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Accidental perforations during root canal treatment: an 8-year nationwide perspective on healthcare malpractice claims

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Abstract

Objectives To assess occurrence and its variation over time of serious accidental perforations during endodontic treatment and the fate of perforated teeth by tooth type and characteristics of patients and dentists.

Materials and methods Data, based on patient documents on healthcare malpractice claims, comprised all endodontic injuries ($n = 970$) verified by the Patient Insurance Centre in Finland in 2002–2006 and 2011–2013. Two specialists in endodontics scrutinized the documents. Accidental perforations were recorded by location (tooth type, chamber/canals) and dichotomized as avoidable (could have been avoided by following good clinical practice) or unavoidable (normal treatment-related risks). Fate of perforation cases was recorded as treatment discontinued, root canal(s) filled, or tooth extracted. Background information included patients' and dentists' sex and age and the service sector. Statistical evaluation used Chi-square tests.

Results Serious accidental perforations comprised 29% of all verified injuries. Most perforations were judged as avoidable: 93% in patients aged below 35 years, 87% when located in the pulp chamber or in molars (84%); 70% of all perforations and 75% of those in molars resulted in tooth extraction. The overall rate of serious accidental perforations was 17.6 cases per 100,000 endodontic patients per year.

Conclusions The rate of serious accidental perforations increased over time. The majority was in molars and resulted in tooth extraction.

Clinical relevance Accidental perforations comprise almost a third of serious injuries during root canal treatment. However, four of five perforations could be avoided by following good clinical practice. Therefore, training is needed before adopting new working equipment and methods.

Keywords Accidental perforation · Endodontics · Injury · Pulp chamber · Root canal treatment

Introduction

Perforation of the pulp chamber or root walls during instrumentation of root canals exposes the supporting tissues of the tooth to bacterial contamination and often leads to loss of the tooth [1]. Numerous reports have been published on how to handle or avoid a perforation, but less is known about the rate of these unexpected incidents in endodontics. Perforations have been estimated to account for up to 10% of all failed endodontic cases [2]. The estimates vary, however, depending on the definition of a perforation and the tooth type evaluated.

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A large study evaluated the records of 2002 patients visiting the university dental clinic in Tel Aviv, Israel, between 1990 and 2008 [3]. Among all the teeth ($n = 56{,}175$) of these patients, 5048 teeth had received root canal treatment (RCT) and 116 teeth were identified with root perforation; thus, a perforation had occurred in 2.3% of all RCT teeth. The report revealed that more than half of the perforations were in the lower molars. Based on these data, perforation occurrence by type of tooth can be estimated at 5.3% for lower molars and for other teeth from 0.6% in lower anteriors to 1.6% in upper anteriors. A report on 333 endodontic patients treated in 1971 found 14 perforations in a total of 501 RCT roots followed for at least 3 years [4]. Thus, perforations seemed to occur in 2.8% of roots and in 4.2% of patients.

Some reports have evaluated perforations as part of failures in endodontics. According to Toure et al. [5], perforation occurred in 4.2% of 119 extracted RCT teeth. A historic report evaluated 146 cases that had 'failed during or after endodontic

therapy performed by experienced endodontists' [6]. The authors classified failures into 15 reasons, perforation occurring in 5 cases (i.e. 3.4%). A recent paper from Turkey evaluated 1000 'endodontically failed teeth', 281 of which were extracted [7]. Perforation was the reason for extraction in 2.9% of cases; prosthetic reasons dominated (40.8%). Reports from some Middle East countries present perforations in 1% of endodontic failures in Iran [8, 9] or from 3 [10] to 5.5% [11] of those in Saudi Arabia. These reports evaluated 90–150 failure cases, except for the first mentioned study, which assessed 1335 cases. Reports evaluating failures only have presented no information about the proportion of failures among the total numbers of RCT teeth or endodontic patients.

Extreme failure cases are considered malpractice, thus leading to official claims and even litigation processes. In Italy, a total of 117 such endodontic malpractice cases were analysed; 15 teeth (13%) had sustained perforation and extraction was suggested for 13 (87%) of these [12]. In Denmark, a nationwide study of 482 endodontic claims in 1995–2002 indicated that root perforations accounted for 10% of 'technical complications' [13].

The aim of this study was to assess how the occurrence of serious accidental perforations during endodontic treatment varied over time and to evaluate how the existence and fate of perforated teeth varied by type of tooth and characteristics of patients and dentists.

Materials and methods

Background

In Nordic countries, failures in healthcare are treated according to fairly similar systems that follow the 'no blame/no fault' rule. According to the Patient Injury Act of 1987 in Finland, all healthcare workers must have a patient insurance contract, and thus pay annual fees to the Patient Insurance Centre (PIC). The PIC is an administrative body to handle all patient healthcare claims in the whole country and from any treatment provider, i.e. from single offices to clinics and hospitals, both in private and public sectors (https://www.pvk.fi/en/). The PIC decides about financial compensation for cases in which the injury could have been avoided by following good clinical practice. With no restrictions regarding service sector, type of treatment, or age of the patient, any patient can submit a claim to the PIC, free of charge, because the handling costs are paid from the insurance, i.e. from the fees all healthcare workers must pay for their contracts.

The PIC decisions are based on patient's and care provider's views of the incident and on patient documents from the care provider. The PIC advisors, all being experienced clinicians, scrutinize the cases and give their statement about the claim: had there been an injury, and if so, had it been avoidable or unavoidable. An avoidable injury means that it could have been avoided had the operator followed generally accepted guidelines for good clinical practice and, in endodontic cases, that the tooth and root canals were within usual anatomical range. Thus, the PIC statement of an avoidable injury refers to shortcomings or faults in the operator's work. The other option for the PIC statement is an unavoidable injury indicating cases with normal treatment-related risks caused for example by exceptional root canal anatomy or problems with defective root canal instruments. The decision between these two options is based on the standardized judgement of the PIC advisors. To keep their judgements standardized, the PIC advisors discuss the cases in monthly meetings, thus keeping on systematic calibration of the level of their decisions.

Endodontics has predominated in dental malpractice claims in Finland in the 2000s and has shown a steady growth in numbers of compensated endodontic injuries over the years [14, 15]. At the same time, new techniques and equipment for endodontic treatment have been introduced, gradually leading to notable growth in the commercial supply of endodontic devices and to increased use of e.g. engine-driven instrumentation and electronic apex locators. The number of endodontic patients treated in the private sector was about 100,000 per year in 2006–2013 [16], with a similar figure reported in the public sector [17]. Thus, altogether, about 200,000 patients per year receive endodontic care in Finland.

Ethical considerations

This study is based on decisions made by the PIC on endodontic malpractice claims in 2002–2006 and 2011–2013. The PIC, together with the Ministry of Social Affairs and Health, approved the study protocol. The original patient documents were handled only by personnel of the PIC and were not shown to anybody outside the PIC. To ensure fulfilment of ethics criteria, running numbers were the only identifiers for the cases in the database.

Data collection and recordings

This study analysed all endodontic malpractice claims with decisions rendered by the PIC in 2002–2006 and 2011–2013. The two periods were selected to illustrate changes in the frequency of injuries over time. According to the PIC decisions, 970 cases had a verified endodontic injury and, thus, were analysed here.

Two dental advisors, both specialists in endodontics, scrutinized all documents gathered in the endodontic malpractice claims. We recorded and then tested the raw data for logicality and possible errors and corrected any mistakes to fit the recordings with original patient documents, re-scrutinized by one of the authors. The data of cases (patients and teeth) and providers were based on the documents collected by the PIC. These background data included the patient's sex and age, the

service sector in which the treatment took place, and the dentist's sex, age, and specialization, if any. The teeth in question were categorized as anteriors (incisors and canines), premolars, or molars.

The endodontic injuries verified by the PIC were categorized as accidental perforation of the root canal or pulp chamber, a broken root canal instrument, injuries caused by any root canal irrigants and medicaments, and miscellaneous injuries such as under-/overfilling, wrong diagnosis, and unnecessary treatment. Root resorptions and apical over-instrumentation were not recorded as perforation. For this study, the injuries were dichotomized as being or not being a perforation. According to the judgements made by the PIC advisors, perforation cases were dichotomized as avoidable or unavoidable injuries.

Based on patient documents, the final fate of perforation cases was defined as (a) treatment discontinued at this clinic; (b) root canal(s) filled; (c) canal(s) filled, but tooth extracted; or (d) tooth extracted before filling the canal(s). Population rates of accidental perforations per year in the whole country were assessed using the available information of numbers of endodontic patients as the basic population.

Statistical analysis

Differences between the frequencies in the subgroups were evaluated by means of Chi-square tests. Analyses were performed with Survo MM software (version 3.4.1; Survo Systems, Helsinki, Finland).

Results

Occurrence of accidental perforations

Serious accidental perforations accounted for 29% of the verified endodontic injuries and were most frequent (42.3%; $p = 0.007$) in anterior teeth and among patients aged 55 years and older (around 39–40%; $p < 0.001$). No other characteristics of the injury cases were related to the occurrence of accidental perforations (Table 1). The estimated occurrence of serious accidental perforations pooled across the 8 years was 0.0176% (i.e. 17.6 cases per 100,000 endodontic patients treated per year). For the earlier 5-year period, the corresponding rate was 0.014% and for the later 3-year period 0.023%, indicating 14 cases and 23 cases, respectively, per 100,000 endodontic patients treated per year.

Location of perforations

Half of the serious accidental perforations were in root canals and half in pulp chambers (Table 2). Perforation located in root canal(s) was more frequent in anterior teeth (90.9%) and in the latter period, i.e. 2011–2013 (56.5%). Chamber perforations dominated in molars (72.8%) and in the earlier period, i.e. 2002–2006 (60.1%). Canal perforations were more frequent in patients aged 45 years and older and chamber perforations in patients under 45 years of age ($p < 0.001$). Neither the dentist's age and sex nor the service sector or specialization had an impact on the location of perforations.

Table 1 Presence (%) of serious accidental perforations during root canal treatments verified in Finland with endodontic injuries ($n = 970$) across 8 years (2002–2006 and 2011–2013)

Characteristics of cases	No. of all injuries	Perforations (n (%))	p value
Total	970	281 (29.0)	–
Type of tooth			0.007
Anterior	104	44 (42.3)	
Premolar	236	64 (27.1)	
Molar	630	173 (27.5)	
Jaw			0.241
Maxilla	441	136 (30.8)	
Mandible	529	145 (27.4)	
Age of patient (years)			< 0.001
< 35	256	67 (26.2)	
35–44	234	49 (20.9)	
45–54	238	69 (29.0)	
55–64	163	65 (39.9)	
65+	79	31 (39.2)	
Sex of patient			0.768
Men	280	83 (29.6)	
Women	690	198 (28.7)	
Age of dentist (years)			0.584
< 40	289	88 (30.4)	
40–49	309	83 (26.9)	
50+	336	100 (29.8)	
Missing data	36		
Sex of dentist			0.742
Men	370	110 (29.7)	
Women	595	171 (28.7)	
Missing data	5		
Service sector			0.050
Private	524	138 (26.3)	
Public	446	143 (32.1)	
Period (years)			0.260
2002–2006	521	143 (27.4)	
2011–2013	449	138 (30.7)	

Avoidability of perforations

Four of five serious accidental perforations could have been avoided had the operator followed good clinical practice, according to the PIC advisors' judgement. Avoidable

Table 2 Location of serious accidental perforations ($n = 281$) during root canal treatments

Characteristics of cases	No. of perforations	In canal(s) (n (%))	In chamber (n (%))	p value
Total	281	135 (48.0)	146 (52.0)	–
Type of tooth				< 0.001
Anterior	44	40 (90.9)	4 (9.1)	
Premolar	64	48 (75.0)	16 (25.0)	
Molar	173	47 (27.2)	126 (72.8)	
Jaw				0.176
Maxilla	136	71 (52.2)	65 (47.8)	
Mandible	145	64 (44.1)	81 (55.9)	
Age of patient (years)				< 0.001
< 35	67	24 (35.8)	43 (64.2)	
35–44	49	12 (24.5)	37 (75.5)	
45–54	69	39 (56.5)	30 (43.5)	
55–64	65	39 (60.0)	26 (40.0)	
65+	31	21 (67.7)	10 (32.3)	
Sex of patient				0.578
Men	83	42 (50.6)	41 (49.4)	
Women	198	93 (47.0)	105 (53.0)	
Age of dentist (years)				0.065
< 40	88	34 (38.6)	54 (61.4)	
40–49	83	43 (51.8)	40 (48.2)	
50+	100	55 (55.0)	45 (45.0)	
Missing data	10			
Sex of dentist				0.598
Men	110	55 (50.0)	55 (50.0)	
Women	171	80 (46.8)	91 (53.2)	
Service sector				0.173
Private	138	72 (52.2)	66 (47.8)	
Public	143	63 (44.1)	80 (55.9)	
Period (years)				0.005
2002–2006	143	57 (39.9)	86 (60.1)	
2011–2013	138	78 (56.5)	60 (43.5)	

perforations were most frequent in the pulp chamber (87.0%), in molars (84.4%), in patients aged below 35 years (92.5%), and when the dentist's age was below 40 years or 50 years and older (Table 3). No differences were found according to patient's or dentist's sex or the service sector or dentist's specialization or the time of RCT.

Fate of teeth with accidental perforation

Of the teeth with serious accidental perforation during RCT, 70% were extracted: 42.3% before and 27.8% after filling the root canals (Table 4). Most likely to be extracted were molars (75.1%) and teeth treated by dentists aged either below 40 years (73.9%) or 50 years and older (72.0%). Other background factors had no impact on extractions of perforated teeth. RCT resulted in root filling(s) in 15.5% and in 14.2% of perforated teeth, in discontinuation of the treatment in this clinic.

Discussion

Serious accidental perforations during RCT were regrettably common in this large material of endodontic injuries. According to the PIC advisors, four of five perforations could have been avoided by following good clinical practice. The irreversible outcome of these perforations increases the gravity of the situation.

Many earlier reports emphasize the role of perforations as reasons for failure in RCT. However, comparisons with previous reports remain limited because of the wide variation in target groups and definitions of perforations and their

Table 3 Serious accidental perforations ($n = 281$) during root canal treatments categorized as avoidable or unavoidable incidents

Characteristics of cases	No. of perforations	Avoidable (n (%))	Unavoidable (n (%))	p value
Total	281	228 (81.1)	53 (18.9)	–
Location of perforation				0.009
Chamber	146	127 (87.0)	19 (13.0)	
Canal(s)	135	101 (74.8)	34 (25.2)	
Type of tooth				0.049
Anterior	44	30 (68.2)	14 (31.8)	
Premolar	64	52 (81.3)	12 (18.8)	
Molar	173	146 (84.4)	27 (15.6)	
Jaw				0.185
Maxilla	136	106 (77.9)	30 (22.1)	
Mandible	145	122 (84.1)	23 (15.9)	
Age of patient (years)				0.058
< 35	67	62 (92.5)	5 (7.5)	
35–44	49	41 (83.7)	8 (16.3)	
45–54	69	53 (76.8)	16 (23.2)	
55–64	65	49 (75.4)	16 (24.6)	
65+	31	23 (74.2)	8 (25.8)	
Sex of patient				0.433
Men	83	65 (78.3)	18 (21.7)	
Women	198	163 (82.3)	35 (17.7)	
Age of dentist (years)				0.059
< 40	88	75 (85.2)	13 (14.8)	
40–49	83	60 (72.3)	23 (27.7)	
50+	100	84 (84.0)	16 (16.0)	
Missing data	10			
Sex of dentist				0.937
Men	110	89 (80.9)	21 (19.1)	
Women	171	139 (81.3)	32 (18.7)	
Service sector				0.767
Private	138	111 (80.4)	27 (19.6)	
Public	143	117 (81.8)	26 (18.2)	
Period (years)				0.365
2002–2006	143	119 (83.2)	24 (16.8)	
2011–2013	138	109 (79.0)	29 (21.0)	

outcome. We analysed cases with verified endodontic injuries and restricted perforations to those occurring during endodontic treatment. Further, we excluded resorptions, apical over-instrumentation, and perforations during preparation of the post space, a situation commonly associated with root canal perforations. A meta-analysis of repair of perforations in the root canal system summarized that 47% of perforations were 'noted or created' during endodontic treatment and 53% were due to prosthodontics [18].

The main strength of our study is the large nationwide data covering 8 years. Practically all serious injuries are claimed to PIC, in part due to the ease of doing so. Furthermore, dentists are willing to help the patient in making the claim since the goal of the process is not to determine guilt, but to pay compensation to the patient. Some minor cases may, however, be settled immediately in the dental office without further consequences.

Our document-based data comprise background information on both patients and operators. We could, thus, assess the occurrence of the serious accidental perforations among the verified endodontic injuries not only by type of tooth but also according to the patient's and dentist's backgrounds. We found dentists' age, either young or old, to have an impact on the fatal outcome of perforations as extraction of the tooth. Young dentists have less endodontic experience/routine practices, whereas older dentists may have neglected their need for continuing education.

Table 4 Fate of teeth with serious accidental perforations ($n = 281$) during root canal treatments

Characteristics of cases	No. of perforations	Treatment discontinued (n (%))	Canals filled (n (%))	Filled, then extracted (n (%))	Extracted before filling (n (%))	p value
Total	281	40 (14.2)	44 (15.7)	78 (27.8)	119 (42.3)	–
Location of perforation						0.698
Chamber	146	24 (16.4)	22 (15.1)	38 (26.0)	62 (42.5)	
Canal(s)	135	16 (11.9)	22 (16.3)	40 (29.6)	57 (42.2)	
Type of tooth						0.029
Anterior	44	11 (25.0)	8 (18.2)	4 (9.1)	21 (47.7)	
Premolar	64	11 (17.2)	11 (17.2)	20 (31.3)	22 (34.4)	
Molar	173	18 (10.4)	25 (14.5)	54 (31.2)	76 (43.9)	
Jaw						0.233
Maxilla	136	18 (13.2)	27 (19.9)	39 (28.7)	52 (38.2)	
Mandible	145	22 (15.2)	17 (11.7)	39 (26.9)	67 (46.2)	
Age of patient (years)						0.377
< 35	67	7 (10.4)	9 (13.4)	20 (29.9)	31 (46.3)	
35–44	49	8 (16.3)	5 (10.2)	20 (40.8)	16 (32.7)	
45–54	69	12 (17.4)	11 (15.9)	13 (18.8)	33 (47.8)	
55–64	65	8 (12.3)	15 (23.1)	15 (23.1)	27 (41.5)	
65+	31	5 (16.1)	4 (12.9)	10 (32.3)	12 (38.7)	
Sex of patient						0.508
Men	83	8 (9.6)	15 (18.1)	23 (27.7)	37 (44.6)	
Women	198	32 (16.2)	29 (14.6)	55 (27.8)	82 (41.4)	
Age of dentist (years)						0.015
< 40	88	17 (19.3)	6 (6.8)	29 (33.0)	36 (40.9)	
40–49	83	16 (19.3)	17 (20.5)	19 (22.9)	31 (37.3)	
50+	100	7 (7.0)	21 (21.0)	27 (27.0)	45 (45.0)	
Missing data	10					
Sex of dentist						0.629
Men	110	24 (14.0)	23 (13.5)	49 (28.7)	75 (43.9)	
Women	171	16 (14.5)	21 (19.1)	29 (26.4)	44 (40.0)	
Service sector						0.165
Private	138	14 (10.1)	23 (16.7)	44 (31.9)	57 (41.3)	
Public	143	26 (18.2)	21 (14.7)	34 (23.8)	62 (43.4)	
Period (years)						0.004
2002–2006	143	30 (21.0)	25 (17.5)	33 (23.1)	55 (38.5)	
2011–2013	138	10 (7.2)	19 (13.8)	45 (32.6)	64 (46.5)	

Unfortunately, dentists' level of endodontic knowledge and skills could not be assessed in this context.

Our data allowed us to relate the occurrence of serious accidental perforations to the number of endodontic patients in the entire population. Such data are available both in the private sector as open data [16] and in the public sector as sporadic publications [17], thus allowing us to relate injury cases to the numbers of endodontic patients in the entire country. Comparable aspects have, to our knowledge, not been reported earlier. Our results suggested that 0.023% of endodontic patients per year experienced accidental perforations in 2011–2013. However, this rate must be considered an underestimation of all accidental perforations as it describes serious incidents only. Further, we could not relate accidental perforations to the numbers of teeth that had undergone RCT per year, which can be taken as a limitation of the study. Further, due to the new techniques and materials available, many smaller perforations certainly are adequately repaired, thus avoiding any injury claim to the PIC. Unfortunately, no information of such incidents is available in patient-based documents or registers.

In our data, 70% of the teeth with accidental perforations ended up being extracted, 42% before and 28% after filling the root(s). This indicates the seriousness of the perforations.

Teeth with perforation comprised 29% of all verified endodontic injuries ($n = 970$), and thus, tooth extractions were the outcome for some 20% of all endodontic injuries. A recent study of 1000 endodontically failed teeth, 28% of which were extracted, reported the reason for extraction to be prosthetic for 41% and perforation for only 3% [7]. Their definition for failure included clinical, restorative, and radiographic problems; nevertheless, our estimated outcome rate of extractions following serious endodontic injuries is in line with their rate of extractions following endodontic failures.

In the long term, teeth with perforation often result in fatal problems and final failures. Our data of verified endodontic injuries proved a high rate of extractions following serious accidental perforations. A similar fate existed in the patient case we presented, as the perforated tooth ended up being extracted after two symptomless years. In line, a recent radiographic analysis of 1146 root canals in 618 endodontically treated teeth reported rather few perforations, but 91% of the perforation cases were with apical radiolucency [19] indicating unsuccessful outcome of the treatment.

Reports of accidental perforations highlight time, size, and location as important factors for prognosis of the incidence [20]. Our data offer information about location only, half were in canals and half in the pulp chamber, but sizes of perforations remained unknown, which can be taken as a limitation of the study. We can, however, infer that the perforations were massive or otherwise serious since the majority of the cases resulted in tooth extraction. A further limitation is that these data cannot answer the question about the reasons leading to accidental perforations because the quality of the patient documents varied widely [21], and consequently, descriptions of the incidents or attempts to repair them varied from detailed to minor or none.

The vast majority of serious accidental perforations analysed here could have been avoided had the operator followed good clinical practice, as stated by the PIC advisors. Similar conclusions have been presented in many review articles and numerous case reports about accidental perforations during RCT. Dentists have at hand a lot of detailed instructions showing methods for adequate root canal preparation, step-by-step, and for avoidance of accidental perforation or file separation [22, 23].

When new preparation techniques have been introduced, their quality has soon been analysed also from the point of avoiding procedural errors. In 1999, an experiment compared automated root canal preparation with hand instrumentation in 45 extracted mandibular molars and concluded that the 'manual instrumentation proved to be safe; no instrument fracture, perforation or loss of working length could be observed, whereas automated preparation resulted in one perforation and two cases of loss of working length' [24]. Opposite findings were recently reported from a university clinic comparing root canal treatments performed by students using manual preparation in 2002–2003, but rotary instrumentation in 2012–2013 [25]. The authors concluded rotary root canal preparation being with fewer procedural errors than manual preparation.

The following questions arise: Has the development of new equipment been too rapid to allow necessary training? Are dentists ignoring the training needed before adopting new working methods? Or are dentists' working schedules too tight to allow adequate time for performing RCTs? These aspects should be seriously discussed in every unit aiming to avoid serious perforation injuries during RCT.

Conclusion

A clear increase in the rate of serious accidental perforations across the years was found, thus suggesting dentists' insufficient preparedness to the use of new techniques. The majority of perforations was in molars, of which three of four resulted in tooth extraction. Our results showed, however, that serious accidental root perforations are a mostly avoidable outcome in endodontics. Therefore, dentists' knowledge of the normal variety in root canal anatomy and their training in the use of new techniques should be encouraged over their entire clinical career.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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