely to suffer from psychosomatic illness and that their pain is governed by emotional factors. Interestingly, in this study psychological disturbances did not impact on the prevalence of review pain, however, this may be due to the limitation of the screening process. Patients in this study were not subjected to a formal psychological/psychiatric interview and no psychomet-

ric tests were applied. Nevertheless, evidence is emerging that biological differences between genders may explain the higher chronic pain prevalence in females (Fillingim & Maixner 1995). In both the clinical and laboratory settings, differences between sexes vary in prevalence, with inconsistent outcomes being attributed to variations in experimental method, data collection, reproductive status and genetic profile. This study was designed to detect levels of persistent pain after endodontic therapy and was not primarily focussed on detection of gender differences.

Patients who had received nonsurgical followed by surgical endodontic treatment were approximately four times more likely to develop chronic pain after successful endodontic treatment. However, this influence was only borderline significant in a single logistic regression model ($P = 0.039$) but inconsistently significant in multiple logistic regression models (Table 6). This could be due to the small proportion of patients that had undergone surgical endodontic treatment (11%). Further prospective studies are required to verify whether 'type of treatment' is a risk factor.

In conclusion, despite the fact that the recall rate limited the useful sample size, this study showed that the prevalence of chronic pain after successful endodontic treatment was relatively high (12%) in a tertiary referral centre. Gaining an insight into the characteristics and clinical details of patients who have increased likelihood of developing chronic pain following endodontic treatment is valuable for both clinician and patient. This information also invites the design of interventions for its clinical prevention. The factors that have been identified as significant risk factors for the prevalence of persistent pain may be influenced by the sample characteristics. For example, these patients were screened in a tertiary referral centre making it more likely that additional or superimposed difficulties would be identified or eliminated. The most significant risk factors were presence and duration of preoperative pain from the tooth. Perhaps an important implication of this finding for prevention of chronic pain is that preoperative pain should be alleviated by prompt intervention through restorative and pharmacological means. Preemptive analgesia may reduce the initial peripheral input and minimize the risk of central neuroplastic changes (Fisher & Meller 1991).

All the patients ($n = 21$) with chronic pain after successful endodontic treatment were referred to a pain management clinic for assessment and treatment. The characteristics of preoperative pain and pain presented at review as well as the outcome of further management of these patients will be presented in a separate paper.

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