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Predictive models of pain following root canal treatment: a prospective clinical study

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Abstract

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Aim To determine the probability of the incidence, intensity, duration and triggering of post-endodontic pain, considering factors related to the patient (age, gender, medical evaluation) and to the affected tooth (group, location, number of canals, pulp vitality, preoperative pain, periapical radiolucencies, previous emergency access, presence of occlusal contacts with antagonist).

Methodology A total of 500 one-visit root canal treatments (RCTs) were performed on patients referred to an endodontist. Shaping of root canals was performed manually with Gates-Glidden drills and K-Flexofiles, and apical patency was maintained with a size 10 file. A 5% NaOCl solution was used for irrigation, and canals were filled with lateral compaction and AH-Plus sealer. Independent factors were recorded during the treatment, and characteristics of post-endodontic pain (incidence, intensity, type and duration) were later surveyed through questionnaires. Of the 500 questionnaires, 374 were properly returned and split in two groups for two different statistical purposes: 316 cases were used to adjust the logistic regression models to predict each characteristic of post-endodontic pain using predictive factors, and the remaining 58 cases were used to test the validity of each model.

Results The predictive models showed that the incidence of post-endodontic pain was significantly lower when the treated tooth was not a molar ($P = 0.003$), demonstrated periapical radiolucencies ($P = 0.003$), had no history of previous pain ($P = 0.006$) or emergency endodontic treatment ($P = 0.045$) and had no occlusal contact ($P < 0.0001$). The probability of experiencing moderate or severe pain was higher with increasing age ($P = 0.09$) and in mandibular teeth ($P = 0.045$). The probability of pain lasting more than 2 days was increased with age ($P = 0.1$) and decreased in males ($P = 0.007$) and when a radiolucent lesion was present on radiographs ($P = 0.1$).

Conclusions Predictive formulae for the incidence, the intensity and the duration of post-endodontic pain were generated and validated taking account of the interrelation of multiple concomitant clinical factors. A predictive model for triggering post-endodontic pain could not be established.

Keywords: logistic regression, pain duration, pain intensity, post-endodontic pain, postoperative pain, predictive models.

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Introduction

Pain following root canal treatment occurs occasionally with a highly variable reported prevalence ranging from 82.9 (Glassman *et al.* 1989) to 10.6% (Oliet 1983). During canal cleaning, shaping or filling procedures, extrusion of microorganisms or debris is common and has been reported to worsen the inflammatory response and cause periradicular inflammation (Cunningham & Mullaney 1992). However, it is not clear which other factors may affect post-endodontic pain (Marshall & Walton 1984).

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Patients frequently ask whether they will have pain after root canal treatment (RCT). If dentists knew precisely which factors were involved in the occurrence of post-endodontic pain and understood their complex interactions, they should be able to answer this question rationally and thus prepare patients for possible pain events after completion of RCT. It would also be useful to have a tool to predict other relevant outcomes modulating post-endodontic pain, such as duration, intensity or triggering, being able to warn patients to avoid the possible eliciting mechanism and to prescribe the proper analgesic therapy (Pisano *et al.* 1985, Lobb *et al.* 1996).

Several studies have reported a high incidence of post-endodontic pain (Harrison *et al.* 1981, Glassman *et al.* 1989, Negm 1989, 1994, Morse *et al.* 1990, Marshall & Liesinger 1993, Walton & Chiappinelli 1993, Siqueira *et al.* 2002, Gopikrishna & Parameswaran 2003, Su *et al.* 2011) whilst others observed low rates (Fox *et al.* 1970, Oliet 1983, El-Mubarak *et al.* 2010, Nixdorf *et al.* 2010). These variations are likely due to differences in study methods. In addition, treatment procedures following root canal treatment, selection of patients and even experience and qualification of the dentists varies when different studies are compared (Seltzer *et al.* 1961, Nixdorf *et al.* 2010).

Incidence of post-endodontic pain after single-visit treatments has been reported previously (Oliet 1983, Ng *et al.* 2004) and reviewed (Figini *et al.* 2007). However, the majority of these studies analysed the association between individual factors related to patient (age, gender and medical evaluation) or to the affected tooth (type, pulp status, preoperative pain, periapical radiolucencies, previous emergency treatment, presence of occlusal contacts) and post-endodontic pain primarily through chi-square tests. Because interrelation of factors has most often not been considered in these reports, the results may be misleading and the data may be interpreted differently if a more complex statistical approach had been taken. Moreover, it has been suggested that due to the multifactorial nature of post-endodontic pain, prevention and treatment strategies should also rely on different factors (Jostes & Holland 1984, Ng *et al.* 2011).

A multivariable predictive model provides information on the concurrent and simultaneous relationships of various factors influencing the outcome under analysis. This approach is closer to real clinical situations where factors are interrelated and interact with each other and with the outcome in multiple ways.

The aim of this study was to investigate the relationship between the incidence, intensity, triggering mechanism and duration of post-endodontic pain after single-visit root canal treatments (with or without previous emergency treatment) and clinically relevant factors. These independent factors were separated into the following two groups: those related to the patient (age, gender and medical history) and those related to the affected tooth (tooth type, number of canals, previous pain, pulp and periapical status, presence of occlusal contacts and previous emergency treatment).

Materials and methods

This study was conducted with the approval of the Ethics Committee of Clinical Research of Saint Carlos Hospital, Madrid.

Five hundred consecutive patients were enrolled and received a single-visit root canal treatment performed by the same endodontist (AA). All patients were informed of the aims and design of the study, and written consent was obtained before their enrolment.

Prior to treatment, the following data were collected and recorded:

- Pulp status (vital/necrotic) was assessed through thermal stimulation with ethyl chloride spray. Status was verified by the presence of bleeding during endodontic access preparations. If thermal stimulation was positive, and there was bleeding during endodontic access, the pulp was considered vital; however, the pulp was categorized as necrotic if the stimulation was negative, or there was no bleeding.
- Presence of preoperative pain (yes/no) was assessed by asking the patient whether they had pain in the 3 days prior to their appointment.
- Presence (yes/no) of detectable radiolucent periapical lesions.
- Group of teeth (posterior/anterior).
- Location (maxillary/mandibular).
- History (yes/no) of previous emergency treatment.
- Occlusal contact (yes/no). If occlusion was absent or was eliminated after treatment because the affected tooth was scheduled for a full crown as a final restorative procedure, the tooth was assigned to the *no* category. In the *yes* category, the tooth had occlusal contacts with antagonists.

- Age (in years) and gender (male/female).
- Medical evaluation (number of ailments) was obtained by interviewing the patients. The number of general ailments was recorded.

Those cases that fulfilled the following criteria were excluded: root canal retreatment, pregnancy, failure to obtain authorization from patients or the presence of accidents or complications during treatment (calcified canals, inability to achieve apical patency in any canal). If the affected tooth had previous emergency treatment, the patient was included in the study only if the referring dentist had not used any instruments inside the root canals. Patients were excluded if any data were uncertain.

All patients were given local anaesthetics (Lidocaine hydrochloride and epinephrine 1 : 80 000; Xilonibsa, Inibsa, Spain).

Access was prepared with a 014 round carbide (Komet, Gebr. Brasseler GmbH & Co. KG, Lemgo, Germany) and Endo-Z burs (Dentsply International, New York, PA, USA), using an air turbine handpiece (KaVo Dental GmbH, Biberach, Germany) and under water coolant. The affected tooth was isolated with a rubber dam.

Working length was determined with a Root ZX apex locator (J Morita Europe GVBH, Frankfurt, Germany) and sizes 10, 12 and 15 files. If there was no agreement between these measures, the outlier was reassessed. If disagreement persisted, the measurement obtained with the larger file was selected. Measures from the electronic apex locator (EAL) were confirmed radiographically. In cases of disagreement between radiographic and electronic measurements, the latter was selected.

Canals were shaped with Gates-Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland) and K-Flexofiles (Dentsply Maillefer). Routine master apical files ranged from size 25 to 30 in narrow canals and from size 30 to 40 in wide canals. After shaping the coronal and middle thirds of the canal, working length was reconfirmed using an EAL. During all procedures, cleaning was performed with a 5% NaOCl solution. Apical patency was maintained throughout shaping and cleaning procedures with a size 10 K-file, passed 1 mm beyond the working length.

Following canal preparation, AH-Plus sealer (Dentsply Maillefer) was placed twice into the canal using the master cone (having the same size as the apical file) as a carrier. Lateral compaction of size 15 gutta-percha cones (Dentsply Maillefer) with size 20 finger nickel-titanium spreaders (Dentsply Maillefer) was performed.

The patients were informed that they could experience pain in the days immediately following treatment and were given a questionnaire to record the absence or presence, duration, level and trigger of post-endodontic pain, to be returned during the following 3 weeks.

The duration of pain was recorded in days.

The patients were asked to record the triggers of pain as: occlusal pressure, spontaneous or both. Pain triggered by occlusal pressure was defined as that caused by any occlusal contact, including mastication. Spontaneous pain was described as pain arising without an immediate identifiable cause.

The level of pain was defined as follows:

- mild pain: any discomfort of any duration that does not require analgesics.
- moderate pain: pain that requires and is relieved with analgesics.
- intense pain: any pain that is not relieved with analgesics.

The recommended medication for pain was ibuprofen (600 mg every 8–12 h).

Of the total number of questionnaires delivered to patients (500), the protocol had determined *a priori* that the responses to the first 420 would be used to adjust the logistic regression models (SPSS 17 for Windows; SPSS Inc, Chicago, IL, USA) to predict the incidence, the intensity, the duration and the triggering of post-endodontic pain using the predictive factors cited above. Responses to the final 80 delivered questionnaires would be used to test the validity of the models with data external to them. The returned questionnaires resulted in 316 valid responses (75.2%) used to adjust the logistic regression models and 58 valid responses (72.5%) to test the external validity. This strategy was used because assessing the predictive power of models using the same data that are used to build them leads to the tendency to generate overly optimistic predictions.

Logistic regression models inform about the probability that an event takes place. As the event has to be binary, outcomes with more than two possible categories were transformed to dichotomous variables. This transformation resulted in the following outcomes: Incidence: yes/no; Intensity: mild/moderate-severe; Duration: short (1–2 days)/long (>2 days); and Triggering: spontaneous/occlusal pressure.

Variables with $P \leq 0.15$ were entered in a stepwise logistic regression model. Odds ratios (OR) that measure the direction and magnitude of effect were estimated.

Validation of models

Both the internal and external validity of the models were assessed.

The internal validity was tested in two steps: assessing calibration and discrimination.

Calibration was assessed using the Hosmer–Lemeshow goodness-of-fit test. This test evaluates whether the rates of the observed event match the expected event rates in subgroups of the model population (Hosmer & Lemeshow 2000). Small *P*-values indicate a lack of fit of the model.

The discrimination of the models was assessed by calculating the areas under the ROC curves.

Using the 58 valid responses that were not used to build the models, the external validity (generalizability) of the models was assessed by calculating the areas under the ROC curves.

Results

Results of incidence of post-endodontic pain and a detailed description of the characteristics of the cohort based on the preoperative data are shown in Table 1.

Of the 374 cases, 177 (47.3%) reported post-endodontic pain. Of these, 123 (69.5) reported pain that lasted for 1 or 2 days, and 54 (30.5%) reported pain that lasted for more than 2 days (range: 3–9 days). In 87 (49.2%) cases, post-endodontic pain was spontaneously triggered, in 64 (36.2%) by occlusal pressure, and in 26 (14.7%) by both mechanisms. In 77 cases (43.5%), post-endodontic pain was mild, in 81 (45.8%) it was moderate and in 17 (9.6%) it was reported to be intense.

Predictive models were able to be established for the incidence, the intensity and the duration of post-endodontic pain. None of the recorded predictive factors significantly influenced the triggering mode of post-endodontic pain, and thus, no model could be fitted.

Predictive models

Values of the k (a specific constant for each model determined by the logistic regression analysis), test and reference categories of variables and coefficients for each individual variable are given in Tables 2–4. These values should be used into the generic model to allow for calculation of the probability of each outcome in a given case.

The odds ratios (95% CI) and the probability for each variable to be included in the model are also cited in the Tables.

Table 1 Incidence of postoperative pain by preoperative data

		Incidence of PP (n)	
		No	Yes
Gender	Female	102	97
	Male	95	80
Group of teeth	Anterior		
	Max.	26	13
	Mand.	11	5
	Premolar		
	Max.	40	23
	Mand.	29	17
	Molar		
	Max.	46	56
	Mand.	45	63
Number of canals	One or two	106	58
	Multiradicular	91	119
Location	Maxillary	112	92
	Mandibular	85	85
Previous pain	No	128	84
	Yes	69	93
Previous emergency access	No	151	118
	Yes	46	59
Pulpal vitality	No	80	42
	Yes	117	135
Periapical radiolucency	No	133	150
	Yes	64	27
Occlusal contact	No	86	33
	Yes	111	144
Age group	0.5–30.5	49	50
	31.5 – 50.5	64	68
	+ de 51.5	84	59
Number of general ailments in medical evaluation	None	148	141
	One or two	22	23
	More than two	27	13

Incidence

By replacing the values in the general formula, the model (Table 2) predicts that the patient with the highest probability of developing post-endodontic pain (0.83) had experienced previous pain in a molar with a previous emergency endodontic treatment, no apical radiolucency and occlusal contacts.

Only the data from the 147 cases with pain, of the 316, were included for the regression analysis to

Table 2 The predictive model for the incidence of pain (n = 316)

k[a]	Variable (test/reference category)	Coefficient	Odds ratio (95% CI)	*P*-value
−0.8537	Periapical radiolucencies (yes/no)	−0.94	0.4 (0.2, 0.7)	0.003
	Previous pain (yes/no)	0.71	2 (1.2, 3.3)	0.006
	Group of teeth (nonmolar/molar)	−0.77	0.5 (0.3, 0.8)	0.003
	Previous emergency access (yes/no)	0.59	1.8 (1, 3.2)	<0.05
	Occlusal contact (yes/no)	1.17	3.3 (1.9, 5.6)	<0.0001

[a]Constant, specific for each model.

determine the predictive models for intensity, duration and triggering of post-endodontic pain.

Intensity

By replacing the values in Table 3 in the general formula, the prediction is that, if post-endodontic pain is present, the probability of it being moderate or severe is higher in mandibular teeth for older patients.

Duration

This model predicts that, if post-endodontic pain is present, the probability of the pain lasting more than 2 days increases in older male patients treated for a tooth with a radiolucent lesion (Table 4).

Validation of models

The results of the internal and external validity tests for each model are shown in Table 5.

High *P*-values in the Hosmer–Lemeshow tests reflect a good fit of the models.

As an example, when using the results for the external cases in the formula to predict the incidence of post-endodontic pain, only 7 of the 20 patients in whom the probability of incidence of post-endodontic pain was lower reported pain, whereas 14 of the 20 with a higher probability of developing post-endodontic pain did so. In the 18 remaining patients, the model predicted an intermediate probability of developing post-endodontic pain, and exactly 9 of whom had pain and 9 did not. These findings

Table 3 The predictive model for moderate–severe pain intensity (n = 147)

k[a]	Variable (test/reference category)	Coefficient	Odds ratio (95% CI)	*P*-value
−0.1984	Location (maxillary/mandibular)	−0.68	0.5 (0.3, 1)	0.05
	Age (in decades)	0.19	1.2 (1, 1.5)	0.09

[a]Constant, specific for each model.

Table 4 The predictive model for pain lasting >2 days (n = 147)

k[a]	Variable (test/reference category)	Coefficient	Odds ratio (95% CI)	*P*-value
−1.0919	Periapical radiolucencies (yes/no)	−1.02	0.4 (0.1, 1.4)	0.14
	Age (in decades)	0.19	1.2 (1, 1.6)	0.11
	Gender (male/female)	−0.13	0.4 (0.2, 0.8)	0.007

[a]Constant, specific for each model.

Table 5 Validity of models

		Incidence	Intensity	Duration
Internal	Hosmer–Lemeshow goodness-of-fit test (p)	$P > 0.73$	$P > 0.92$	$P > 0.76$
	Area under ROC curve (316 internal cases)	0.75	0.62	0.67
External	Area under ROC curve (58 external cases)	0.65	0.58	0.61

Area under ROC curve of a classifier measures its discrimination power and is equivalent to the probability that the classifier will rank a randomly chosen positive instance higher than a randomly chosen negative instance (Fawcett 2006).

reveal the good sensitivity and specificity of the model.

Discussion

The treatment protocol in this study was simple. Manual canal shaping and lateral compaction were performed, and apical patency was maintained in all cases. Clearly, it has yet to be determined whether other studies with different techniques (rotary shaping, vertical compaction) will have comparable results.

The perception of pain is subjective and strongly dependent on the cultural, individual and economic background of the patient (Dorner *et al.* 2011). Measuring pain as an outcome is difficult; therefore, the questionnaire asked for a simple verbal categorization, as recommended in a recent Cochrane Review (Figini *et al.* 2007) of the intensity (mild, moderate and intense), which was defined by the need for and relief from an analgesic. In addition, using questionnaires answered and returned by patients has the inherent risk of bias because patients who experience more severe outcomes (especially higher levels of pain) will be more prone to answering them (Ferreira-Valente *et al.* 2011).

Triggering (by occlusal pressure, spontaneous or both) of post-endodontic pain was also assessed. It is sometimes difficult for patients to identify a painful tooth (McCarthy *et al.* 2010), and there is always the risk of false positives, especially because there is always the possibility that pain is produced by a concurrent disease in neighbouring teeth.

Post-endodontic pain was present in 47.3% of cases, which is similar to reports assessing post-instrumentation pain (Seltzer *et al.* 1961, Soltanoff 1978, Harrison *et al.* 1983a, 1983b, Jostes & Holland 1984, Georgopoulou *et al.* 1986, Ince *et al.* 2009) and to others assessing pain following canal filling (Ng *et al.* 2004).

Very low incidence rates of pain (10%) have been reported previously (Fox *et al.* 1970), which may be due to assigning mild pain cases to the *no pain* category; this was not performed in the present study. Moreover, one systematic review of 26 different studies (Nixdorf *et al.* 2010) revealed an even lower incidence of post-endodontic pain (5.3%). Another report (El-Mubarak *et al.* 2010) also described the intensity of post-endodontic pain (1.3% mild, 0.9% moderate and 9% severe) after 24 h. In contrast, in the present study, pain intensity was reported to be mild in 21.1%, moderate in 21.7% and intense in 4.5% of cases.

Single-variable analysis is normally used to study post-endodontic pain. However, the information this approach provides, although highly valuable in learning about the intensity or magnitude of an event and in balancing its association with other factors, is insufficient to meet one of the main goals of a dentist: to provide the patient with an approximate prognosis.

Although patients frequently wonder about the long-term outcome of RCTs, they are, without exception, very interested in knowing if and how pain will interfere with their daily life after the anaesthetic wares off. An accurate and informed tool to allow estimation of the incidence, intensity and duration of post-endodontic pain would be of great value.

Such a tool can be approximated with a predictive statistical model considering multiple patient- and tooth-related factors. These models generate a probability of occurrence of a given event through a mathematical formula, with the advantage that each predictive factor is taken into consideration and related to all other variables that may intervene in the process. Knowledge of such interrelation of factors is crucial as the biological processes are often so complex that cannot be adequately assessed with descriptive statistics alone.

In this study, each outcome was predicted by several variables. All the variables were included in the calculations, and each model selected which of the variables were appropriate to be maintained in the resulting formula for the prediction of each outcome. This selection was automatic and decided based on the significance of each variable.

The clinical meaning of each factor in every model depends on the odds ratios. For reasons of clarity, each model is addressed separately.

Incidence

The results reveal that the most influential factor in predicting the incidence of post-endodontic pain is the absence of occlusal contacts, with an OR = 3.3 (95% CI = 1.9 – 5.6). This OR is 1.6 times higher than the next factor in order of importance (presence of preoperative pain). The clinical relevance of the rest of the factors studied is lower. In the results section, an example of the highest probability of developing post-endodontic pain was given. In contrast, a hypothetical patient with no previous pain in an incisor, a cuspid or a bicuspid with an apical radiolucency and

free from occlusion will have a 0.07 probability of developing post-endodontic pain. Those odds would be a very good bet.

Some of these factors have been previously reported as influencing the post-obturation pain experience, such as tooth type (Ng *et al.* 2004). The same study also reported gender, size of periapical lesion, history of post-preparation pain or generalized swelling and number of treatment visits as influencing factors, but it has to be considered that there are important differences between both protocols. In the cited report, root canal treatments were performed by 20 different dentists, most of them general practitioners and not all treatments were completed in a single visit.

It has also been reported that previous pain is associated with a higher incidence of post-endodontic pain (Seltzer *et al.* 1961, O'Keefe 1976, Genet *et al.* 1986, Flath *et al.* 1987, Yesilsoy *et al.* 1988, Imura & Zuolo 1995, Mattscheck *et al.* 2001, Siqueira *et al.* 2002, Gopikrishna & Parameswaran 2003), and the present results support this finding.

One report (Yesilsoy *et al.* 1988) explains this relationship in two different ways. First, any possible pre-existing inflammation in periapical tissues when preoperative pain is present would be made worse by treatment; second, patients experiencing preoperative pain tend to suffer from post-endodontic pain because this pain is what they expect. Another study (Flath *et al.* 1987) further suggested that studies analysing the incidence of post-endodontic pain should include previously symptomatic and asymptomatic cases, as in the present report.

More controversial is the role of occlusal contacts in the literature. In the present study, the incidence of post-endodontic pain was lower in the absence (27.7%) than in the presence of occlusion (56.5%), which is similar to previously reported results (Rosenberg *et al.* 1998). Other authors have reported that this association does not exist (Creech *et al.* 1984, Jostes & Holland 1984). However, these studies are different to the present report, as they either only analysed post-instrumentation pain and did not assess spontaneous pain (Jostes & Holland 1984), or they provided varying degrees of occlusal reduction to all patients, and all patients were told that this was a pain-relieving procedure (Creech *et al.* 1984).

The results of this study revealed that the existence of periapical radiolucencies reduced the incidence of post-endodontic pain. Other studies (Fox *et al.* 1970, Siqueira *et al.* 2002) also found a higher incidence of postoperative pain in teeth without periapical radiolucencies, probably due to the lack of space available for the release of the pressure in the absence of apical radiolucencies and therefore when there is no bone resorption (Alacam & Tinaz 2002). However, it has been reported previously that the incidence of post-endodontic pain was higher when periapical radiolucency was present (Yesilsoy *et al.* 1988), but no statistical analysis was provided in this study due to the small number of cases.

In accordance with other studies (Clem 1970, O'Keefe 1976, Genet *et al.* 1986), the results of the present study reveal that the incidence of post-endodontic pain was higher in teeth with three or more canals, which may be due to the increase of potential periapical pain foci.

The results showing a higher incidence of post-endodontic pain in teeth with previous emergency treatment could be explained because the presence of a temporary restoration can led to leakage and contamination or microbial invasion of root canals (Su *et al.* 2011).

Intensity

The results demonstrated that preoperative pain was a good predictor of the incidence but not of the intensity of post-endodontic pain. Through mere descriptive statistical analyses, other authors report that the intensity of preoperative pain is related to the intensity of post-endodontic pain (Torabinejad *et al.* 1988) or even that patients experiencing moderate or severe preoperative pain were five times more likely to have this same intensity level of pain after the treatment relative to patients with mild or no preoperative pain (O'Keefe 1976). The present results identified tooth type as the main factor in predicting the intensity of post-endodontic pain, with the age of the patient being the other predictive factor.

The fact that the mandible has a thicker cortical than the maxilla could be the reason for the more intense pain in mandibular teeth, whilst the decrease in the pulp canal size in older people that leads to more difficult root canal treatments could explain the influence of the age of patients in the higher intensity of post-endodontic pain.

Duration

The results identified the main factor in predicting post-endodontic pain lasting more than 2 days to be gender. Factors were considered valid for inclusion in

the model if p was lower than 0.15. In spite of the consensus that p should be <0.05 in most of the statistical analysis, an arbitrariness in specifying values from 0.15 to 0.25 even to 0.30 have been established for predictive models. The defaults in stepwise analysis are an entry level and a stay level of 0.15. It has been shown that if one has to pick a unique critical *P*-value, one should choose it around 0.15 (Hosmer & Lemeshow 1989) or that it should be 0.157 exactly (Steyerberg *et al.* 2000), although there are authors that recommend the use of any value in the interval between $0.15 \leq \alpha \leq 0.20$ (Lee & Koval 1997) even to 0.30 (Hosmer & Lemeshow 2000).

Age and the presence of radiolucencies were also included for this reason (in both cases $P > 0.1$).

The results did not show a relationship between gender and incidence, intensity or triggering of post-endodontic pain, which is in agreement with other reports (Maddox *et al.* 1977, Oliet 1983, Georgopoulou *et al.* 1986, Yesilsoy *et al.* 1988, Mor *et al.* 1992, Torabinejad *et al.* 1994, Eleazer & Eleazer 1998, Watkins *et al.* 2002, Ryan *et al.* 2008). However, a longer duration of post-endodontic pain was noted in female patients. Previous studies have reported a higher incidence of post-endodontic pain in female patients, but they do not refer to duration. It is difficult to compare these results to those of the present study because treatment protocols were not explained in one of the reports (Fox *et al.* 1970), and treatment required three visits in another report (Mulhern *et al.* 1982).

All the models presented in this report demonstrated good statistical fit, but their generalizability should only be extended to situations other than the single-visit treatments following the present protocol, because difference in procedures, intracanal medications or the presence of filtration due to temporary restorations in multiple-visit treatments most probably affect the development of inflammatory processes (Wang *et al.* 2010).

The models presented are intended to have direct clinical relevance. Patients can be rationally informed of the probability of the incidence, the intensity and the duration of post-endodontic pain.

Conclusions

Predictive models demonstrated that the probability of developing post-endodontic pain depended on the following factors in order of importance: presence of occlusal contacts, presence of preoperative pain, presence of radiolucency, tooth type and presence of previous emergency endodontic treatment. The intensity of post-endodontic pain depended on the type of the tooth and the age of the patient. The duration of post-endodontic pain was predicted by the following factors: age, gender and the presence of radiolucencies.

Conflict of interest

Authors deny any conflict of interest.

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