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Assessment of alternative emergency treatments for symptomatic irreversible pulpitis: a randomized clinical trial

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Abstract

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Aim To evaluate three emergency procedures for their ability to alleviate clinical symptoms associated with symptomatic teeth having signs of (at least) partial irreversible pulpitis.

Methodology Sixty-six maxillary and mandibular molars were randomly assigned to a total pulpectomy group (TP; $n = 22$), partial pulpectomy group (PP; $n = 22$) or pulpotomy group (P; $n = 22$). Procedure durations were recorded. Patients answered a questionnaire on daily analgesic requirements and about clinical symptoms (pain intensity, chewing sensitivity and thermal sensitivity) after the anaesthetic effect had disappeared (Day 0) and on Days 1, 3 and 7 post-treatment.

Results The total pulpectomy group was associated with the longest procedures (median, 24 min), followed by the partial pulpectomy and pulpotomy groups ($P < 0.001$ for all). In all three groups, pain intensity, thermal sensitivity and chewing sensitivity decreased significantly from the preoperative time-point to Day 7 ($P < 0.001$ for all). The total pulpectomy group reported greater reductions in pain intensity than the pulpotomy group between Days 0 and 7, Days 1 and 3, and Days 1 and 7 ($P < 0.001$ for all). No other intergroup differences were noted regarding reductions in pain intensity, and none were observed with respect to changes in prevalence of thermal sensitivity and chewing sensitivity. There were also no significant intergroup differences regarding the analgesic requirements throughout the 7 days.

Conclusion As emergency treatments for teeth having signs of irreversible pulpitis, pulpotomy, partial pulpectomy and total pulpectomy were comparable with respect to relieving clinical symptoms. Pulpotomy may be preferred because it requires significantly less time and is a simple technique that relieves symptoms quickly and effectively.

Keywords: emergency treatment, endodontics, irreversible pulpitis, pain, pulpotomy, treatment modalities.

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Introduction

Ideally, emergency treatment for irreversible pulpitis involves removing the irritants (e.g. caries, defective restorations), a pulpectomy followed by cleaning the root canal to the level of the canal terminus, as confirmed with an electronic apex locator, placing an intracanal medicament (i.e. calcium hydroxide) and a temporary filling to avoid reinfection (Lee *et al.* 2009). In recent years, there has also been a greater tendency to provide endodontic therapy in one visit, especially in nonproblematic cases where the pulp is vital. Most studies have revealed a similar or lower incidence of pain after single-visit root canal treatment (De Oliveira Alves 2010, Tanalp *et al.* 2013).

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However, endodontic emergencies due to irreversible pulpitis require unscheduled patient visits, cause inconvenience and disrupt routine schedules. In such cases, the time required to intervene is often an issue (Hasselgren & Reit 1989). Given the potential time constraints and inevitable differences amongst the skill levels of clinicians, it may not be feasible to complete comprehensive canal cleaning during the initial emergency visit. Moreover, emergency endodontic procedures, like other dental treatments, may be interrupted by unexpected and unfavourable 'procedural errors' (Thusu *et al.* 2012). Many such problems can be avoided by applying acceptable, simplified treatment techniques that will relieve symptoms quickly and effectively in cases of irreversible pulpitis. Accordingly, pulpotomy (removal of the coronal pulp) (Rosenberg 2002) or partial pulpectomy (removal of the pulp tissue from the largest canal) (Kolzet 1979) has been recommended for emergency treatment of irreversible pulpitis in multi-rooted teeth. One clinical study of various emergency procedures demonstrated that pulpotomy was highly effective at reducing acute dental pain for this condition (Oguntebi *et al.* 1992).

As with other dental specialties, endodontics has advanced in the past two decades. These developments include materials, instruments and theoretical approaches, all of which increase the likelihood of successful long-term maintenance of root filled teeth. Despite these improvements, rapidly and effectively managing symptomatic irreversible pulpitis within a busy clinical setting and time constraints remains a challenge. The aim of this randomized clinical study was to assess the efficacy of partial pulpectomy and pulpotomy in comparison with total pulpectomy for patients with symptoms and signs suggestive of symptomatic irreversible pulpitis.

Materials and methods

Patients

This single-blinded, single-centre, randomized controlled trial was designed and reported in accordance with the Consolidated Standards of Reporting Trials statement (Schulz *et al.* 2010). It was approved by the Baskent University Institutional Review Board and Ethics Committee (Project no: D-KA16/08, Ankara, Turkey), and written informed consent was obtained from all participants. All patients between the ages of 18 and 60 years who were referred to the Department of Endodontics, Baskent University School of Dentistry with severe dental pain in posterior maxillary or mandibular molar teeth were considered for enrolment (Fig. 1). Patients diagnosed with symptomatic irreversible pulpitis with or without symptomatic apical periodontitis were selected. Each individual's clinical examination included visual assessment of the tooth and surrounding tissues, periodontal probing, palpation and percussion tests. Vital pulp status was confirmed before treatment. The pulp was determined to be vital if the tooth responded to cold stimulus (i.e. ice sticks), to an electric pulp tester (Parkell, Farmingdale, NY, USA), and exhibited haemorrhage on opening the pulp chamber. In each case, radiographic evaluation involved examining and recording findings from a periapical radiograph of the tooth taken with a digital radiography device (Planmeca Dixi® 3; Planmeca, Helsinki, Finland).

Exclusion criteria included history of American Society of Anesthesiologists (2014) III–VI status, pregnancy or nursing, mental disability, history of allergy to nonsteroidal anti-inflammatory drugs, and analgesic treatment during the 12 h prior to presentation. Patients were also excluded if the specific tooth had moderate or severe marginal periodontitis, horizontal or vertical fractures, internal or external root resorption, root canal calcification or a nonrestorable crown. In addition, patients were excluded if an opposing and/or neighbouring tooth had defective restorations, deep caries, moderate or severe marginal periodontitis, wear, or history of recent tooth preparation.

Sample size and randomization

Sample size estimation was performed taking the visual analogue scale (VAS) as the main outcome, and using G* Power version 3.0.10 (Faul *et al.* 2009). Based on data obtained from a pilot study, with an alpha value of 0.05 and a power of 80%, a sample size of 20 teeth per group was estimated to be required in order to detect a minimum between-group difference of 1.6 points with respect to changes in pain intensity. With an expected 5% dropout rate, 66 patients were enrolled (one tooth per patient) and each was randomly allocated to the total pulpectomy group (TP; $n = 22$), partial pulpectomy group (PP; $n = 22$) or pulpotomy group (P; $n = 22$). An online random-number generator (www.randomization.com) was used to create the randomization sequence with a 1 : 1 : 1 allocation ratio. Simple randomization was implemented. To ensure proper randomization,

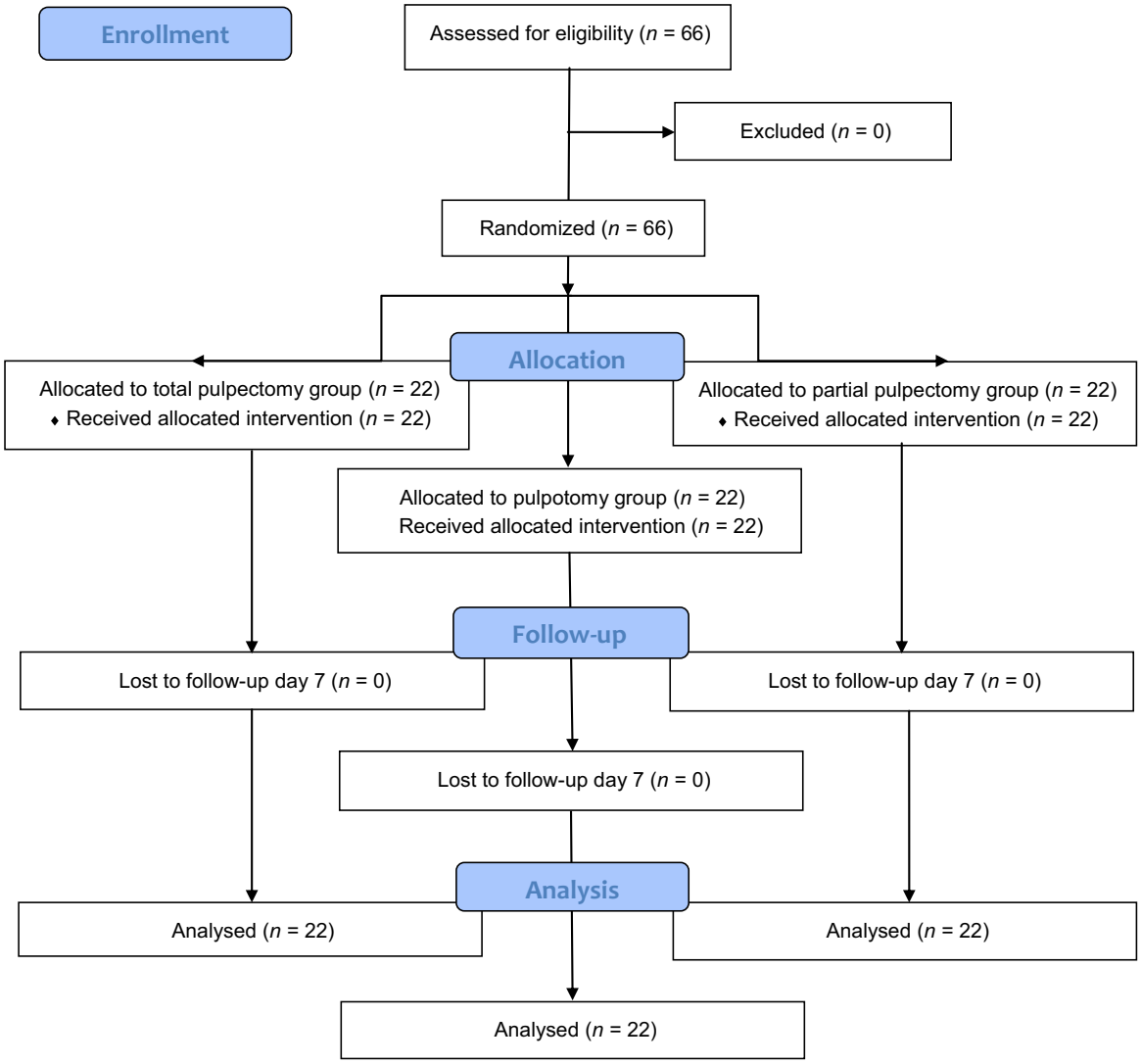

Figure 1 Consolidated Standards of Reporting Trials (CONSORT) flow diagram showing the progress of subjects at each stage of the clinical trial.

allocations were concealed using sequentially numbered, opaque, sealed envelopes. Allocation was performed immediately before the intervention and involved the patient selecting one envelope amongst the initial 66 sealed envelopes, which designated the emergency procedure total pulpectomy, partial pulpectomy or pulpotomy (Fig. 1).

Procedures

All clinical procedures were performed by the same operator (BE). Because of the nature of procedures, the operator was not blinded to the treatments; however, patients were blinded to their allocation. Preoperative pain intensity was assessed using a VAS that ranged from no pain [0] to unbearable pain [10]. History of pain upon chewing and thermal stimulus was also recorded prior to treatment. Patients who presented with a maxillary tooth received a buccal infiltration, and those with a mandibular tooth received an inferior alveolar nerve block of 1.7 mL of 4% articaine hydrochloride containing epinephrine hydrochloride (1 : 1 000 000) (Ultracain D-S Forte; Aventis, Istanbul, Turkey) injected via a 50-mm

27-gauge needle. Patients who experienced pain during cavity preparation were given a supplemental buccal infiltration using 1.7 mL of the same anaesthetic solution. Once access cavities were prepared, with modifications to ensure complete excavation of caries and removal of defective restorations, the tooth was isolated with a rubber dam.

Total pulpectomy was performed by first removing the pulp tissue from the canals with barbed broaches. The working length (1 mm short of the radiographic apex) was confirmed using an apex locator (Root ZX; J. Morita Corp, Tokyo, Japan) and a radiograph. The middle and coronal thirds were prepared using Gates Glidden drills 1-3 (Produits Dentaires S.A., Vevey, Switzerland). The preparation was carried out by applying manual nickel–titanium files (Dentsply Sirona, Ballaigues, Switzerland) in a step-back technique to two sizes larger than the file that bound first at the working length. The minimum size of the file for preparing the working length was size 25 in the buccal canals of maxillary molars and in the mesial canals of mandibular molars, whereas it was size 35 in the palatal canals of maxillary molars and in the distal canals of mandibular molars. One millilitre of 2.5% sodium hypochlorite (NaOCl) was used to irrigate between each instrument. Once prepared, the root canal was dried with paper points and then a thick creamy paste prepared by mixing calcium hydroxide powder with distilled water was placed as an intracanal medicament using a lentulo spiral filler (Dentsply Sirona, Ballaigues, Switzerland). The access cavities were filled by inserting a dry sterile cotton pellet and applying zinc oxide eugenol cement (IRM; Caulk/Dentsply, Milford, DE, USA).

Partial pulpectomy was performed by removing the pulp tissue from the pulp chamber and the largest canal (i.e. the palatal canals of maxillary molars and distal canals of mandibular molars) with sterile curettes and barbed broaches. Working length determination, cleaning, initial shaping procedures, dressing and filling methods were as described above for total pulpectomy. The other canals remained intact, with no instrumentation or medication.

Pulpotomy was performed by removing the coronal pulp tissue with a sterile curette. Haemostasis was achieved using dry cotton pellets and applying light pressure. The access cavities were then filled by inserting a dry sterile cotton pellet and applying zinc oxide eugenol cement.

The total time per procedure was recorded for each tooth, with timing initiated once access cavity preparation was complete. Once a procedure was finished, the patient was prescribed 600 mg ibuprofen and instructed to return to the emergency dental service, and to inform the researcher (BE) if the pain intensity increased to a level where it could not be controlled by the prescribed analgesics.

Clinical evaluation

Once treatment was completed, each patient was given a questionnaire and was asked to record any postoperative symptoms experienced once the anaesthetic effect had disappeared (Day 0), and subsequently on Days 1, 3 and 7 post-procedure. For each of these time-points, the patient was also asked to record three pain measures: postoperative pain intensity (VAS score), pain upon chewing (absent/present) and pain upon thermal stimulus (absent/present). Patients were also asked to note frequencies and amounts of analgesic use from the time the anaesthetic wore off to the end of that day (Day 0), and on each subsequent day of the first postoperative week. All participants were scheduled for root canal treatment completion at appropriate intervals after the research period.

Statistical analysis

Data were analysed using IBM SPSS Statistics version 17.0 software (IBM Corporation, Armonk, NY, USA). Differences in mean age amongst the groups were compared using one-way analysis of variance (ANOVA). For variables that were not normally distributed, differences between two independent groups were analysed using the Mann–Whitney *U*-test; the Kruskal–Wallis test was applied for comparisons amongst more than two independent groups. When the *P* value from a Kruskal–Wallis test was statistically significant, Conover's multiple comparison test was applied to determine which group differed from others. Categorical data were analysed using Pearson's chi-square test, Fisher's exact test or the likelihood ratio test, where appropriate. The Friedman test or Cochran's *Q* test, as appropriate, was used to assess differences in VAS scores, thermal sensitivity and chewing sensitivity for the various time intervals. When the *P* value from either test was statistically significant, the Wilcoxon signed-rank test or McNemar's test was used to identify which interval differed from which others. *P* values less than 0.05 were considered statistically significant. Bonferroni's

correction was applied to all multiple comparisons to control Type I error.

Results

Patient demographic characteristics, tooth types, symptomatic diagnosis at both the pulpal and periapical levels and procedure durations are summarized in Table 1. No significant differences were found amongst the treatment groups regarding demographic characteristics, tooth type and symptomatic diagnosis at both the pulpal and periapical levels (Table 1). The total pulpectomy group was associated with the longest procedures (median, 24 min), followed by the partial pulpectomy group (median, 13 min) and the pulpotomy group (median, 5 min), and the three medians were significantly different ($P < 0.001$ for all; Table 1).

Within each treatment group, when data were stratified by gender, age (18–35 years vs. 36–60 years) or tooth type (mandibular molars vs. maxillary molars), no significant differences were detected with respect to reductions in pain intensity (i.e. VAS score) chewing sensitivity, or thermal sensitivity during the 7 days.

None of the patients returned for emergency treatment after the anaesthetic had worn off on Day 0, or at any time throughout the 7-day period.

Pain intensity

In all three treatment groups, pain intensity decreased consistently over time. Figure 2 shows the differences within each treatment group regarding pain intensity at the reporting time-points (preoperative and Days 0, 1, 3 and 7). In the partial pulpectomy and pulpotomy groups, the first significant decrease in pain intensity was observed from preoperative to Day 0 (both $P < 0.001$). In the total pulpectomy group, the first significant reduction in pain intensity was observed on Day 1 ($P < 0.001$).

When the treatment groups were compared, the total pulpectomy group reported larger reductions in pain intensity than the pulpotomy group between Days 0 and 7, Days 1 and 3, and Days 1 and 7 ($P < 0.001$ for all; Table 2). No other intergroup differences were noted regarding changes in pain intensity.

Thermal sensitivity

Figure 3 shows the differences within each treatment group regarding proportions of patients with thermal sensitivity at the reporting time-points (preoperative and Days 0, 1, 3 and 7). In the total pulpectomy and pulpotomy groups, the first significant reduction in the prevalence of thermal sensitivity was observed on Day 0 relative to the preoperative level (both $P < 0.001$). In the partial pulpectomy group, the first significant decrease in the prevalence of thermal sensitivity was observed on Day 1 ($P < 0.001$).

No significant intergroup differences were detected with respect to changes in prevalence of thermal sensitivity between the time-points.

Table 1 Group demographics, teeth types treated, symptomatic diagnosis at both the pulpal and periapical levels, and duration of treatment protocols

Variable	TP (n = 22)	PP (n = 22)	P (n = 22)	P
Age (mean ± SD)	35.7 ± 9.3	34.0 ± 13.6	37.8 ± 9.9	0.532[†]
Sex (n [%])				0.780[‡]
Male	10 (45.5)	10 (45.5)	8 (36.4)	
Female	12 (54.5)	12 (54.5)	14 (63.6)	
Tooth type (n [%])				0.152[‡]
Mandibular molar	13 (59.1%)	8 (36.4%)	14 (63.6%)	
Maxillary molar	9 (40.9%)	14 (63.6%)	8 (36.4%)	
Patients diagnosed with IP + SAP (n [%])	19 (86.4%)	17 (77.3%)	19 (86.4%)	0.657[§]
Total procedure duration in minutes (median [min–max])	24 (15–30)[a,b]	13 (8–16)[a,c]	5 (4–7)[b,c]	**<0.001**[¶]

TP, total pulpectomy; PP, partial pulpectomy; P, pulpotomy; SD, standard deviation; IP + SAP, irreversible pulpitis with symptomatic apical periodontitis.
[†]One-way ANOVA.
[‡]Pearson's chi-square test.
[§]Likelihood ratio test.
[¶]Kruskal–Wallis test.
[a,b,c]Differences between groups identified with the same superscript symbol were significant (all $P < 0.001$, in bold).

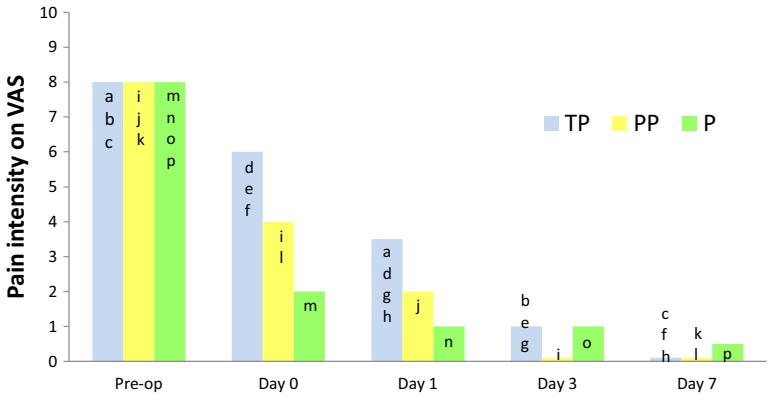

Figure 2 Group median pain intensity scores rated on a 10-cm visual analogue scale (VAS) at each time-point investigated. TP, total pulpectomy; PP, partial pulpectomy; P, pulpotomy; Pre-op, preoperative baseline. Intragroup differences identified with the same letter were significant (Friedman test, Bonferroni's correction; all $P < 0.001$).

Table 2 Group results for pain relief observed during each observation interval

	Pain relief value (median VAS score [min–max])*			
Observation interval	TP ($n = 22$)	PP ($n = 22$)	P ($n = 22$)	$P^{\dagger}$
Pre-op–Day 0	−1.5 (−9 to 2)	−4 (−8 to 1)	−6 (−10 to 3)	0.017
Pre-op–Day 1	−4 (−9 to 2)	−6 (−9 to −1)	−7 (−10 to 0)	0.066
Pre-op–Day 3	−7 (−10 to 0)	−7 (−10 to −1)	−7 (−10 to 2)	0.707
Pre-op–Day 7	−8 (−10 to 2)	−7.5 (−10 to −1)	−7 (−10 to 1)	0.046
Day 0–Day 1	−2 (−8 to 2)	−1.5 (−7 to 2)	−1 (−8 to 2)	0.450
Day 0–Day 3	−3.5 (−10 to 2)	−2 (−8 to 1)	−1 (−8 to 4)	0.020
Day 0–Day 7	−5.5 (−10 to 0)[a]	−3 (−8 to 4)	−1 (−8 to 9)[a]	**<0.001**
Day 1–Day 3	−1.5 (−6 to 0)[b]	0 (−6 to 2)	0 (−3 to 4)[b]	**<0.001**
Day 1–Day 7	−2.5 (−8 to 0)[c]	−1.5 (−7 to 2)	0 (−6 to 10)[c]	**<0.001**
Day 3–Day 7	−1 (−6 to 2)	0 (−5 to 3)	0 (−8 to 6)	0.010

TP, total pulpectomy; PP, partial pulpectomy; P, pulpotomy; Pre-op, preoperative baseline time-point; VAS, visual analogue scale.
*Minus symbol indicates reduced pain.
†Kruskal–Wallis test, Bonferroni's correction.
[a,b,c]Differences between groups identified with the same superscript symbol were significant ($P < 0.001$, in bold).

Chewing sensitivity

Figure 4 shows the differences within each treatment group regarding proportions of patients with pain upon chewing at the reporting time-points (preoperative and Days 0, 1, 3 and 7). In the total pulpectomy and partial pulpectomy groups, the first significant decrease in the prevalence of chewing sensitivity was observed on Day 7 relative to the preoperative level (both $P < 0.001$). In the pulpotomy group, the first significant decrease in the prevalence of chewing sensitivity was observed on Day 1 ($P < 0.001$).

No significant intergroup differences were observed with respect to the changes in prevalence of chewing sensitivity between the time-points.

Postoperative analgesic use

There were no significant intergroup differences regarding the proportions of patients who reported no postoperative analgesic use or those who took at least one analgesic from the time the anaesthetic wore off throughout the 7 days (Table 3; Fig. 5). There were also no significant differences amongst the groups with respect to overall median intake of analgesic (Table 3).

Discussion

Whilst a number of prospective and retrospective studies (Hasselgren & Reit 1989, Oguntebi *et al.*

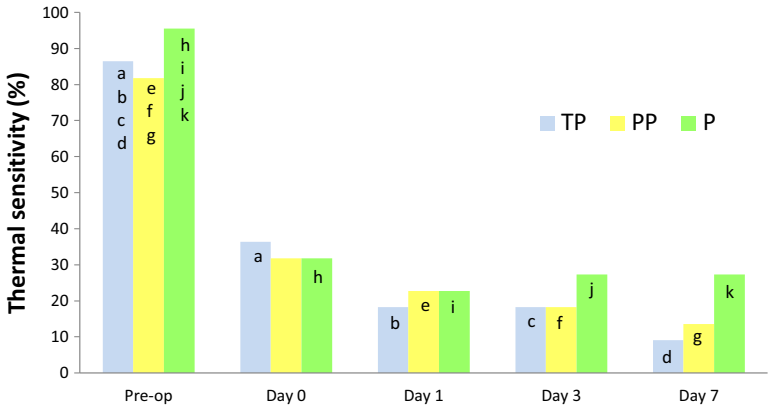

Figure 3 Proportions of each group with thermal sensitivity at each time-point investigated. TP, total pulpectomy; PP, partial pulpectomy; P, pulpotomy; Pre-op, preoperative baseline. Intragroup differences identified with the same letter were significant (Cochran's *Q* test, Bonferroni's correction; all $P < 0.001$).

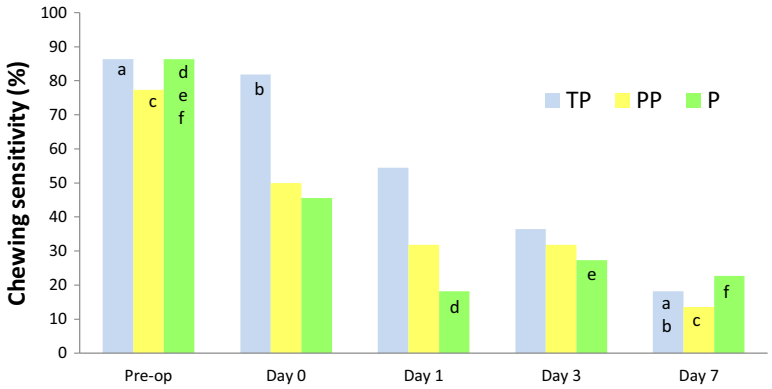

Figure 4 Proportions of each group with chewing sensitivity at each time-point investigated. TP, total pulpectomy; PP, partial pulpectomy; P, pulpotomy; Pre-op, preoperative baseline. Intragroup differences identified with the same letter were significant (Cochran's *Q* test, Bonferroni's correction; all $P < 0.001$).

1992, Nyerere *et al.* 2006, Asgary & Eghbal 2010) have reported the dramatic pain-relieving effect of pulpotomy, particularly in teeth with vital pulps no randomized controlled trials have evaluated the efficacy of this procedure for providing pain relief in patients with irreversible pulpitis. The present study demonstrates that pulpotomy was highly effective at alleviating severe dental pain upon emergency treatment for irreversible pulpitis, and that it can be performed in significantly shorter time than total pulpectomy or partial pulpectomy.

Previous studies of patients with irreversible pulpitis have provided *in vivo* experimental and histological findings that suggest the pulpal inflammation is principally contained within the coronal pulp tissue and not generalized throughout the pulp (Tønder & Kvinnsland 1983, Ricucci *et al.* 2014). Accordingly, the efficacy of pulpotomy for relieving pain was thought to be attributed to venting of the pulp chamber with reduction in local pressure, lowering of inflammatory mediator concentrations and severing of the nociceptive sensory nerve endings (Rosenberg 2002). A review of the literature also revealed that a spread of inflammation that leads to diffusion of various inflammatory mediators, chemokines, proinflammatory cytokines and bacterial toxins into the periapical area may occur prior to total pulp necrosis in cases of irreversible pulpitis with symptomatic apical periodontitis (Lin & Langeland 1981, Kovacević *et al.* 2008). Therefore, the rationale behind

Table 3 Group results for analgesic requirements

	TP (n = 22)	PP (n = 22)	P (n = 22)	P
Analgesic intake (n [%])				0.277†
None	7 (31.8%)	11 (50.0%)	12 (54.5%)	
Minimum 1 tablet	15 (68.2%)	11 (50.0%)	10 (45.5%)	
Tablets required per patient (median [min–max])	1 (0–9)	0.5 (0–11)	0 (0–9)	0.365‡

TP, total pulpectomy; PP, partial pulpectomy; P, pulpotomy.
†Pearson's chi-square test.
‡Kruskal–Wallis test. There were no significant differences between groups.

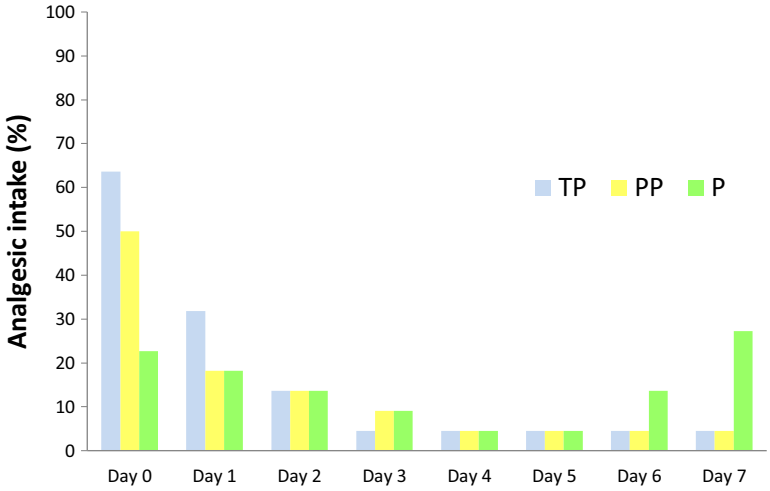

Figure 5 Proportions of patients in each group who required analgesic intake (1 tablet minimum) at each time-point investigated. TP, total pulpectomy; PP, partial pulpectomy; P, pulpotomy. There were no significant intergroup differences at each time-point (Bonferroni's correction; $P > 0.00625$).

emergency partial pulpectomy was to intervene in the largest and simplest root canal that was considered to be affected by the inflammatory process during the transition from pulpitis to apical periodontitis. However, there is still insufficient evidence to determine whether the presence, nature and duration of clinical symptoms gives accurate information about the extent of pulp inflammation, as pulpotomy was found to be an effective emergency treatment strategy with respect to relieving clinical symptoms, even in cases of irreversible pulpitis with symptomatic apical periodontitis. Advanced diagnostic strategies are needed to determine whether there is a correlation between clinical symptoms and actual pulpal inflammation (Zanini *et al.* 2017).

Oguntebi *et al.* (1992) observed a greater incidence of postoperative pain (i.e. first 24 h) in partial pulpectomy cases compared to pulpotomy and total pulpectomy cases, and Rosenberg (2002) proposed that this could be associated with haemorrhage that occurs when wide-diameter vessels in the central part of the pulp are ruptured. In contrast to the study by Oguntebi *et al.* (1992), the present investigation measured degrees of pain relief after three different emergency treatments for irreversible pulpitis, as opposed to comparing overall group incidences of postoperative pain. It can be hypothesized that these end-points are more statistically robust because the baseline data for each group differed. No differences were found in reduction of pain intensity between the partial pulpectomy group and either the total pulpectomy or pulpotomy group during the 7-day study period; however, the total pulpectomy group did report greater pain relief than the pulpotomy group between Days 0 and 7, Days 1 and 3, and Days 1 and 7. This is not surprising given the definitive nature of total pulpectomy, which is known to provide significant pain relief over time. Whilst there were no significant differences amongst the groups with respect to magnitude of pain relief between the preoperative time-point and Day 0,

intragroup comparisons revealed more rapid resolution of pain after the anaesthetic effect disappeared in the pulpotomy and partial pulpectomy groups compared to the total pulpectomy group. Whilst a sample size ($n = 22$ per group) was calculated to reveal significant differences in pain amongst the treatment groups, it is possible that a larger sample size would have shown significantly greater pain relief in the pulpotomy or partial pulpectomy groups compared to the total pulpectomy group during the preoperative to Day 0 interval.

All three groups had a significant decrease in thermal sensitivity over the 7 days studied; however, it is notable that some patients in the total pulpectomy group were still experiencing thermal sensitivity, particularly to cold, after the emergency treatment. Many questions remain about what causes such sustained thermal sensitivity in pulpless teeth (Tidwell *et al.* 1999). One possible explanation is the presence of undetected extra canals that might generate ongoing thermal sensitivity, particularly in maxillary molars. In the present study, a standardized protocol was used to locate mesiobuccal root canal (MB2); a rhomboid-shaped access cavity was prepared and the mesial dentinal protuberance overlying the canal orifice was removed with burs or ultrasonic instruments, all under magnification with an operating microscope. Only three maxillary molars in the total pulpectomy group had ongoing thermal sensitivity after the procedure, and two of these had a negotiable MB2. A second potential explanation for sustained thermal sensitivity is phantom sensation phenomenon (Jacobs *et al.* 2002), the condition in which a body part has been lost by trauma or surgery but the patient continues to sense the body part still present, with or without pain. This phenomenon can also be accompanied by a catastrophic way of thinking, which has been broadly conceived of as an exaggerated negative 'mental set' brought to bear during an actual or anticipated pain experience (Edwards *et al.* 2004).

Once the inflammation has spread throughout the pulp and has involved the periodontal ligament, the tooth becomes tender to bite on (Carotte 2004). In the present study, the total pulpectomy and partial pulpectomy procedures achieved significant reductions in chewing sensitivity substantially later than the pulpotomy procedure. Although total pulpectomy and partial pulpectomy were performed with the benefit of an accurate canal length measurement, it is possible that these procedures could have caused increased postoperative chewing sensitivity because they carry greater risk of periapical involvement than pulpotomy.

Only one type of analgesic was prescribed in an attempt to standardize the data and be able to relate use of analgesics to postoperative discomfort or change in pain. None of the patients had received analgesics or other drugs in the 12 h before their procedure, and this enrolment criterion was important because oral steroidal anti-inflammatory drugs have been demonstrated to substantially reduce postoperative pain (Jalalzadeh *et al.* 2010). It has been shown that postoperative pain is more likely to occur within the first 24 h after root canal treatment (Harrison *et al.* 1983). No significant differences were observed between the three treatment groups regarding proportions of patients who took analgesics or the total amounts of analgesics received during the 7-day study period. However, a greater proportion of total pulpectomy patients (>60% of the group) tended to require analgesics within the first 24 h after the emergency procedure, with the partial pulpectomy group ranking second (approximately 50% of the group) and the pulpotomy group significantly lower. It is also notable that although there were no significant differences in analgesic intake amongst the treatment groups at each time-point post-procedure, pulpotomy patients tended to require more analgesics after Day 5. In this regard, it would be advisable to perform a pulpectomy 1 week after a patient undergoes emergency pulpotomy for irreversible pulpitis.

There is controversy regarding the relationship between 4% articaine administration and neurological complications. Some studies have demonstrated no evidence of injury to the nervous structure (Baroni *et al.* 2013, Rogers *et al.* 2014), whereas others have shown increased risk of neurotoxicity (presenting as paraesthesia) related to the use of 4% articaine for regional blocks (e.g. inferior alveolar) (Haas & Lennon 1995, Hillerup & Jensen 2006, Garisto *et al.* 2010, Kingon *et al.* 2011). One potential limitation of the study might be that all inferior alveolar nerve blocks were administered using 4% articaine with 1 : 100 000 epinephrine hydrochloride. None of the patients developed paraesthesia or any other neurologic complication; however, the possible mechanisms of paraesthesia caused by 4% articaine injection remain unclear. Further randomized controlled trials are needed to explain the possible relationship between 4% articaine administration and increased risk of paraesthesia (Malamed 2006, Yapp *et al.* 2011).

Conclusion

As emergency treatments for cases of irreversible pulpitis with or without periapical changes on radiographs, pulpotomy, partial pulpectomy and total pulpectomy were similar with respect to pain relief, reduction in thermal and chewing sensitivity, and postoperative analgesic use. In a busy clinical setting with limited time for emergencies, pulpotomy may be preferred because it requires significantly less time and is a simple technique that relieves symptoms effectively.

Acknowledgement

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Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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