Received: 14 October 2021 | Accepted: 26 December 2021

DOI: 10.1111/iej.13678

INTERNATIONAL ENDODONTIC JOURNAL | WILEY

REVIEW ARTICLE

# Present status and future directions: Managing endodontic emergencies

**Paul V. Abbott**

UWA Dental School, The University of Western Australia, Nedlands, Western Australia, Australia

**Correspondence**
Paul V. Abbott, UWA Dental School, The University of Western Australia, 17 Monash Avenue, Nedlands, WA 6009 Australia.
Email: paul.v.abbott@uwa.edu.au

## Abstract

Endodontic emergencies are common in both general dental practices and specialist Endodontic practices. The aim of this review is to provide an overview of endodontic emergencies. Endodontic emergencies can be a result of many different conditions of the pulp, root canal and periradicular tissues. They may occur before endodontic treatment has been started, between appointments when treatment is being performed over multiple visits, or after endodontic treatment has been completed. In the latter situation, the emergency may be very soon after the treatment or it may occur many years later, in which case it is usually a new disease process as a result of the root canal system becoming infected. An emergency can be a stressful situation for both the patient and the dentist (or endodontist) as it is usually an unexpected event. It is incumbent on dental professionals to provide timely assistance to patients who have an emergency, and it is also important to allow sufficient time to manage the situation comprehensively. Management of endodontic emergencies should follow the principles of the 3D's—Diagnosis, Definitive dental treatment and Drugs—and in that sequence. An accurate diagnosis, the first "D", is essential so the appropriate treatment can be provided. Diagnosis requires a thorough understanding of the various conditions that can cause the emergency and this can be helped by having a comprehensive classification of the various conditions. The diagnosis should also direct the clinician to the appropriate Definitive dental treatment, the second "D". Root canal treatment will not always be required as some cases can be managed conservatively. Other cases may require root canal re-treatment. The specific details of how the treatment are done can also vary, according to the diagnosis. The final "D" is Drugs—the use of drugs should also be dependent on the diagnosis and the dental treatment. Drugs should only be an adjunct following the treatment. The clinician must also differentiate between inflammation and infection in order to provide the appropriate treatment and to prescribe the appropriate medication for effective pain relief and resolution of other symptoms or signs such as swelling.

**KEYWORDS**

analgesics, antibiotics, apical abscess, apical periodontitis, emergencies, endodontics, medication, non-steroidal anti-inflammatory drugs, pulpitis, root canal treatment

## INTRODUCTION

All dentists and endodontists must be able to manage patients who present with a dental emergency. Emergencies usually involve pain as a result of inflammation, but they can also involve swelling and other signs of infection. The aim of this review is to provide an overview of endodontic emergencies. The details of the mechanical aspects of endodontic treatment of emergencies and their outcomes will not be discussed as these can be found in numerous textbooks and journal articles. In this review, the term 'endodontic treatment' has been used to include all possible treatments for pulp, root canal and periradicular conditions—these include indirect pulp capping, direct pulp capping, partial pulpotomy, pulpotomy, pulpectomy with root canal treatment, root canal re-treatment and periradicular surgery. The term 'root canal treatment' has been used to specifically refer to pulpectomy and its associated procedures to clean, disinfect and fill the root canals.

## WHAT IS AN ENDODONTIC EMERGENCY?

An endodontic emergency can be defined as occurring when a patient has pain associated with inflammation of the pulp and/or periradicular tissues, or when there is pain (with or without swelling) caused by infection of the root canal system and/or the periradicular tissues. This description is somewhat broader than that proposed by Wolcott et al. (2011) and used by Farmakis et al. (2016), where an endodontic emergency was defined as "pain and/or swelling caused by inflammation or infection of the pulp and/or periapical tissues". However, their definition is limited since it does not include teeth that do not have pulps (e.g. a tooth with a pulpless infected root canal system; a tooth with a root canal filling, etc.), and it does not include all of the periradicular tissues (e.g. acute lateral periodontitis associated with a lateral canal or with a tooth that has external lateral inflammatory resorption). Hence, the above broader description is proposed as it is more comprehensive and representative of all possible emergencies that may occur as a result of endodontically related conditions.

There are many different causes of dental pain, but the most common will be associated with dental caries, defective restorations and trauma to a tooth. In this review, traumatic dental injuries will not be discussed as they are adequately covered in other publications—such as textbooks (e.g., Andreasen et al., 2019) and other journals (e.g., *Dental Traumatology*). Comprehensive guidelines have been published by the International Association of Dental Traumatology that provide background information and recommendations for the emergency management of traumatic dental injuries (Abbott & Levin, 2020; Bourguignon et al., 2020; Day et al., 2020; Fouad et al., 2020; Levin et al., 2020).

## HOW OFTEN DO ENDODONTIC EMERGENCIES OCCUR?

There is limited information available in the dental literature regarding the incidence of endodontic emergencies in day-to-day general dental practice. Most studies regarding dental emergencies have been conducted many years ago and most were in military environments (Chaffin & Moss, 2008; Colthirst et al., 2012, 2013; Dunn et al., 2004; Gunepin et al., 2011; Simecek, 2008; Wilmowsky et al., 2014; York et al., 2008), university dental schools or hospitals. The latter have been mainly performed in general hospitals rather than in dental hospitals (Austin et al., 2009; Bae et al., 2011; Cheng et al., 2006; Gibson et al., 1993; Maneliene & Balciuniene, 2004; Naidu et al., 2005; Pennycook et al., 1993; Riley & Gilbert, 2005; Tiradentes et al., 2012; Widstrom et al., 1988). Despite the lack of data, it is very likely that most general dentists would see endodontic emergencies on a regular, if not daily, basis since the pulp, root canal and periradicular tissues are the most common locations for infections and inflammatory conditions associated with teeth.

In a study of 553 patients who attended the Emergency Clinic of the Athens Dental School in Greece on 117 days over a period of 7 months (excluding weekends and holidays), pain of endodontic origin was the most common presentation with almost 48.8% of the patients having reversible pulpitis, irreversible pulpitis and/or acute apical periodontitis (Farmakis et al., 2016). There was a highly significant difference between these endodontic conditions and other reasons for presentation. As a result, the most frequent treatment provided was pulpectomy followed by drainage of an abscess. Gibson et al. (1993) and Tiradentes et al. (2012) reported that reversible pulpitis, irreversible pulpitis and pulp necrosis with or without a periapical abscess were the causes of pain in 76% and 44%, respectively, of their patients. These figures contrast with reports from military studies where less than 20% of acute pain cases were a result of pulp disease (Gunepin et al., 2011; Simecek, 2008; Wilmowsky et al., 2014). The low numbers amongst military personnel may be a result of them having more regular dental care to ensure their fitness and readiness for active duty.

Private specialist endodontic practices will often have patients referred for the management of endodontic emergencies. A survey of dentists who limited their practices to

endodontics in the United Kingdom in 1992 reported that 13.7% of referrals were for the management of patients where the referring dentist had been unable to control the pain and/or swelling (Harty, 1992), while a report from New Zealand indicated that 9% of referrals to an endodontist were because of pain and swelling (Manning, 1992). In Australia, a private specialist endodontic practice reported that 24.1% of 2000 patients were referred for the management of pain and a further 5.9% of the patients were referred for the diagnosis of pain, but they did not require root canal treatment because the pain was not a result of pulp, root canal or periradicular conditions (Abbott, 1994a).

## WHEN DO ENDODONTIC EMERGENCIES OCCUR?

Endodontic emergencies have been classified in several ways by various authors, but a common system has been to consider endodontic emergencies in relation to the timing of root canal treatment (Carrotte, 2004; Walker, 1984), such as:

1. Endodontic emergencies that occur *prior to* endodontic treatment—this applies to teeth that have not had any previous endodontic treatment;
2. Endodontic emergencies that occur *during* endodontic treatment (usually root canal treatment or root canal retreatment)—this applies to teeth undergoing treatment over more than one appointment; these emergencies are often referred to as a "flare-up" (Azim et al., 2017); and
3. Endodontic emergencies that occur *after* endodontic treatment—this applies either to post-operative pain following the root canal filling stage of treatment or to teeth that have had previous root canal treatment at some time in the past and have become infected again which has led to acute apical periodontitis or an acute apical abscess.

This is a convenient way to discuss endodontic emergencies and allows the clinician to categorize the various conditions that cause a patient to seek urgent treatment because they have an endodontic emergency. However, this approach is very general, and a more detailed diagnosis is required for each case in order to discuss and manage endodontic emergencies. Hence, a comprehensive classification system is required for the various pulp, root canal and periradicular conditions that may occur.

## WHAT CONDITIONS MAY PRESENT AS ENDODONTIC EMERGENCIES?

In discussing the various pulp, root canal and periapical conditions that may present as endodontic emergencies, it is essential to have a clear and concise classification of these conditions. There has been debate in the literature regarding the terminology used in classifications of these conditions with little, if any, agreement (Abbott & Yu, 2007; Tronstad, 1991). The terms used in most diagnostic classifications for pulp, root canal and periradicular conditions have not been based on, or do not adequately describe, what is happening (or has already happened) within the tissues or the anatomical location even though this is arguably the most important requirement of a classification system. Other requirements are that the classification system and terminology are possible to use in the clinical setting, useful, clear and universal. In order to be possible to use, the diagnosis has to be able to be formulated by considering the information obtained from the patient via the history, symptoms, clinical signs, results of diagnostic tests and the radiographic findings. To be useful, a diagnosis using the classification system should indicate the management options for the presenting condition and to be clear, the terminology should be understood by all relevant clinicians. Ideally, there should be one universal classification for any group of diseases or conditions so clinicians throughout the world can communicate effectively, educators can teach effectively and researchers can report in a consistent manner (Abbott, 2019; Abbott & Yu, 2007).

Scarpelli et al. (2020) outlined eight approaches to developing a classification of diseases and/or conditions. They are based on the anatomy, physiology, pathology, aetiology, topography, juristic aspects, epidemiology and statistics. The latter five approaches do not apply to pulp, root canal and periradicular conditions or clinical dental practice. However, the first three approaches can be combined to develop appropriate classifications of the various pulp, root canal and periradicular conditions. Abbott and Yu (2007) developed a classification for pulp and root canal conditions and Abbott (2004a) developed one for periradicular conditions—both of these classifications use a combined approach that considers the anatomy (which tooth, which tissues), the physiology (normal responses to injury or stimuli) and the pathology (the diseases that develop over time).

A further important consideration is that previous classifications and publications have typically only referred to "pulp and periapical diseases". There are several problems with this general term. The first is that not all presenting problems are diseases. A disease is defined as "a disordered or incorrectly functioning organ, part, structure or system of the body resulting from the effect of genetic or developmental errors, infection, poisons, nutritional deficiency or imbalance, or unfavourable environmental factors; illness; sickness; ailment" (https://www.dictionary.com/browse/disease). There are several pulp conditions

that do not fit this definition, and, therefore, it is inappropriate to call them all "diseases". Examples of pulp conditions that are not "diseases" are clinically normal pulps, pulp atrophy and pulp canal calcification. Secondly, inflammatory conditions within the pulp are not necessarily "diseases". Inflammation is the cellular and vascular response of tissues to an injury (American Association of Endodontists, 2020) and hence it is the body's natural response to protect itself from a stimulus and/or to manage an injury or infection. Hence, a tissue that is inflamed is not necessarily "disordered or incorrectly functioning". Inflammation should be considered as a physiological response although it can progress to become a true disease state. Thirdly, pulp conditions and root canal conditions must be distinguished from each other since pulps are not present in all teeth. Some examples include teeth with pulpless, infected root canal systems—as shown by Jansson et al. (1993)—and teeth with previous root canal treatment which may be incomplete (such as following the commencement of root canal treatment) or complete (after the root canal filling has been placed). Hence, the general heading "pulp and root canal conditions" is more appropriate.

It is also more appropriate to use the general term "periradicular conditions" as opposed to "periapical diseases" for several reasons. The first two reasons are similar to that outlined above since not all conditions that occur in the periradicular tissues are diseases—some examples include clinically normal periapical/periradicular tissues and periapical scars. Apical periodontitis is, by definition, inflammation within the periapical tissues, and it is a physiological response to a stimulus (usually bacteria within the root canal system), but it is not a disease unless it progresses to other conditions such as when an abscess or a cyst forms. Thirdly, the periapical region of a tooth is not the only location for the various endodontically related conditions to occur as several of them occur in other locations surrounding the root of the tooth—examples include the various types of external tooth resorption and when there is an infected lateral root canal (Ne et al., 1999; Trope, 1998). A further example is when a crack extends into the tooth root and inflammation occurs in the adjacent periodontal ligament and bone—this can be termed "lateral periodontitis".

Another problem that has slowly crept into the endodontic literature over the last decade or so has been the use of terms describing the presence or absence of symptoms—that is, "symptomatic" and "asymptomatic". These have seemingly replaced the terms "acute" and "chronic" even though there is little, if any, support in the historic or contemporary peer-reviewed literature and no scientific basis for their use (Gutmann et al., 2009). In addition, it is inconsistent with the terminology used in all other dental disciplines and in medicine. These terms over-simplify the diagnosis, and they are not very specific about the true nature of the presenting problem, especially if used for endodontic emergencies since they will always be "symptomatic" according to the above definition of an endodontic emergency. In addition, Bestall et al. (2020) reported that the use of these terms significantly affects dentists' decision making regarding treatment with significantly fewer dentists opting to treat a condition labelled as "asymptomatic" as opposed to when the same condition is called "chronic"—for example "asymptomatic apical periodontitis" compared to "chronic apical periodontitis". Likewise, there were also significant differences in treatment choices when "acute" was used instead of "symptomatic" (Bestall et al., 2020). These results were similar to a study where medical practitioners were significantly more likely to treat "chronic malaria" than "asymptomatic malaria" (Chen et al., 2016) even though the two conditions are the same. The results of the Bestall et al. (2020) study imply that many teeth with pulp, root canal and periradicular conditions may be left untreated because of the lack of symptoms rather than being treated to resolve the condition or to remove any disease that is present. That study indicated that "words do matter" and appropriate terminology should always be used.

The above study also emphasises that practitioners need to understand that a lack of symptoms does not imply a lack of disease or a lack of a condition that requires treatment. There are many examples of conditions in humans that do not have symptoms yet they need treatment. Two common medical examples are hypertension and diabetes—both lack symptoms in their early stages but the medical profession would advocate early intervention to avoid their progression to life-threatening or catastrophic events. In dentistry, caries and periodontal diseases are examples of conditions that usually have no symptoms until they reach an advanced stage, yet dentists usually treat these conditions as soon as they diagnose them. Pulp, root canal and periradicular conditions can develop into very serious, and even life-threatening, situations if left untreated—for example, chronic apical periodontitis associated with a pulpless, infected root canal system can develop into an acute apical abscess and could then further progress to become facial cellulitis and a spreading infection that may compromise the airway (e.g. Ludwig's angina) and lead to death of the patient.

In the remainder of this review of endodontic emergencies, the classifications of Abbott and Yu (2007) for pulp and root canal conditions and Abbott (2004a) for periradicular conditions will be used since they meet the requirements of a useful, meaningful, clear and universal classification that is possible to use in the clinical setting. The typical symptoms, clinical findings, radiographic

findings, the key findings to diagnose each condition and the features that distinguish each condition from other similar conditions have been outlined in detail by Abbott (2019). That textbook chapter also links each pulp and root canal condition with the various periradicular conditions that can occur as a result of the pulp/root canal condition, and *vice versa*. All dentists should be familiar with these conditions, and their inter-relationships in order to be able to accurately diagnose and to effectively manage endodontic emergencies so the patient obtains relief of pain in an expeditious manner.

Tables 1–3 list the various conditions in the classifications by Abbott & Yu (2007) and Abbott (2004a) that may present as endodontic emergencies, according to the above definition for an endodontic emergency, and in consideration of when the emergency occurs in relation to endodontic treatment—that is, before, during or after treatment.

It is important to recognise that each condition listed in Tables 1–3 does not occur in isolation. The periradicular conditions are a direct result of what is happening within the pulp or root canal system. Inflammation of the pulp and infection within the root canal system will initially cause periradicular (and especially periapical) inflammation. If no treatment is provided, the periradicular inflammation can progress to become a periradicular infection (e.g. abscess, facial cellulitis, extra-radicular infection). Hence, when diagnosing endodontic emergencies, it is essential to diagnose all tissues and locations that are involved—some examples of thorough diagnoses are:

- acute irreversible pulpitis with primary acute apical periodontitis;
- a pulpless and infected root canal system with secondary acute apical periodontitis;
- a root filled and infected root canal system with a secondary acute apical abscess; etc.

## WHAT CAUSES ENDODONTIC EMERGENCIES?

As part of the diagnostic process when assessing teeth for endodontically related conditions, it is essential to determine what has caused the condition. Whilst the presence of bacteria within the tooth is the major cause of pulp, root canal and periradicular conditions, it is far more relevant and essential to determine how the bacteria have entered the tooth so this pathway of entry can be removed as the first stage of managing the condition. Identifying and removing the cause of a disease or condition is the first principle of management (Abbott, 2019).

**TABLE 1** The various conditions that may present as emergencies prior to endodontic treatment

| Emergencies that occur prior to endodontic treatment | |
|---|---|
| **Pulp and/or root canal conditions** | **Periradicular conditions that may be associated with each pulp or root canal condition** |
| Acute reversible pulpitis | • Primary acute apical periodontitis<br>• Condensing osteitis |
| Acute irreversible pulpitis | • Primary acute apical periodontitis<br>• Condensing osteitis |
| Pulp hyperplasia (pulp polyp) | • Primary acute apical periodontitis |
| Pulp necrobiosis | • Primary acute apical periodontitis |
| Necrotic and infected pulp | • Primary acute apical periodontitis<br>• Primary acute apical abscess<br>• External inflammatory resorption |
| Pulpless and infected root canal system | • Secondary acute apical periodontitis<br>• Secondary acute apical abscess<br>• Facial cellulitis<br>• Extra-radicular infection<br>• External inflammatory resorption |
| Internal inflammatory resorption | • Secondary acute apical periodontitis<br>• Secondary acute apical abscess<br>• Facial cellulitis<br>• Extra-radicular infection<br>• External inflammatory resorption |

*Note:* The various conditions listed for the pulp and root canal system may occur with a variety of periradicular conditions, as listed.

**TABLE 2** The various conditions that may present as emergencies after endodontic treatment has been commenced, but it has not been completed (i.e. associated with multi-visit treatment)

| **Emergencies that occur after endodontic treatment has been commenced but before it has been completed (i.e. associated with multi-visit treatment)** | |
|---|---|
| **Pulp and/or root canal conditions** | **Periradicular conditions that may be associated with each pulp or root canal condition** |
| Acute irreversible pulpitis (following initial management of reversible pulpitis where symptoms have continued and become worse, indicating irreversible pulpitis) | • Primary acute apical periodontitis |
| Acute irreversible pulpitis (where the pulp has not been completely removed) | • Primary acute apical periodontitis |
| Pulp necrobiosis (where the pulp has not been completely removed) | • Primary acute apical periodontitis |
| Necrotic and infected pulp (where the necrotic pulp has not been completely removed) | • Primary acute apical periodontitis<br>• Primary acute apical abscess<br>• External inflammatory resorption |
| Pulpless and infected root canal system (where initial root canal treatment has not controlled the infection) | • Secondary acute apical periodontitis<br>• Secondary acute apical abscess<br>• Facial cellulitis<br>• Extra-radicular infection<br>• External inflammatory resorption |
| Internal inflammatory resorption (where initial root canal treatment has not controlled the infection and/or the inflammation) | • Secondary acute apical periodontitis<br>• Secondary acute apical abscess<br>• Facial cellulitis<br>• Extra-radicular infection<br>• External inflammatory resorption |

*Note:* The various conditions listed for the pulp and root canal system may occur with a variety of periradicular conditions, as listed.

The most common pathways for bacteria to enter teeth are via caries, cracks, fractures and restoration margins that are breaking down. These pathways are not always evident during routine clinical and radiographic examinations but that does not mean that a pathway does not exist and that they can be ignored (Abbott, 2004b). Clinicians should understand and remember that pulps do not become inflamed without a specific reason. Likewise, they do not become necrotic and infected without a reason. There must always be a cause and this has to be identified so it can be removed. In a clinical study, Abbott (2004b) examined teeth with pulp, root canal and periradicular conditions both before and after removing all the existing restorations. He reported that caries was only evident on periapical radiographs of 19.2% of the teeth but 86.1% of the teeth actually had caries, and most of these teeth were only identified as having caries after the restorations were removed. The pre-operative clinical examination, which included transillumination of the teeth, revealed caries in 37% of the teeth, cracks in 23% and marginal breakdown of the restorations in 39% of the teeth. After removing the restorations and re-examining the teeth, the corresponding figures were 86.1% had caries, 60% had cracks and 99.6% of the teeth had marginal breakdown of the restorations. That is, there were approximately 2.5 times as many teeth with caries, cracks and restorations breaking down when the teeth were examined after removal of the restoration compared to the pre-operative examination. Over 93% of the teeth had more than one of these pathways present. This study clearly showed that the pathways of entry for bacteria cannot be accurately

**TABLE 3** The various conditions that may present as emergencies soon after root canal treatment has been completed, or many years later

| Emergencies that occur soon after root canal treatment has been completed or many years after root canal treatment | |
|---|---|
| **Root canal conditions** | **Periradicular conditions that may be associated with each root canal condition** |
| Recent root canal filling (with no signs of infection of the root canal system) | • Secondary acute apical periodontitis (postoperative inflammation soon after a root canal filling has been completed) |
| Root filled and infected root canal system | • Primary acute apical periodontitis<br>• Secondary acute apical periodontitis<br>• Primary acute apical abscess<br>• Secondary acute apical abscess<br>• Facial cellulitis<br>• Extra-radicular infection<br>• External inflammatory resorption |

*Note:* The various conditions listed for the root canal system may occur with a variety of periradicular conditions, as listed.

determined when a restoration is present in a tooth with pathological pulp, root canal and/or periradicular conditions. Hence, the restorations must be removed as the initial stage of root canal treatment in order to remove the cause of the problem.

The results of the above study were supported by Kwang and Abbott (2012) who reported that the fitting surface of all restorations removed from teeth with infected root canal systems, and apical periodontitis was coated with a biofilm containing various forms of bacteria. In order to be included in this study, the teeth had to have had no caries or cracks, and the restorations were judged to be "clinically satisfactory". However, after removing the restorations from the teeth and examining the fitting surface under scanning electron microscopy, the bacterial contamination was noted to be extensive. Thus, the only pathway for the bacteria to have entered the tooth to then infect the root canal system was via the restoration:tooth interface as a result of marginal breakdown of the restoration. This study provides further evidence that existing restorations should be removed as the initial stage of root canal treatment in order to remove the cause of the pulp/root canal and periradicular conditions or diseases.

## FACTORS THAT MAY AFFECT THE MANAGEMENT OF ENDODONTIC EMERGENCIES

Patients who present to a dentist with an endodontic emergency will usually have an acute pain problem, as outlined later. Considerable time may be required in order to thoroughly manage the situation (which includes taking the history, performing the examination, discussing the findings, making treatment recommendations, gaining informed consent and then providing the required treatment). However, emergencies are generally unexpected, and the dentist may already have a full schedule of patients so there may be only a limited amount of time available unless the dentist works beyond his/her normal clinic hours (Abbott, 2000a).

In addition to the time constraints that are often faced, endodontic emergencies may be further complicated by the patient presenting in a distressed state. This distress may be a result of the intensity of the pain, which often has an unexpected onset and may have caused a lack of sleep. The patient may be seeing a new dentist, which can cause further apprehension. This "new patient situation" also makes it more difficult for the dentist to assess the problem as there may be no history available and the dentist will be unfamiliar with the patient's attitudes towards dentistry, their perception of pain and the strategies that the patient uses to cope with pain (Abbott, 2000a). Many patients are apprehensive about having root canal treatment, even in non-emergency situations or when attending a scheduled appointment. A survey by the American Association of Endodontists (2016) reported that 67% of Americans said the "fear of pain" was their primary concern regarding root canal treatment. Wong and Lytle (1991) reported that root canal treatment is one of the dental procedures that causes the greatest anxiety and pain for patients, second only to oral surgery. In an Australian survey of patients who were about to undergo root canal treatment by specialist endodontists, 55% were concerned about the cost, 51% were concerned about pain during and after the treatment and those with pre-treatment pain had an average anxiety score of 48.9% (Chandraweera et al., 2019). These fears and negative attitudes towards root canal treatment may be a result of anecdotal accounts or second-hand experiences. They can be problematic as they may complicate the management of a patient who has an endodontic emergency. Anxiety may increase the patient's perception

of the treatment as being painful as well as potentially fostering a misdiagnosis (Eitner et al., 2006) and leading to the patient avoiding treatment (Watkins et al., 2002).

In order to overcome, or at least minimise, these potential complicating factors, adequate time should be reserved in a dentist's appointment schedule for emergencies. The patients must also be educated about the need for, and the nature of, the treatment for their presenting problem. Good patient management commences with good communication and a reassuring manner on the part of the dentist. The patient should not feel that his/her treatment is being rushed because of the dentist's time constraints as this may lead to poorer outcomes and poor attitudes about the treatment and the dentist.

## GENERAL MANAGEMENT OF ENDODONTIC EMERGENCIES

When managing a patient who presents with pain, the principles of the "Three D's" should be followed (Kaiser & Byrne, 2011). In addition, these principles should be followed in the correct sequence, which is (1) Diagnosis, (2) Definitive dental treatment and (3) Drugs. The first step, diagnosis, has been discussed earlier. With an accurate diagnosis, definitive dental (endodontic) treatment is the most predictable way to manage an endodontic emergency and to resolve a patient's pain. The type and details of the treatment depend on the diagnosis of the presenting problem and the amount of remaining tooth structure as this will dictate whether the tooth is suitable for further restoration and how it can be restored. Options for managing the endodontic emergency include conservative pulp treatment, root canal treatment, root canal re-treatment and extraction. Drugs can be used intra-dentally (sedative liners, root canal medicaments) and as systemic medications, but it is essential to understand that systemic drugs should only be used as an adjunct to the dental treatment.

If the above definition of an endodontic emergency is applied, not all endodontic emergencies will require root canal treatment—for example, if the pain is associated with reversible pulpitis, then some form of conservative pulp treatment should be considered. In this case, the options include an indirect pulp cap, a direct pulp cap, a partial pulpotomy or a pulpotomy. The choice will depend on many factors with the most important one being the amount of remaining tooth structure and how the tooth can be restored once the emergency has been resolved.

It may be feasible to do root canal treatment or root canal re-treatment on some teeth with infected root canal systems and apical periodontitis, but some teeth may not be suitable for further restoration following such treatment because of extensive loss of tooth structure as a result of caries, cracks, fractures and/or previous restorations. Such teeth will require extraction.

Some teeth may have endodontic complications that preclude the dentist or endodontist from providing root canal treatment and therefore extraction may be necessary. Examples of such complications may include calcified canals that cannot be located or negotiated, blocked/ledged canals that cannot be fully negotiated to the apical constriction, fractured instruments that cannot be removed or by-passed, large perforations that are not amenable to repair, extensive or untreatable resorptive defects, cement-type root filling materials that cannot be removed, etc. Teeth with these problems may need to be extracted, or alternative treatment, such as periapical surgery, may be indicated. Such problems are discussed in various textbooks.

An essential part of the initial management of any tooth with pulp, root canal and periradicular conditions or diseases is to "investigate" the tooth to determine its suitability for further treatment. The term "investigation" was proposed by Jensen et al. (2007) to describe the procedure whereby all existing restorations, caries and significant cracks are removed from teeth prior to commencing root canal treatment. This allows the clinician to assess the remaining tooth structure to determine whether the tooth is suitable for further restoration following the root canal treatment. It also allows the clinician to assess the suitability of the root canal system for root canal treatment plus whether it is feasible for the clinician to perform such treatment without complications. Some teeth will be indicated for extraction following the investigation, some may be indicated for referral to a specialist endodontist and others may be suitable for the general dentist to perform the treatment.

Aldhufairi (2015) reviewed the clinical records of 5775 teeth following consultation with either a specialist Endodontist or a postgraduate student training to be an Endodontist. A total of 680 (11.8%) teeth were recommended for extraction, either because there was insufficient tooth structure remaining to enable the tooth to be adequately restored again ($n = 475$; 8.2%) or there were significant cracks or fractures ($n = 205$; 3.5%) which precluded further treatment. Subsequently, 4218 teeth were investigated by removing all existing restorations, caries and cracks—this revealed insufficient tooth structure remained in 503 (11.9%) teeth and 306 (7.3%) teeth had significant cracks which could not be managed conservatively—hence, a total of 809 (19.2%) teeth were recommended for extraction. The latter figure means that one out of every five teeth was judged to be unsuitable for treatment once the tooth had been investigated, and this emphasizes the importance of the tooth investigation prior to starting root canal treatment.

That is, if these teeth had not been investigated then one in five teeth would have been endodontically treated but with a poor prognosis which was likely to lead to extraction within a short period of time after the treatment. The finding of 19.2% of teeth being recommended for extraction is similar to the number of teeth extracted within 2–3 years of having root canal treatment (average 14%, range 3%–64%) that was reported in a systematic review by Ng et al. (2010).

In another study performed by Ng et al. (2011), the reasons for extraction of endodontically treated teeth were analysed. This was a prospective study where teeth were followed for 2–4 years after treatment. There were two groups—one group had 759 teeth that underwent primary root canal treatment and the second group consisted of 858 teeth that had root canal re-treatment. The main reasons for extraction were "endodontic problems" (28.6% and 39.0% respectively), tooth/root fractures (28.6% and 29.3%, respectively), restoration "failures" (22.9% and 22.0%, respectively), change of treatment plan (17.1% and 9.7%, respectively) and periodontal problems (2.8% and 0%, respectively). If the figures for tooth/root fracture and restoration "failure" are combined, they total 51.5% and 51.3%, respectively. Hence, just over half of the teeth were extracted because of "tooth structure problems"—that is, the lack of sufficient tooth structure leads to tooth fracture and loss, or otherwise leads to problems with, and especially loss of, the restoration. Other studies have reported similar proportions of teeth being extracted because of "tooth structure" problems within short periods of time following root canal treatment—for example: Sjögren et al. (1990)—51.5% over 8–10 years; Vire (1991)—59.4% after 1 year; Fuss et al. (1999)—55%; Zadik et al. (2008)—72.8% over 2 years; and Touré et al. (2011) (40.4%). All of these findings highlight the need to assess the amount and quality of remaining tooth structure prior to undertaking root canal treatment. They demonstrate that it is essential to assess whether the tooth can be adequately restored following the root canal treatment. This approach must apply to endodontic emergencies in the same manner as for any tooth requiring root canal treatment as there is little point in doing such treatment if the tooth does not have a good prognosis and expected longevity. If insufficient time is available to properly investigate a tooth when a patient presents as an emergency, then it may be reasonable to simply open an endodontic access cavity to provide the emergency treatment and then do the investigation at a subsequent appointment when sufficient time has been reserved—however, this requires an extra appointment before the prognosis is determined and, if extraction was then deemed to be necessary, the patient has been inconvenienced, has undergone unnecessary treatment and has been subjected to extra expense.

The remainder of this review will assume that all teeth with endodontic emergencies are investigated as the first stage of management and they have been deemed to be suitable for conservative pulp treatment, root canal treatment or root canal re-treatment, plus the subsequent restoration. However, as outlined later, teeth that require extraction still need to be carefully and thoroughly assessed to determine the diagnosis and to assess their suitability for treatment. Those teeth with potential endodontic complications should ideally be assessed by attempting to manage the problem before deciding to extract the tooth.

## SPECIFIC MANAGEMENT OF ENDODONTIC EMERGENCIES

### Emergencies prior to endodontic treatment

As outlined in Table 1, there are various conditions of the pulp and root canal system that can cause acute pain where the patient will present as an emergency and each condition can cause a variety of periradicular (especially periapical) conditions. The various conditions can be grouped as either inflammation or infection. Inflammatory conditions may be present without infection (e.g. reversible pulpitis, irreversible pulpitis), but when infection is present, there will also always be inflammation (e.g. an infected root canal system and apical periodontitis). When an abscess is present within the periradicular (usually periapical) tissues, the tissues surrounding the abscess will be also inflamed—hence, a tooth that has an apical abscess will always also have apical periodontitis (Nair et al., 1996).

The stimulating factors that cause the pain and the nature of the pain will indicate whether the emergency is due to acute inflammation and/or infection of the pulp, root canal and/or periradicular tissues. It is essential to understand that these are interrelated so they must be managed concurrently. Fortunately, if the pulp or root canal condition is managed effectively, the periradicular condition will resolve almost immediately in most cases. This is a result of two factors—first, the most common condition within the periradicular tissues is inflammation caused by the pulp or root canal condition (Nair et al., 1996); and secondly, removing the causative problem from the root canal means there will be no ongoing irritation to the periradicular tissues and therefore they will begin to heal (Abbott, 2004b; Jensen et al., 2007). Hence, in most endodontic emergency cases, once the diagnosis has been established, and the tooth has been investigated and deemed suitable for treatment, the focus should be on managing

the pulp or root canal condition through mechanical endodontic procedures, which is consistent with the principles of the 3D's (Kaiser & Byrne, 2011). In most cases, if the periradicular tissues need to be managed (e.g. because of pain), they can be managed secondarily through pharmaceutical means rather than by invasive dental procedures. The exception will be when there is an acute apical abscess that requires an incision and drainage.

As discussed earlier, a comprehensive history must be taken of the presenting problem and a thorough clinical and radiographic examination must be performed. The clinical examination should include pulp sensibility tests (cold, electric and sometimes heat), percussion, palpation, mobility and biting tests plus periodontal probing and transillumination. Once the diagnosis has been established, the management options should be obvious, and these should be discussed with the patient before a final treatment plan is decided. A detailed outline of the procedures that should be followed during an endodontic examination and the various tests that should be performed as part of the diagnostic process can be found in various textbook chapters, such as that by Abbott (2019).

Table 4 outlines the emergency management required for the various pulp and root canal conditions that may present as endodontic emergencies prior to treatment. Table 5 outlines the emergency management of the

**TABLE 4** Emergency and follow-up management of pulp and root canal conditions that may present as emergencies prior to endodontic treatment

| Pulp/Root canal condition | Emergency treatment | Follow-up treatment |
|---|---|---|
| Acute reversible pulpitis | • Remove all restorations, caries, cracks—if the tooth is suitable for restoration, the conservative pulp treatment options are<br>a. Indirect pulp cap<br>b. Direct pulp cap<br>c. Partial pulpotomy, or<br>d. Pulpotomy | • Minimum 3–4 months review<br>a. Re-test pulp sensibility<br>b. Periapical radiograph to assess periradicular tissues |
| Acute irreversible pulpitis | • Remove all restorations, caries, cracks<br>• If the tooth is suitable for RCT and restoration:<br>a. Pulpectomy<br>b. Irrigate and medicate canal (CS-AB paste preferred) | • Continue the root canal treatment<br>a. Fully prepare/clean all canals<br>b. Irrigate with NaOCl, EDTAC<br>c. Medicate with $Ca(OH)_2$<br>d. Root canal filling<br>• Restore tooth as required<br>• Review 6 months after root canal treatment has been completed<br>a. Assess periradicular healing |
| Pulp hyperplasia (pulp polyp) | • Remove all restorations, caries, cracks<br>• If the tooth is suitable for RCT and restoration:<br>a. Pulpectomy<br>b. Irrigate and medicate canal (CS-AB paste preferred) | |
| Pulp necrobiosis | • Remove all restorations, caries, cracks<br>• If the tooth is suitable for RCT and restoration:<br>a. Pulpectomy (including removal of necrotic and infected tissue)<br>b. Irrigate and medicate canal (CS-AB paste preferred) | |
| Necrotic and infected pulp | • Remove all restorations, caries, cracks<br>• If the tooth is suitable for RCT and restoration:<br>a. Remove the necrotic and infected tissue<br>b. Irrigate and medicate canal (CS-AB paste preferred) | |
| Pulpless & infected root canal system | • Remove all restorations, caries, cracks<br>• If the tooth is suitable for RCT and restoration:<br>a. Access the root canal system and remove debris<br>b. Irrigate and medicate canal (CS-AB paste preferred) | |
| Internal inflammatory resorption | • Remove all restorations, caries, cracks<br>• If the tooth is suitable for RCT and restoration:<br>a. Pulpectomy (including removal of necrotic and infected tissue)<br>b. Irrigate and medicate canal (CS-AB paste preferred) | |

*Note:* This table should be read in conjunction with Tables 1 and 5 in order to manage the associated periradicular conditions.

Abbreviations: $Ca(OH)_2$, calcium hydroxide; CS-AB, corticosteroid-antibiotic; EDTAC, ethylene diamine tetra-acetic acid with cetrimide; NaOCl, Sodium hypochlorite; RCT, root canal treatment.

**TABLE 5** Emergency and follow-up management of periradicular conditions that may present as emergencies prior to endodontic treatment

| Per radicular condition | Specific emergency treatment<br>- In addition to the treatment of the pulp or root canal system | Follow-up treatment |
|---|---|---|
| Condensing osteitis | • This condition is not usually painful in itself<br>a. Hence, additional treatment/medication not usually required<br>• But if also associated with primary or secondary acute apical periodontitis or abscess:<br>a. Manage as below | *If conservative treatment of reversible pulpitis:*<br>• Minimum 3–4 months review<br>a. Re-test pulp sensibility<br>b. Periapical radiograph to assess periradicular tissues<br>*If root canal treatment commenced:*<br>• Continue root canal treatment<br>a. Fully prepare/clean all canals<br>b. Irrigate with NaOCl, EDTAC<br>c. Medicate with $Ca(OH)_2$<br>d. Root canal filling<br>• Restore tooth as required<br>• Review 6 months after root canal treatment has been completed<br>a. Assess periradicular healing |
| Primary acute apical periodontitis | • Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 hrs) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | • Continue the root canal treatment<br>a. Fully prepare/clean all canals<br>b. Irrigate with NaOCl, EDTAC<br>c. Medicate with $Ca(OH)_2$<br>d. Root canal filling<br>• Restore tooth as required<br>• Review 6 months after root canal treatment has been completed<br>a. Assess periradicular healing |
| Primary acute apical abscess | • Drainage via the root canal and/or incision and drainage of the swelling<br>• Consider antibiotics if systemic signs of illness (malaise, increased temperature, lymph node involvement, etc.)<br>• Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Secondary acute apical periodontitis | • Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Secondary acute apical abscess | • Drainage via the root canal and/or incision & drainage of the swelling<br>• Consider oral antibiotics if systemic signs of illness (malaise, increased temperature, lymph node involvement, etc.)<br>• Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Facial cellulitis | • Drainage via the root canal and/ or incision and drainage of the swelling<br>• Antibiotics will be required due to systemic signs of illness (malaise, increased temperature, lymph node involvement, etc.)<br>a. Usually need intra-muscular or intra-venous antibiotic therapy<br>• Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Extra-radicular infection | • This condition cannot be distinguished from apical periodontitis or apical abscesses—hence, if suspected to be present, manage as outlined above for these conditions | |
| External inflammatory resorption | • Not usually associated with acute pain; hence, no specific periradicular treatment required. If acute pain, manage as for acute apical periodontitis | |

*Note:* This table should be read in conjunction with Tables 1 and 4 in order to manage the associated pulp and/or root canal conditions.

Abbreviations: $Ca(OH)_2$, calcium hydroxide; EDTAC, ethylene diamine tetra-acetic acid with cetrimide; NaOCl, sodium hypochlorite.

periradicular conditions that can be associated with these pulp and root canal conditions. Tables 4 and 5 also outline the follow-up treatment that should be provided once the acute symptoms have resolved. These recommendations are very general in nature as it is beyond the scope of this review to discuss the details of the treatment procedures or their technical aspects. Such details can be found in many textbooks and journal articles.

## Emergencies during endodontic treatment

Emergencies that occur after root canal treatment has been commenced but before it has been completed have also been termed "inter-appointment flare-ups" or simply "flare-ups". There have been numerous definitions of "flare-up" in the endodontic literature, but the most widely accepted definition is "swelling and/or pain within a few days following an endodontic appointment that requires the patient to attend for an unscheduled emergency visit with their dentist or endodontist" (Azim et al., 2017; Walton & Fouad, 1992). The many definitions in the literature have led to uncertainty amongst clinicians, and it has prevented or hindered comparisons between research reports. In addition, the need for an unscheduled appointment with the dentist limits the inclusion criteria for any research regarding postoperative pain. The term "flare-up" tends to suggest a more severe problem than what could occur after treatment since some patients with postoperative pain may not contact their dentist let alone attend for an appointment. Instead, they may manage the pain with self-administered analgesics and/or non-steroidal anti-inflammatory drugs, or they may consult with their medical practitioner or another dentist for advice. It is not unusual for medical practitioners to prescribe antibiotics (Biniecki et al., 2018) even though these are rarely indicated since the pain is most likely inflammatory in nature. Furthermore, the term "flare-up" is not indicative of the presenting problem as it is not a diagnostic term and it does not indicate any particular disease or condition—it simply means there is pain. Hence, this term should not be used in the literature or in discussions with patients or dental colleagues. A more appropriate, and all encompassing, term is "postoperative pain" but this is also only a descriptive term. The dentist should establish a diagnosis of the condition that is causing the pain and part of that process should include an assessment of why there is pain. Such an approach is simply "best practice" whenever a patient presents with a problem.

The diagnosis for a patient with pain following the commencement of endodontic treatment is likely to be different to the original diagnosis prior to the commencement of treatment because some treatment has already been provided. As an example, when a patient returns with pain several days after root canal treatment was started and a calcium hydroxide dressing was placed in the root canals of a tooth that initially had a pulpless, infected root canal system with secondary acute apical periodontitis, then the pain may be due to the ongoing acute apical periodontitis, whilst the root canal system may no longer be infected because of the initial treatment and the calcium hydroxide dressing. Another example is when a tooth with reversible pulpitis becomes more painful after conservative pulp treatment because the pulp inflammation has progressed to become irreversible pulpitis as a result of the irritation and reaction to the treatment. Hence, another clinical examination should be performed and a new diagnosis must be established whenever pain occurs after treatment has been commenced.

Table 2 lists the various conditions and reasons why pain may occur after root canal treatment has been started but before it is finished. Tables 6 and 7 summarise the emergency and follow-up management for these conditions. The management for these conditions is very similar to the management of the same conditions when they occur prior to endodontic treatment being commenced because the conditions are the same. In many cases, more dental treatment may be necessary—for example if the pulp had not been completely removed from a tooth with acute irreversible pulpitis and pain persists, then the remaining pulp should be removed by fully preparing the root canals, along with thorough irrigation and further medication with an appropriate medicament. In such a case, a corticosteroid-antibiotic paste would be appropriate (Ehrmann, 1965) because the pain is inflammatory in origin, whereas calcium hydroxide would be more appropriate for a tooth with an infected root canal system (Fava & Saunders, 1999) and persistent acute apical periodontitis or a persistent acute apical abscess. These examples highlight the need for an accurate diagnosis of the presenting problem that may differ from the patient's initial presenting problem and reasons for the commencement of root canal treatment.

The incidence of the so-called "flare-ups" following the commencement of root canal treatment has been reported to range from 1.4% to 19% (Walton & Fouad, 1992). There are several factors that may be associated with, or cause, a tooth to have continuing symptoms after root canal treatment has been started. Studies concerning "flare-ups" have attempted to correlate postoperative pain with many factors such as gender, age, tooth type, pulp and root canal conditions, periapical conditions, preoperative signs and symptoms certain systemic conditions and operator skills (Iqbal et al., 2009). Other factors such as preoperative and postoperative medications, number of appointments, technical quality of the root canal filling (Eleazer

**TABLE 6** Emergency and follow-up management of pulp and root canal conditions that may present as emergencies during endodontic treatment—that is after treatment has been commenced but it has not been completed

| Pulp/Root canal condition | Emergency treatment | Follow-up treatment |
|---|---|---|
| *Acute irreversible pulpitis* (following initial management of reversible pulpitis where symptoms have continued and become worse, indicating irreversible pulpitis) | • Pulpectomy<br>• Irrigate and medicate canal (CS-AB paste preferred) | • Continue the root canal treatment<br>a. Re-medicate with $Ca(OH)_2$<br>b. Root canal filling<br>• Restore tooth as required<br>• Review 6 months after root canal treatment has been completed<br>a. Assess periradicular healing |
| *Acute irreversible pulpitis* (where the pulp has not been completely removed) | • Ensure complete removal of any remaining pulp tissue<br>• Fully prepare/clean all canals<br>• Irrigate with NaOCl, EDTAC<br>• Medicate canal (CS-AB paste preferred) | |
| *Pulp necrobiosis* (where the pulp has not been completely removed) | • Ensure complete removal of any remaining pulp tissue<br>• Fully prepare/clean all canals<br>• Irrigate with NaOCl, EDTAC<br>• Medicate canal (CS-AB paste preferred) | |
| *Necrotic and infected pulp* (where the necrotic pulp has not been completely removed) | • Ensure complete removal of any remaining pulp tissue<br>• Fully prepare/clean all canals<br>• Irrigate with NaOCl, EDTAC<br>• Medicate canal—CS-AB paste or $Ca(OH)_2$ paste | |
| *Pulpless & infected root canal system* (where initial root canal treatment has not controlled the infection) | • Ensure complete removal of any remaining pulp tissue<br>• Fully prepare/clean all canals<br>• Irrigate with NaOCl, EDTAC<br>• Medicate canal—$Ca(OH)_2$ paste preferred | |
| *Internal inflammatory resorption* (where initial root canal treatment has not controlled the infection and/or the inflammation) | • Ensure complete removal of any remaining pulp tissue<br>• Fully prepare/clean all canals<br>• Irrigate with NaOCl, EDTAC<br>• Medicate canal—CS-AB paste or $Ca(OH)_2$ paste | |

*Note:* This table should be read in conjunction with Tables 2 and 7 in order to manage the associated periradicular conditions. The emergency treatment outlined in this table assumes that the tooth has been investigated by removing all restorations, caries and cracks at the initial appointment and the tooth has been assessed as being suitable for root canal treatment and further restoration.

Abbreviations: $Ca(OH)_2$, calcium hydroxide; CS-AB, corticosteroid-antibiotic; EDTAC, ethylene diamine tetra-acetic acid with cetrimide; NaOCl, sodium hypochlorite.

& Eleazer, 1998; Imura & Zuolo, 1995; Mor et al., 1992; Ng et al., 2004; Torabinejad et al., 1988; Walton & Fouad, 1992). However, there is no consensus, and there is a lack of evidence regarding these factors (Tsesis et al., 2008). Despite this, the state of the root canal system appears to be the main factor with more cases of postoperative pain associated with teeth that have infected root canal systems than with either previously root filled teeth or teeth with irreversible pulpitis (Azim et al., 2017).

A different approach was taken to determine the treatment factors associated with continuing pain following the commencement of root canal treatment by the patient's general dentist in a study by Abbott (1994b). The study analysed the way the root canal treatment had been performed in 100 consecutive patients who had been referred to an Endodontist by 78 different general dentists because of the ongoing symptoms. The original diagnosis for approximately half the teeth was acute irreversible pulpitis and the other half had pulpless, infected root canal systems with acute apical periodontitis. There were 23 different factors associated with the continuing pain and all patients had more than one factor. Most patients (78%) had four, five or six factors with up to nine factors in 2% of the cases. The most commonly occurring factors were the lack of use of dental dam (87%), unsatisfactory temporary restorations (80%), and inappropriate use of intracanal medicaments (71%). The other factors were related to diagnostic or treatment errors, inadequacies

**TABLE 7** Emergency and follow-up management of periradicular conditions that may present as emergencies during endodontic treatment—that is after treatment has been commenced but it has not been completed

| Periradicular condition | Specific emergency treatment - In addition to the treatment of the pulp or root canal system | Follow-up treatment |
|---|---|---|
| Primary acute apical periodontitis | • Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h), and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | • Continue the root canal treatment<br>a. Fully prepare/clean all canals<br>b. Irrigate with NaOCl, EDTAC<br>c. Re-medicate with $Ca(OH)_2$<br>d. Root canal filling<br>• Restore tooth as required<br>• Review 6 months after root canal treatment has been completed<br>a. Assess periradicular healing |
| Primary acute apical abscess | • Drainage via the root canal and/or incision and drainage of the swelling<br>• Consider antibiotics if systemic signs of illness (malaise, increased temperature, lymph node involvement, etc.)<br>• Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h), and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Secondary acute apical periodontitis | • Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Secondary acute apical abscess | • Drainage via the root canal and/or incision and drainage of the swelling<br>• Consider oral antibiotics if systemic signs of illness (malaise, increased temperature, lymph node involvement, etc.)<br>• Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h), and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Facial cellulitis | • Drainage via the root canal and/ or incision and drainage of the swelling<br>• Antibiotics will be required due to systemic signs of illness (malaise, increased temperature, lymph node involvement, etc.)<br>a. Usually need intra-muscular or intra-venous antibiotic therapy<br>• Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Extra-radicular infection | • This condition cannot be distinguished from apical periodontitis or apical abscesses—hence, if suspected to be present, manage as outlined above for these conditions | |
| External inflammatory resorption | • Not usually associated with acute pain; hence, no specific periradicular treatment required. If acute pain, manage as for acute apical periodontitis | |

*Note:* This Table should be read in conjunction with Tables 2 and 6 in order to manage the associated pulp and/or root canal conditions. The emergency treatment outlined in this Table assumes that the tooth has been investigated by removing all restorations, caries and cracks at the initial appointment and the tooth has been assessed as being suitable for root canal treatment and further restoration.

Abbreviations: $Ca(OH)_2$, calcium hydroxide; EDTAC, ethylene diamine tetra-acetic acid with cetrimide; NaOCl, sodium hypochlorite.

in management, lack of attention to the details of treatment, or inappropriate management—all of which could have been avoided (Abbott, 1994b). This study emphasises the need for an accurate diagnosis and appropriate, well-performed treatment to be provided when the patient first presents with an endodontic emergency in order to reduce the possibility of a further emergency or extra treatment being required.

Although root canal treatment can usually be provided without the patient having any pain during treatment, postoperative pain has been reported to occur in some cases. A very strong predictor of postoperative pain is the presence and degree of preoperative pain—15 studies reported this factor amongst more than 6600 patients (Kaiser & Byrne, 2011). O'Keefe (1976) reported that patients who have severe preoperative pain are five times more likely to have severe postoperative pain compared to patients with mild or moderate preoperative pain. In another study, the probability of moderate or severe pain was higher in mandibular teeth and lower in males (Arias et al., 2013). Law et al. (2015) also reported that pretreatment pain is a predictor of postoperative pain. They noted that acute apical periodontitis was a major predictor, and stress increased the level of pain. The level of anxiety was also reported to be a factor by Kahn et al. (2014), and patients with pretreatment pain had an average anxiety score of 48.9% when they were surveyed just prior to having root canal treatment (Chandraweera et al., 2019). These studies all emphasise that an assessment of the preoperative pain and the patient's level of anxiety should be an integral part of the clinician's approach to managing a patient's pain with a view to preventing, or minimising, postoperative pain. This can largely be achieved through the appropriate choice and use of intracanal medicaments that address the presenting pulp or intracanal condition(s) plus the use of appropriate systemic medications to assist with managing any pain associated with the periradicular tissues. These are discussed in more detail below.

## Emergencies after endodontic treatment

Emergencies that occur after root canal treatment has been completed fall into two categories—those that occur soon after the root canal filling has been placed (typically within a few days) and those that occur at some later time, which could be up to many years later.

Emergencies occurring within a few days of the placement of a root canal filling are likely to be postoperative pain due to inflammation—that is, secondary acute apical periodontitis. This inflammation is likely to be a result of the mechanical procedures involved in filling the canal or it may be due to bacteria that have been extruded through the apical foramen. The materials used for the root canal filling may also cause inflammation of the periapical tissues if any particles have been extruded through the apical foramen or any other foramen. These cases generally resolve quite rapidly and can usually be managed with systemic anti-inflammatory drugs and/or analgesics. In general, the non-steroidal anti-inflammatory drugs are the most effective and lead to rapid relief of pain since they help to resolve the inflammation that is occurring (Hargreaves & Kaiser, 2002). Occasionally, the symptoms may resolve but there can be ongoing chronic apical periodontitis as a result of a foreign body reaction (Nair et al., 1996). Fortunately, this is relatively rare but, if it does persist, then a periapical curettage may be necessary.

Emergencies that occur many years after root canal treatment have been completed should not be considered as "failures" of the treatment. Such a term is potentially too harsh and may not reflect the true nature of the situation. For example, if a tooth has a periapical true cyst, radiographic signs of periapical bone repair are not expected, yet the root canal treatment may have been entirely successful in that the root canal system may no longer be infected. Hence, in this situation, the root canal treatment itself has not "failed". Instead, the real problem is the lack of the dental profession's ability to clinically diagnose a periapical true cyst. It can only be diagnosed after surgical removal and histological examination of the biopsy specimen (Nair et al., 1996). On the other hand, if there are symptoms and/or signs to suggest that the root canal system has remained infected despite the root canal treatment, then it is more appropriate to consider it as a persistent infection of the root canal system in conjunction with an appropriate diagnosis of the periradicular tissues, according to the presenting symptoms and signs (Abbott, 2011). That is, the terminology used should be the same as any other time the same symptoms and/or signs are present, and the presence or absence of a root canal filling should not alter the diagnosis except to include that the tooth has been endodontically treated.

If the original root canal treatment had been effective at disinfecting the root canal system and the periapical radiolucency had healed but then another radiolucency subsequently developed some years later, then this should be considered as a "new disease process" (Abbott, 2011). There are only two differences between a root filled tooth with such disease and a tooth that has not been endodontically treated in the past—these differences are: (1) the lack of a pulp, and (2) the presence of the root canal filling. For example, secondary acute apical periodontitis can occur with a pulpless, infected root canal system and also with a root filled and infected root canal system. Hence, the general management, with the aim to disinfect the root canal system, will be the same for these two examples, and

the only specific difference is the need to remove the root canal filling in the latter case. Each tooth will still require investigation to assess its suitability for further treatment and another restoration, as outlined earlier. An extra part of the assessment during the investigation of the root filled tooth will be to determine whether the root canal filling materials can be removed from the root canals since this is not always possible—such as when a hard cement has been used alone rather than with gutta percha (and minimal cement).

Table 3 lists the various conditions where pain may occur after root canal treatment has been completed. Tables 8 and 9 summarise the emergency and follow-up management for these conditions. The management for these periradicular conditions is very similar to the management of the same conditions when they occur prior to endodontic treatment being commenced because the conditions are the same.

## PHARMACOLOGICAL MANAGEMENT OF ENDODONTIC EMERGENCIES

The third "D" of the 3D's principle for managing dental pain is to consider the use of drugs as an adjunct to the definitive dental treatment (Kaiser & Byrne, 2011). Drugs should only be used where the dental treatment may not fully resolve the patient's pain or other symptoms (e.g. swelling) in a timely manner. If endodontic emergencies are managed well, then the adjunctive use of systemic medication is not often required.

A key element for the predictable management of pain associated with an endodontic emergency is to determine whether the pain is only inflammatory in nature, or, whether there is also an infection that is causing the inflammation, and thus the pain. In considering the adjunctive use of drugs for emergency treatment, inflammatory conditions

**TABLE 8** Emergency and follow-up management of root canal conditions that may present as emergencies after root canal treatment or re-treatment—that is after the root canal filling has been completed

| Pulp/Root canal condition | Emergency treatment | Follow-up treatment |
|---|---|---|
| *Recent root canal filling* (with no signs of infection of the root canal system) | • Re-evaluate the recent treatment procedure<br>• *If the treatment has been technically adequate, prescribe:*<br>a. Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h), and/or<br>b. Analgesics (e.g. acetaminophen 1000 mg every 4–6 h)<br>• *If the treatment has been technically inadequate:*<br>a. Remove the root canal fillings and commence root canal re-treatment<br>b. Irrigate with NaOCl, EDTAC<br>c. Medicate canal—CS-AB paste (preferred) | *If root canal filling is technically adequate*<br>• Review 3–5 days later<br>• If asymptomatic<br>a. Restore tooth as required<br>b. Review 6 months after root canal treatment has been completed to assess periradicular healing<br>• If still symptoms:<br>a. Reconsider/change the systemic medication<br>b. Reconsider the root canal treatment and the need for re-treatment<br>*If root canal filling is technically inadequate*<br>• Continue root canal re-treatment<br>a. Fully prepare/clean canals<br>b. Re-medicate with $Ca(OH)_2$<br>c. Root canal filling<br>• Restore tooth as required<br>• Review 6 months after root canal treatment has been completed<br>a. Assess periradicular healing |
| Root filled and infected root canal system | • Remove all restorations, caries, cracks<br>• If the tooth is suitable for RCT and restoration:<br>a. Remove the root canal fillings<br>b. Irrigate with NaOCl, EDTAC<br>c. Medicate canal—CS-AB paste (if acute apical periodontitis) or $Ca(OH)_2$ paste | • Continue the root canal treatment<br>a. Fully prepare/clean canals<br>b. Re-medicate with $Ca(OH)_2$<br>c. Root canal filling<br>• Restore tooth as required<br>• Review 6 months after root canal treatment has been completed<br>a. Assess periradicular healing |

*Note:* This Table should be read in conjunction with Tables 3 and 9 in order to manage the associated periradicular conditions.

Abbreviations: $Ca(OH)_2$, calcium hydroxide; CS-AB, corticosteroid-antibiotic; EDTAC, ethylene diamine tetra-acetic acid with cetrimide; NaOCl, sodium hypochlorite; RCT, root canal treatment.

**TABLE 9** Emergency and follow-up management of periradicular conditions that may present as emergencies after root canal treatment or re-treatment—that is after the root canal filling has been completed

| Periradicular condition | Specific Emergency Treatment - In addition to the Treatment of the Root Canal System | Follow-up treatment |
|---|---|---|
| Acute apical periodontitis (postoperative inflammation soon after a root canal filling has been completed) | • Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | • Review 3–5 days later<br>• If asymptomatic<br>a. Restore tooth as required<br>b. Review 6 months after root canal treatment has been completed to assess periradicular healing<br>• If still symptoms:<br>a. Reconsider/change the systemic medication<br>b. Reconsider the root canal treatment and the need for re-treatment |
| Primary acute apical periodontitis | • Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | • Continue the root canal re-treatment<br>a. Fully prepare/clean all canals<br>b. Irrigate NaOCl, EDTAC<br>c. Re-medicate with $Ca(OH)_2$<br>d. Root canal filling<br>• Restore tooth as required<br>• Review 6 months after root canal treatment has been completed<br>a. Assess periradicular healing |
| Primary acute apical abscess | • Drainage via the root canal and/or incision and drainage of the swelling<br>• Consider antibiotics if systemic signs of illness (malaise, increased temperature, lymph node involvement, etc.)<br>• Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Secondary acute apical periodontitis | • Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Secondary acute apical abscess | • Drainage via the root canal and/or incision and drainage of the swelling<br>• Consider oral antibiotics if systemic signs of illness (malaise, increased temperature, lymph node involvement, etc.)<br>• Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Facial cellulitis | • Drainage via the root canal and/ or incision and drainage of the swelling<br>• Antibiotics will be required due to systemic signs of illness (malaise, increased temperature, lymph node involvement, etc.)<br>• Usually need intra-muscular or intra-venous antibiotic therapy<br>• Non-steroidal anti-inflammatory drugs (e.g. ibuprofen 400 mg every 4–6 h) and/or<br>• Analgesics (e.g. acetaminophen 1000 mg every 4–6 h) | |
| Extra-radicular infection | • This condition cannot be distinguished from apical periodontitis or apical abscesses—hence, if suspected to be present, manage as outlined above for these conditions | |
| External inflammatory resorption | • Not usually associated with acute pain; hence, no specific periradicular treatment required. If acute pain, manage as for acute apical periodontitis | |

*Note:* This Table should be read in conjunction with Tables 3 and 8 in order to manage the associated root canal conditions.

$Ca(OH)_2$, calcium hydroxide; EDTAC, ethylene diamine tetra-acetic acid with cetrimide; NaOCl, sodium hypochlorite.

are best managed by using anti-inflammatory agents, whilst infections must be managed with antibacterial agents. The latter may also be combined with anti-inflammatory agents since infections always also have inflammation of the surrounding tissues and that is where the pain originates.

There are several routes of administration of drugs that can be used as adjuncts to dental treatment. They may be given locally (intra-dental), topically or systemically. If used locally within the tooth, they may be used as part of a sedative lining (typically a hard-setting cement-like material) or part of an intracanal medicament (typically as a paste). The topical use of drugs is unlikely to be effective for endodontic emergencies as the site of the inflammation (i.e. pain) is not accessible to topical drugs. The systemic route of administration can be oral, intramuscular or intravenous. The latter two routes are usually only used in endodontics for very serious infections where antibiotics are indicated and they are required to be given urgently at high doses. These will not be discussed in this review as they are beyond the scope of most dental practices and they require medical intervention, including hospitalisation when intravenous drugs are indicated. Dentists' prescribing of antibiotics is typically via the oral route. Analgesics and anti-inflammatory agents are also often prescribed by dentists for oral use.

## Local use of drugs

The local use of drugs has several advantages over their systemic use (Rogers et al., 1999). The first is that the drugs are applied directly, or adjacent, to the site where their action is required—such as directly to the pulp, root canal and/or periradicular tissues (Abbott et al., 1988, 1989). Secondly, local application allows a faster onset of action as there is no time delay in waiting for the drug to be absorbed (e.g. via the gastrointestinal tract if taken orally) and then distributed via the blood stream. Thirdly, local application does not require the patient to take any action, and, therefore, there are no problems related to patient compliance with directions given by the clinician. Lastly, and very importantly, the local application of drugs is safer as it avoids systemic complications and side effects, apart from the possibility of allergic reactions (Kaufman et al., 2014), which fortunately are very rare. As an example of the efficacy of local drug use, significantly greater and faster pain relief occurred when a corticosteroid, dexamethasone, was placed within the root canals after initial root canal treatment than when ibuprofen was taken systemically—that is, orally (Rogers et al., 1999).

The choice of drugs for local, intra-dental application will depend on the condition being treated. When performing conservative pulp treatments for reversible pulpitis, once the cause has been removed from the tooth, a cement material containing a corticosteroid is advantageous and typically provides rapid pain relief (Abbott & Leow, 2009). However, other materials have also been used—such as calcium hydroxide and the various bioceramic materials (Cao et al., 2016). The choice will depend on the clinician's preferences and the availability of materials. The hard-setting corticosteroid-antibiotic cement material, Ledermix Cement (OzDent Dental Products, Australia), has a number of advantages. First, the corticosteroid component provides anti-inflammatory action to the pulp. Second, the antibiotic component provides anti-bacterial action. Third, it contains calcium hydroxide (approximately, one-third of the powder) which provides anti-bacterial action as well as stimulating hard tissue repair. Fourth, it contains zinc oxide-eugenol, and the eugenol component has anti-bacterial and anti-inflammatory properties (Hume, 1984a, 1984b, 1986). Research has shown that the corticosteroid component is released and diffuses through dentine within the first 3 days following application (Hume & Kenney, 1981) so there is no long-term effect which has been a concern of some clinicians in the past. This rapid release of the anti-inflammatory agent leads to rapid resolution of symptoms. The other components are likely to be released more slowly, and many studies have demonstrated the therapeutic actions of calcium hydroxide and eugenol when used as pulp capping or pulpotomy agents. The typical response of the pulp following the use of Ledermix Cement in these situations is to have normal pulp tissue in contact with the cement with no inflammation (Barker, 1975; Clarke, 1971; Ehrmann, 1965, 1981; Schroeder, 1968, 1972).

Paste materials containing drugs are used as medications within the root canal. Their purposes are to destroy any remaining bacteria in the root canal system and to reduce inflammation either in any remaining pulp tissue and/or within the periradicular tissues (and especially the periapical tissues). Hence, the ideal medicament should be antibacterial and anti-inflammatory. There are several choices of pastes that can be used as intracanal medicaments. The most common material is calcium hydroxide which has excellent anti-bacterial action and can stimulate hard tissue formation. However, it does not have any direct anti-inflammatory properties and it is an irritant to the tissues. Hence, it is not an ideal medicament for an endodontic emergency, especially if the emergency is due to irreversible pulpitis since the calcium hydroxide may increase the pain initially when placed on any remaining inflamed pulp tissue. Therefore in such cases, a corticosteroid-antibiotic paste, such as Ledermix Paste (OzDent Dental Products, Australia) is advantageous. This paste is different to the cement form mentioned above as it does not set and it does not contain calcium hydroxide or zinc oxide-eugenol. Ledermix paste has been reported to be very effective at relieving

the symptoms associated with acute irreversible pulpitis (Heithersay et al., 1990; Negm, 2001; Schroeder, 1965) and acute apical periodontitis (Ehrmann et al., 2003). In the latter study, Ledermix paste was significantly more effective than calcium hydroxide and when no medicament was placed. It provided more rapid relief of symptoms (within 4 h following treatment) even though the patients in the Ledermix paste group had a higher level of pre-operative pain. The authors even commented that "the rapidity of action of the intracanal medicament containing corticosteroid was striking". Ledermix paste has also been reported to prevent external inflammatory resorption from occurring following trauma to a tooth, plus it has been successfully used to treat external inflammatory resorption that is already present (Abbott, 2016; Bryson et al., 2002; Chen et al., 2008; Pierce & Lindskog, 1987) The one disadvantage of Ledermix paste is the limited anti-bacterial action of the tetracycline component (Athanassiadis et al., 2007). Hence, if this paste is used as an initial intracanal medicament to relieve pain associated with an infected root canal system, the tooth should have a further intracanal medicament placed and a material with a broader spectrum of anti-bacterial action should be used (Heithersay et al., 1990). Ideally, this should be calcium hydroxide as many research projects have demonstrated that it is the most effective anti-bacterial agent in endodontics (Athanassiadis et al., 2007; Fava & Saunders, 1999).

A further consideration regarding intracanal medication is that when removing an inflamed pulp (i.e. a pulp with irreversible pulpitis), the neurovascular bundle at the apical foramen will be severed. This can not only exacerbate the inflammatory response that is already present in the periapical tissues but it can also lead to periapical nerve sprouting and the potential for postoperative neuropathic pain to develop (Holland, 1995; Vickers & Cousins, 2000). Root canal treatment has been reported to be related to 41% of cases of neuropathic pain (Lynch & Elgeneidy, 1996), and it is a difficult condition to manage with most patients experiencing symptoms for extended periods of time. Hence, it is better to avoid the potential for this to occur. Holland (1996) reported that systemic corticosteroids can reduce the nerve sprouting effect in animals. However, rather than giving corticosteroids systemically in human patients, the intracanal application of a medicament containing a corticosteroid can deliver the drug rapidly and directly to the periapical tissues (Abbott et al., 1988, 1989) and hence it is likely to reduce the possibility of nerve sprouting and neuropathic pain.

## Systemic use of drugs

The systemic use of drugs following emergency dental/endodontic treatment usually involves non-steroidal anti-inflammatory drugs (NSAID's), analgesics, antibiotics or combinations of one or more of these types of drugs (Hargreaves & Kaiser, 2002; Kaiser & Byrne, 2011). As discussed earlier, the diagnosis of the presenting problem will determine which drug(s) is/are required. If the condition is inflammatory in nature, then a non-steroidal anti-inflammatory drug is the medication of choice. Analgesics may be used to supplement the NSAID in cases where severe postoperative pain is expected. If the patient cannot use an NSAID, then pain management will rely on the use of analgesics alone. Some cases of severe pain may require the use of narcotic agents such as opioids.

### NSAID's and analgesics

Although there are numerous NSAIDs available for the management of pain and inflammation, ibuprofen is generally considered to be the most effective NSAID available. It is easily obtained in most countries as an "over the counter" drug so it does not need a written prescription. Ibuprofen is very effective in reducing pain associated with inflamed tissues because it works both locally (as an anti-inflammatory drug) and centrally (as an analgesic). Its action is largely through the inhibition of cyclo-oxygenase that reduces the synthesis of inflammatory mediators such as prostaglandins from arachidonic acid. It is particularly useful for postoperative pain management following dental treatment where the cause of the inflammation has been removed (Hargreaves & Kaiser, 2002). Ibuprofen has a dose-related effect in reducing pain—that is, as the dose increases, its pain relieving effects increase. At a dose of 200 mg, about 48% of patients report at least 50% pain relief over 4–6 h—but at this dose, it has little, if any, anti-inflammatory action. With a 400 mg dose, the number of patients with at least 50% pain relief rises to 55%. A dose of 600 mg provides at least 50% pain relief to 79% of patients, and with 800 mg, 100% of patients have at least 50% pain relief [Oxford League Table of Analgesic Efficacy (bandolier.org.uk)]. However, if doses of 600 mg or 800 mg are taken, then the maximum daily dose (2400 mg) is likely to be quickly exceeded, depending on how often the medication is taken.

Acetaminophen (also known as paracetamol in some countries) is the recommended alternative non-narcotic drug for patients who cannot take or tolerate ibuprofen or other NSAIDs. Acetaminophen has no anti-inflammatory action, and it works by simply blocking the pain by selectively inhibiting prostaglandin release in the central nervous system. Acetaminophen is not as effective as ibuprofen in relieving pain—with a standard adult dose of 1000 mg, only 46% of patients reported at least 50% pain relief [Oxford League Table of Analgesic Efficacy

(bandolier.org.uk)]. Increasing the dose to 1500 mg increased the number of patients to 65%, but the maximum daily dose will soon be reached if this dose is used. The maximum daily dose varies in different countries with some recommending 4000 mg (e.g. Australia, Canada, UK) and others 3000 mg (e.g. USA).

Codeine is the most commonly used opioid in dentistry, but like all opioids, it can have serious side effects so it is best avoided whenever possible. Ideally, it should be reserved for severe pain situations. Codeine metabolises to form morphine that inhibits neurons in the brain and the dorsal horn of the central nervous system. A dose of at least 30 mg is required for codeine to be effective in most adults, but codeine is not effective in about 7%–10% of Caucasians, 1%–2% of Asians and up to 20% of Africans because they are poor metabolisers of codeine to morphine (Therapeutic Guidelines, 2012). With these patients, the temptation is to increase the dose of codeine, but this will not improve their pain management and instead can lead to side effects such as constipation and drowsiness.

Even when codeine is used alone at a dose of 60 mg, it is not particularly effective as only 15% of patients reported at least 50% pain relief—this was even less than the 18% of patients who used a placebo. However, when used in combination with an NSAID (such as ibuprofen) or an analgesic (such as acetaminophen), it is much more effective. For example, a combination of 1000 mg acetaminophen and 60 mg codeine provided at least 50% pain relief for 57% of patients [Oxford League Table of Analgesic Efficacy (bandolier.org.uk)].

Kaiser and Byrne (2011) have discussed the concept of a flexible pain management strategy. The main aim of this strategy is to achieve a maximally effective dose of a non-narcotic analgesic (preferably, an NSAID or otherwise acetaminophen if an NSAID cannot be taken). The second part of their strategy is to consider the use of additional drugs that increase the effect of the NSAID or acetaminophen—this should only be applied in the rare situations where the patient still has moderate to severe pain after dental treatment.

The combination of ibuprofen and codeine has not been widely investigated but commercial preparations are available in some countries. Typically, these preparations contain 200 mg ibuprofen and 12.8 mg codeine with a recommended adult dose of two tablets to provide 400 mg ibuprofen and only 25.6 mg of codeine. However, the latter is below the 30 mg required by most adults for codeine to be effective. In a study by Cooper et al. (1982), the combination of 400 mg ibuprofen and 60 mg codeine was the most effective analgesic, but it was not statistically better than 400 mg ibuprofen alone. A Cochrane review of six studies concluded that there were very limited data to suggest that the combination of ibuprofen and codeine was better than the same dose of either drug used alone (Derry et al., 2015). Hence, because most commercial combinations of ibuprofen and codeine typically only contain 12.8 mg codeine per tablet, it is questionable as to whether such combinations have any true therapeutic advantages over ibuprofen used alone.

The combination of ibuprofen and acetaminophen has been reported to provide better pain relief than when either drug was used alone for moderate to severe postoperative pain after surgery to remove third molar teeth (Mehlisch et al., 2010). The use of 400 mg ibuprofen with 1000 mg acetaminophen was significantly better than the same dose of each drug used alone. Using half these doses (200 mg ibuprofen with 500 mg acetaminophen) was also significantly better than the same dose of each drug used alone, plus it was significantly better than 1000 mg acetaminophen alone. However, it was not significantly better than 400 mg ibuprofen used alone. Menhinick et al. (2004) investigated pain relief after root canal treatment and they reported that 600 mg ibuprofen combined with 1000 mg acetaminophen was significantly more effective than 600 mg ibuprofen used alone at all postoperative time intervals tested from 90 min to 8 h. Hence, the combined use of ibuprofen and acetaminophen appears to provide better pain relief than either acetaminophen or ibuprofen alone following dental treatment.

## Antibiotics

Antibiotics should only be used when the patient has an infection that is causing systemic symptoms or signs—such as fever (increased body temperature), malaise, swelling and/or lymph node involvement (Therapeutic Guidelines, 2012). A localised swelling adjacent to the tooth is not usually an indication for the use of antibiotics which should be limited to cases where there is a spreading infection or facial cellulitis. When prescribing antibiotics, several principles should be applied—the indications should be evidence-based, microbiology should guide the choice of drug, a narrow spectrum drug should be the first choice, the dose should be appropriate for the type of infection, the duration of therapy should be as short as possible and monotherapy is preferred (Therapeutic Guidelines, 2012). The purpose of these principles is to minimise the possibility of resistant strains of bacteria developing and surviving. Many studies have reported increased resistance amongst bacteria following antibiotic use. One such study (Lewis, 2008) directly related to endodontic emergencies reported that the percentage of bacteria from acute dental abscesses

that were resistant to penicillin rose from 5% in 1998 to 55% in 2008. Over the same time period, the number of hospital admissions for severe dental infections doubled from 800 in 1998 to 1600 in 2008 (Lewis, 2008). Both these findings should be of serious concern to dental practitioners.

Unfortunately, antibiotics have been over-used and mis-used in the past with many dentists and endodontists inappropriately using them for pain management rather than reserving them for situations where they are truly indicated—that is, for infections with systemic manifestations, as outlined above. As an example, Whitten et al. (1996) reported that 51% of the general dentists and 25% of the endodontists that they surveyed would use antibiotics to treat acute irreversible pulpitis even though this condition is inflammatory in nature and not an infection. When there was chronic apical periodontitis present, 35% of both groups (general dentists, endodontists) would prescribe antibiotics and when the patient had acute apical periodontitis, the numbers increased to 62% of the general dentists and 67% of the endodontists. Similarly, for a chronic apical abscess, 62% of the general dentists and 29% of the endodontists would prescribe antibiotics and this increased to 95% and 97%, respectively, when there was an acute apical abscess. These large increases in clinicians who would prescribe antibiotics for acute conditions compared to chronic conditions are highly suggestive of them using the antibiotic for pain management rather than considering the nature of the condition and whether an antibiotic was actually indicated. Other studies have reported similar findings and inappropriate use of antibiotics (Abbott, 2000b; Mainjot et al., 2009).

If an antibiotic is required, then usually a beta-lactam penicillin is sufficient (Therapeutic Guidelines, 2012). These are narrow spectrum drugs that are effective against most bacteria associated with infected root canal systems and apical abscesses. Baumgartner & Xia (2003) reported that 85% of bacteria sampled from periapical abscesses were susceptible to phenoxymethyl penicillin which was only slightly lower than the 91% susceptible to amoxicillin. When amoxicillin was combined with clavulanic acid, 100% of the bacteria were susceptible. In a similar study where bacteria were sampled from root canals and periapical abscesses, Skucaite et al. (2010) reported that 81% of the bacteria were very susceptible to penicillin with another 17.4% having intermediate susceptibility—hence, a total of 98.4% were susceptible. This was only slightly less than the susceptibility to amoxicillin (84% very susceptible, 16.3% intermediate susceptibility—total 100%). In considering these results, it is important that clinicians understand that there is no need to eliminate every micro-organism that may be present in an infection since dental infections are poly-microbial and each species of bacteria relies on other species within the colony for their survival (Fabricius et al., 1982; Sundqvist, 1976, 1990). If a significant number of the organisms are removed by the dental treatment and the vast majority of any remaining organisms are destroyed by the antibiotic, then those that are resistant to the antibiotic are unlikely to survive without their co-colonising species being present to provide the various nutrients and by-products that are essential for their survival. Hence, the concept of using a narrow spectrum antibiotic is an extremely important aspect of antimicrobial stewardship with the aim to reduce the possibility of antibiotic resistance developing. Therefore, phenoxymethyl penicillin should be the first choice antibiotic for endodontic infections if an antibiotic is indicated as long as the patient does not have an allergy to this drug, and there are no other contra-indications to its use.

## OCCLUSAL REDUCTION

When a tooth has acute apical periodontitis or an acute apical abscess, there is inflammation present within the periradicular tissues—in particular, within the periapical tissues. In addition, when the pulp is removed from a tooth, there will be severance of the neuro-vascular bundle at the apical foramen, and this can exacerbate the already inflamed tissues (Holland, 1995; Vickers & Cousins, 2000). Furthermore, the mechanical procedures that are performed to remove the pulp and other debris from the root canal will exacerbate the periapical inflammation. This increased inflammation can cause the tooth to be painful to biting or chewing following treatment—since the pressure of biting and chewing is essentially being applied to the inflamed periradicular tissues. In order to reduce the effects of this increased inflammation, a simple occlusal adjustment to remove the tooth from contact in centric occlusion plus lateral and protrusive movements can help to reduce the postoperative discomfort. This was demonstrated by Rosenberg et al. (1998) who performed occlusal reduction in one group of teeth and compared the postoperative pain levels to a sham group where a rubber cup was used to simulate occlusal reduction and a control group whose occlusal surfaces were not altered in any way. The teeth with actual occlusal reduction had significantly less postoperative pain than both of the other groups whilst the sham (rubber cup) group had the same amount of pain as the control group. Ahmed et al. (2020) reported that the risk of moderate to severe pain 12 h after root canal instrumentation could be reduced by about 40% following occlusal reduction of mandibular premolars and molars with acute irreversible pulpitis and sensitivity to percussion (presumably, acute apical periodontitis).

They also reported that the overall risk of postoperative pain was reduced by 25% at 24 h after treatment. In contrast, Parirokh et al. (2013) did not find any difference in postoperative pain following occlusal reduction of teeth with acute irreversible pulpitis and only mild tenderness to percussion. The mild tenderness is likely to indicate that there was only mild inflammation of the periapical tissues and therefore the effects of the occlusal reduction were less noticeable.

Most teeth that need root canal treatment will also require a comprehensive restoration after the root canal treatment. This typically involves full occlusal coverage restorations that require considerable reduction of the occlusal surface. Hence, reducing the occlusal surface at the initial, or emergency, appointment when the tooth is being investigated is a logical approach. It helps to reduce the patient's postoperative pain and simply brings forward that part of the tooth reduction procedure that will need to be done later when the tooth is being prepared for a definitive restoration following completion of the root canal filling.

## FOLLOW-UP ONCE THE EMERGENCY SITUATION HAS RESOLVED

As with all dental procedures, follow-up of a patient who has had treatment for an endodontic emergency is essential for several reasons. Most importantly, the clinician needs to ensure that the emergency treatment has been effective in removing the inflammation and/or infection, and that the patient is free of symptoms and any other signs such as swelling.

In cases of acute reversible pulpitis where conservative pulp treatment has been provided, it is important to review the pulp status after 3–4 months to ensure the pulp has recovered and returned to a clinically normal condition. This implies that pulp sensibility tests and a periapical radiograph are required. It is not sufficient to simply rely on a lack of symptoms since the pulp may have necrosed rather than recovered. A necrotic pulp can be asymptomatic for some time before it becomes infected and subsequently causes apical periodontitis, and then there may be further time before the apical periodontitis becomes acute (Abbott, 2019).

In teeth that have had root canal treatment commenced, the treatment will need to be continued and completed. A definitive restoration will then be required. Such cases are usually straightforward once the emergency has been resolved.

If a patient returns with pain that is not resolving, or if it develops again, then the clinician must assess the situation again. In such cases, the principles of the three R's can be applied—that is, Review (and re-examine), Reassess, and Reconsider. The first "R" is to review the patient by taking a detailed history of what has happened following the initial treatment and by re-examining the tooth or teeth involved. In doing this, the diagnosis should be reassessed (the 2nd "R")—since the pain may now be a result of a different problem to what was present at the initial emergency examination. As examples, a tooth with acute reversible pulpitis may progress to have acute irreversible pulpitis, or a tooth with acute irreversible pulpitis and clinically normal periapical tissues may now have primary acute apical periodontitis as a result of removing the pulp at the initial appointment; there may also be periapical nerve sprouting and the early stages of neuropathic pain (see above). The clinician should not assume that the problem is the same as it was when the patient first presented with the emergency condition. Once the diagnosis has been reassessed, the management must be reconsidered (the 3rd "R"). This may involve further operative treatment of the tooth and/or the root canal system. Alternatively, non-invasive management may be indicated such as the use of systemic medication to control the symptoms. The decision about the management or treatment should be based on the new diagnosis. The same principles outlined above for the initial management of the emergency apply when the patient returns with further pain - the only difference when the patient returns is the diagnosis since the initial treatment has changed the overall situation within the tooth (i.e. pulp and/or root canal) and within the surrounding tissues (i.e. the periradicular, and especially the periapical, tissues).

## CONCLUSIONS

Endodontic emergencies are a common presentation to general dentists and specialist endodontists. The patients usually have significant pain that requires immediate and comprehensive management. They are generally not something that can be managed quickly and this poses several challenges to a busy dentist or endodontist. Endodontic emergencies require considerable time to manage them predictably so the patient and clinician can be confident that the pain will resolve very quickly. The initial management should follow the principles of the 3-D's—that is, Diagnosis, Definitive dental treatment and Drugs—in that sequence. If these principles are followed, then the presenting problem and the pain are highly likely to resolve to a point where further treatment can be continued when it is convenient for both the patient and the dentist or endodontist. Once the initial treatment has been provided, the principles of the 3R's should then

be followed—that is, Review, Reassess and Reconsider. In most cases, only the first "R" will be required as the pain will usually resolve if appropriate and comprehensive treatment has been provided. However, if the pain has continued, or subsequently returned at a later time, then reassessment of the new problem must be undertaken so that the management can be reconsidered in the light of the revised diagnosis.

## ETHICAL STATEMENT

There are no ethical considerations as this is a Review article discussing previously published articles. This review does not report any new experimentation involving humans or animals.

### AUTHOR CONTRIBUTIONS

Paul Abbott is the sole author of this Review article.

### CONFLICT OF INTEREST

The author declares that he occasionally acts as a Consultant or delivers lectures for OzDent Dental Products Australia for which he receives an Honorarium. He has no other commercial interest in any product manufactured or sold by OzDent Dental Products Australia.

### ORCID

*Paul V. Abbott* https://orcid.org/0000-0001-5727-4211

### REFERENCES

Abbott, P.V. (1994a) Analysis of a referral-based endodontic practice. Part 1. Demographic data and reasons for referral. *Journal of Endodontics*, 20, 93–96.

Abbott, P.V. (1994b) Factors associated with continuing pain in endodontics. *Australian Dental Journal*, 39, 157–161.

Abbott, P.V. (2000a) Endodontic emergencies. Part 1. *Endodontic Practice*, 3, 14–20.

Abbott, P.V. (2000b) Selective and intelligent use of antibiotics in endodontics. *Australian Endodontic Journal*, 26, 30–39.

Abbott, P.V. (2004a) Classification, diagnosis and clinical manifestations of apical periodontitis. *Endodontic Topics*, 8, 36–54.

Abbott, P.V. (2004b) Assessing restored teeth with pulp and periapical diseases for the presence of cracks, caries and marginal breakdown. *Australian Dental Journal*, 49, 33–39.

Abbott, P.V. (2011) Diagnosis and management planning for root-filled teeth with persisting or new apical pathosis. *Endodontic Topics*, 19, 1–21.

Abbott, P.V. (2016) Prevention and management of external inflammatory resorption following trauma to teeth. *Australian Dental Journal*, 61(Suppl. 1), 82–94.

Abbott, P.V. (2019) Examination and diagnosis of pulp, root canal, and periapical/periradicular conditions. In: Rotstein, I. & Ingle, J.I. (Eds.) *Ingle's endodontics 7*, 7th edition. Raleigh, NC: PMPH-USA Ltd., pp. 215–266.

Abbott, P.V., Heithersay, G.S. & Hume, W.R. (1988) The release and diffusion through human tooth roots *in vitro* of corticosteroid and tetracycline trace molecules from Ledermix paste. *Endodontics & Dental Traumatology*, 4, 55–62.

Abbott, P.V., Hume, W.R. & Heithersay, G.S. (1989) Barriers to diffusion of Ledermix paste in radicular dentine. *Endodontics & Dental Traumatology*, 5, 98–104.

Abbott, P.V. & Leow, N. (2009) Predictable management of cracked teeth with reversible pulpitis. *Australian Dental Journal*, 54, 306–315.

Abbott, P.V. & Levin, L. (2020) Introducing the revised IADT guidelines for the management of traumatic dental injuries. *Dental Traumatology*, 36, 307–308.

Abbott, P.V. & Yu, C. (2007) A clinical classification of the status of the pulp and the root canal system. *Australian Dental Journal*, 52(Suppl. 1), S17–S31.

Ahmed, Y.E., Emara, R.S., Sarhan, S.M., El Boghdadi, R.M., El-Bayoumi, M.A.A., El-Far, H.M.M. et al. (2020) Post-treatment endodontic pain following occlusal reduction in mandibular posterior teeth with pulpitis and sensitivity to percussion: a single center randomized controlled trial. *International Endodontic Journal*, 53, 1170–1180.

Aldhufairi, F. (2015) *Assessment of teeth referred for endodontic treatment*. (DClinDent Thesis). Perth, WA, Australia: The University of Western Australia.

American Association of Endodontists. (2016) Dispelling myths of root canals through education. Available from http://www.aae.org/about-aae/news-room/press-releases/dispelling-myths-of-root-canals-through-education.aspx [Accessed 15th September 2021]

American Association of Endodontists. (2020) *Glossary of endodontic terms*, 10th edition. Chicago, IL: American Association of Endodontists, p. 28.

Andreasen, J.O., Andreasen, F.M. & Andersson, L. (2019) *Textbook and Color Atlas of traumatic injuries to the teeth*, 5th edition. Copenhagen, Denmark: Wiley, pp. 648–717.

Arias, A., de la Macorra, J.C., Hidalgo, J.J. & Azabal, M. (2013) Predictive models of pain following root canal treatment: a prospective clinical study. *International Endodontic Journal*, 46, 784–793.

Athanassiadis, B., Abbott, P.V. & Walsh, L.J. (2007) The use of calcium hydroxide, antibiotics and biocides as antimicrobial medicaments in endodontics. *Australian Dental Journal*, 52(Suppl. 1), S64–S82.

Austin, R., Jones, K., Wright, D., Donaldson, N. & Gallagher, J.E. (2009) Use of the out-of-hours emergency dental service at two south-east London hospitals. *BMC Oral Health*, 19, 19–30.

Azim, A., Azim, K. & Abbott, P.V. (2017) Prevalence of interappointment endodontic flare-ups and host-related factors. *Clinical Oral Investigations*, 21, 889–894.

Bae, J., Kim, Y. & Choi, Y. (2011) Clinical characteristics of dental emergencies and prevalence of dental trauma at a university hospital emergency center in Korea. *Dental Traumatology*, 27, 374–378.

Barker, B.C.W. (1975) Conservative treatment of cariously exposed vital pulps in posterior teeth with a glucocorticosteroid-antibiotic compound. *Journal of the British Endodontic Society*, 8, 5–15.

Baumgartner, J. & Xia, T. (2003) Antibiotic susceptibility of bacteria associated with endodontic abscesses. *Journal of Endodontics*, 29, 44–47.

Bestall, S., Flynn, R., Charleson, G. & Abbott, P.V. (2020) Assessment of Australian dentists' treatment planning decisions based on diagnosis. *Journal of Endodontics*, 46, 483–489.

Biniecki, E., Foote, C., Gilbert, G. & Abbott, P. (2018) General medical practitioners' knowledge and management of oral and dental problems. *Australian Medical Journal*, 11, 390–396.

Bourguignon, C., Cohenca, N., Lauridsen, E., Flores, M.T., O'Connell, A.C., Day, P.F. et al. (2020) International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 1. Fractures and Luxations. *Dental Traumatology*, 36, 314–330.

Bryson, E., Levin, L., Banchs, F., Abbott, P. & Trope, M. (2002) Effect of immediate intracanal placement of Ledermix paste on healing of replanted dog teeth after extended dry times. *Dental Traumatology*, 18, 316–321.

Cao, Y., Bogen, G., Lim, J., Shon, W.-J. & Kang, M.K. (2016) Bioceramic materials and the changing concepts in vital pulp therapy. *Journal of the Californian Dental Association*, 44, 278–290.

Carrotte, P. (2004) Endodontics: part 3. Treatment of endodontic emergencies. *British Dental Journal*, 197, 299–305.

Chaffin, J. & Moss, D. (2008) Review of current U.S. Army dental emergency rates. *Military Medicine*, 173, 23–28.

Chandraweera, L., Goh, K., Lai-Tong, J., Newby, J. & Abbott, P.V. (2019) A survey of patients' perceptions about, and their experiences of, root canal treatment. *Australian Endodontic Journal*, 42, 225–232.

Chen, H., Teixira, F.B., Ritter, A.L., Levin, L. & Trope, M. (2008) The effect of intracanal anti-inflammatory medicaments on external root resorption of replanted dog teeth after extended extra-oral dry time. *Dental Traumatology*, 24, 74–78.

Chen, I., Clarke, S.E., Gosling, R., Hamainza, B., Killeen, G., Magill, A. et al. (2016) "Asymptomatic" malaria: a chronic and debilitating infection that should be treated. *PLoS Medicine*, 13, e1001942.

Cheng, Y., Cheung, G.S.P., Bian, Z. & Peng, B. (2006) Incidence and factors associated with endodontic inter-appointment emergency in a dental teaching hospital in China. *Journal of Dentistry*, 34, 516–521.

Clarke, N.G. (1971) The corticosteroid-antibiotic dressing as a capping for inflamed dental pulps. *Australian Dental Journal*, 16, 71–76.

Colthirst, P.M., Berg, R.G., DeNicolo, P. & Simecek, J.W. (2013) Operational cost analysis of dental emergencies for deployed US Army personnel during operation Iraqi freedom. *Military Medicine*, 178, 427–431.

Colthirst, P., DeNicolo, P., Will, R. & Simecek, J.W. (2012) Use of the dental disease non-battle injury encounter module to assess the emergency rate on an Army military installation within the United States. *Military Medicine*, 177, 1100–1104.

Cooper, S.A., Engel, J., Ladov, M., Precheur, H., Rosenheck, A. & Rauch, D. (1982) Analgesic efficacy of an ibuprofen-codeine combination. *Pharmacotherapy*, 2, 162–167.

Day, P., Flores, M.T., O'Connell, A., Abbott, P.V., Tsilingaridis, G., Fouad, A.F. et al. (2020) International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: injuries in the primary dentition. *Dental Traumatology*, 36, 343–359.

Derry, S., Karlin, S. & Moore, R.A. (2015) Single dose oral ibuprofen plus codeine for acute postoperative pain in adults. *The Cochrane Database of Systematic Reviews*, 2015, CD010107. https://doi.org/10.1002/14651858.CD010107.pub3

Dunn, W.J., Langsten, R.E., Flores, S. & Fandell, J.E. (2004) Dental emergency rates at two expeditionary medical support facilities supporting operations enduring and Iraqi Freedom. *Military Medicine*, 169, 510–514.

Ehrmann, E.H. (1965) The effect of triamcinolone with tetracycline on the dental pulp and periodontium. *The Journal of Prosthetic Dentistry*, 15, 144–152.

Ehrmann, E.H. (1981) Pulpotomies in traumatized and carious permanent teeth using corticosteroid antibiotic preparation. *International Endodontic Journal*, 14, 149–156.

Ehrmann, E.H., Messer, H.H. & Adams, G.G. (2003) The relationship of intracanal medicaments to postoperative pain in endodontics. *International Endodontic Journal*, 36, 868–875.

Eitner, S., Wichmann, M., Paulsen, A. & Holst, S. (2006) Dental anxiety—an epidemiological study on its clinical correlation and effects on oral health. *Journal of Oral Rehabilitation*, 33, 588–593.

Eleazer, P.D. & Eleazer, K.R. (1998) Flare-up rate in pulpally necrotic molars in one-visit versus two-visit endodontic treatment. *Journal of Endodontics*, 24, 614–616.

Fabricius, L., Dahlen, G., Öhman, A.E. & Möller, A.J.R. (1982) Predominant indigenous oral bacteria isolated form infected root canals after varied times of closure. *Scandinavian Journal of Dental Research*, 90, 134–144.

Farmakis, E.-T., Palamidakis, F.D., Skondra, F.G., Nikoloudaki, G. & Pantazis, N. (2016) Emergency care provided in a Greek dental school and analysis of the patients' demographic characteristics: a prospective study. *International Dental Journal*, 66, 280–286.

Fava, L.R.G. & Saunders, W.P. (1999) Calcium hydroxide pastes: classification and clinical indications. *International Endodontic Journal*, 32, 257–282.

Fouad, A.F., Abbott, P.V., Tsilingaridis, G., Cohenca, N., Lauridsen, E., Bourguignon, C. et al. (2020) International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 2. Avulsion of permanent teeth. *Dental Traumatology*, 36, 331–342.

Fuss, Z., Lustig, J., Katz, A. & Tamse, A. (1999) An evaluation of endodontically treated vertical root fractured teeth: impact of operative procedures. *Journal of Endodontics*, 27, 46–48.

Gibson, G., Blasberg, B. & Hill, S. (1993) A prospective survey of hospital ambulatory dental emergencies Part 1: patient and emergency characteristics. *Special Care in Dentistry*, 13, 61–65.

Guidelines, T. (2012) *Therapeutic guidelines oral and dental version 2*. Melbourne, Australia: Therapeutic Guidelines Ltd.

Gunepin, M., Derache, F., Ausset, I., Berlizot, P. & Simecek, J. (2011) The rate of dental emergencies in French Armed forces deployed to Afghanistan. *Military Medicine*, 176, 828–832.

Gutmann, J.L., Baumgartner, J.C., Gluskin, A.H., Hartwell, G.R. & Walton, R.E. (2009) Identify and define all diagnostic terms for periapical/periradicular health and disease states. *Journal of Endodontics*, 35, 1658–1674.

Hargreaves, K.M. & Kaiser, K. (2002) Development of new pain management strategies. *Journal of Dental Education*, 66, 113–121.

Harty, F.J. (1992) A survey of endodontic procedures performed by practitioners in limited practice. *International Endodontic Journal*, 25, 25–28.

Heithersay, G.S., Hume, W.R. & Abbott, P.V. (1990) Conventional root canal therapy, II: Intracanal medication. In: Harty, F.J.

(Ed.) *Endodontics in clinical practice*, 3rd edition, dental practitioner handbook no. 24. London, UK: Wright Butterworth Scientific, pp. 162–185.

Holland, G.R. (1995) Periapical neural changes after pulpectomy. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics*, 80, 726–734.

Holland, G.R. (1996) Steroids reduce the periapical inflammatory and neural changes after pulpectomy. *Journal of Endodontics*, 22, 455–458.

Hume, W.R. (1984a) Effect of eugenol on respiration and division in human pulp, mouse fibroblasts and liver cells. *Journal of Dental Research*, 63, 1262–1265.

Hume, W.R. (1984b) An analysis of the release and the diffusion through dentin of eugenol from zinc oxide-eugenol mixtures. *Journal of Dental Research*, 63, 881–884.

Hume, W.R. (1986) The pharmacologic and toxicological properties of zinc oxide-eugenol. *Journal of the American Dental Association*, 113, 789–791.

Hume, W.R. & Kenney, A.E. (1981) Release of 3H-triamcinolone from Ledermix. *Journal of Endodontics*, 7, 509–514.

Imura, N. & Zuolo, M.L. (1995) Factors associated with endodontic flare-ups: a prospective study. *International Endodontic Journal*, 28, 261–265.

Iqbal, M., Kurtz, E. & Kohli, M. (2009) Incidence and factors related to flare-ups in a graduate endodontic programme. *International Endodontic Journal*, 42, 99–104.

Jansson, L., Ehnevid, H., Lindskog, S. & Blomlöf, L. (1993) Development of periapical lesions. *Swedish Dental Journal*, 17, 85–93.

Jensen, A.L., Abbott, P.V. & Castro Salgado, J. (2007) Interim and temporary restoration of teeth during endodontic treatment. *Australian Dental Journal*, 52(Suppl. 1), S83–S99.

Kahn, A.A., Maixner, W. & Lim, P.F. (2014) Persistent pain after endodontic therapy. *Journal of the American Dental Association*, 145, 270–272.

Kaiser, K. & Byrne, B.E. (2011) Endodontic pharmacology. In: Hargreaves, K.M. & Cohen, S. (Eds.) *Pathways of the pulp*, 10th edition. St Louis, Missouri, USA: Mosby Elsevier, pp. 671–690.

Kaufman, A.Y., Solomonov, M., Galieva, D. & Abbott, P.V. (2014) Allergic reaction to Ledermix paste: a case report. *International Endodontic Journal*, 47, 1090–1097.

Kwang, S. & Abbott, P.V. (2012) Bacterial contamination of the fitting surfaces of restorations in teeth with infected root canal systems and apical periodontitis: a SEM study. *Australian Dental Journal*, 57, 421–428.

Law, A., Nixdorf, D., Aguirre, A., Reams, G., Tortomasi, A., Manne, B. et al. (2015) Predicting severe pain after root canal therapy in the National Dental PBRN. *Journal of Dental Research*, 94(3_suppl), 37S–43S.

Levin, L., Day, P., Hicks, M.L., O'Connell, A., Fouad, A.F., Bourguignon, C. et al. (2020) International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: general introduction. *Dental Traumatology*, 36(4), 309–313.

Lewis, M.A.O. (2008) Why we must reduce dental prescription of antibiotics: European Union Antibiotic Awareness Day. *British Dental Journal*, 205, 537–538.

Lynch, M.E. & Elgeneidy, A.K. (1996) The role of sympathetic activity in neuropathic orofacial pain. *Journal of Orofacial Pain*, 10, 297–305.

Mainjot, A., D'Hoore, W., Vanheusden, A. & Van Nieuwenhuysen, J.-P. (2009) Antibiotic prescribing in dental practice in Belgium. *International Endodontic Journal*, 42, 1112–1117.

Maneliene, R. & Balciuniene, I. (2004) Retrospection—analysis of patients treated by the endodontist. *Stomatologija*, 6, 59–62.

Manning, S.A. (1992) Profile of a specialist endodontic practice. *New Zealand Endodontic Journal*, 18, 21–23.

Mehlisch, D.R., Aspley, S., Daniels, S.E. & Bandy, D.P. (2010) Comparison of the analgesic efficacy of concurrent ibuprofen and paracetamol with ibuprofen or paracetamol alone in the management of moderate to severe acute postoperative dental pain in adolescents and adults: a randomized, double-blind, placebo-controlled, parallel-group, single-dose, two-center, modified factorial study. *Clinical Therapeutics*, 32, 882–895.

Menhinick, K.A., Gutmann, J.L., Regan, J.D., Taylor, S.E. & Buschang, P.H. (2004) The efficacy of pain control following nonsurgical root canal treatment using ibuprofen or a combination of ibuprofen and acetaminophen in a randomized, double-blind, placebo-controlled study. *International Endodontic Journal*, 37, 531–541.

Mor, C., Rotstein, I. & Friedman, S. (1992) Incidence of interappointment emergency associated with endodontic therapy. *Journal of Endodontics*, 18, 509–511.

Naidu, R.S., Boodoo, D., Percival, T. & Newton, J.T. (2005) Dental emergencies presenting to a university-based paediatric dentistry clinic in the West Indies. *International Journal of Paediatric Dentistry*, 15, 177–184.

Nair, P.N.R., Pajarola, G. & Schroeder, H. (1996) Types and incidence of human periapical lesions obtained with extracted teeth. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics*, 81, 93–102.

Ne, R.F., Witherspoon, D.E. & Gutmann, J.L. (1999) Tooth resorption. *Quintessence International*, 30, 9–25.

Negm, M.M. (2001) Intracanal use of a corticosteroid-antibiotic compound for the management of post-treatment endodontic pain. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics*, 4, 435–439.

Ng, Y.L., Glennon, J.P., Setchell, D.J. & Gulabivala, K. (2004) Prevalence of and factors affecting post-obturation pain in patients undergoing root canal treatment. *International Endodontic Journal*, 37, 381–391.

Ng, Y.L., Mann, V. & Gulabivala, K. (2010) Tooth survival following non-surgical root canal treatment: a systematic review of the literature. *International Endodontic Journal*, 43, 171–189.

Ng, Y.L., Mann, V. & Gulabivala, K. (2011) A prospective study of the factors affecting outcomes of non-surgical root canal treatment: part 2: tooth survival. *International Endodontic Journal*, 44, 610–625.

O'Keefe, E.M. (1976) Pain in endodontic therapy: preliminary study. *Journal of Endodontics*, 2, 315–319.

Parirokh, M., Rekabi, A.R., Ashouri, R., Nakhaee, N., Abbott, P.V. & Gorjestani, H. (2013) The effect of occlusal reduction on postoperative pain in teeth with irreversible pulpitis and mild tenderness to percussion. *Journal of Endodontics*, 39, 1–5.

Pennycook, A., Makeover, R., Brewer, A., Moulton, C. & Crawford, R. (1993) The management of dental problems presenting to an accident and emergency department. *Journal of the Royal Society of Medicine*, 86, 702–703.

Pierce, A. & Lindskog, S. (1987) The effect of an antibiotic/corticosteroid paste on inflammatory root resorption in vivo. *Oral Surgery Oral Medicine Oral Pathology*, 64, 216–220.

Riley, J.L., Gilbert, G.H. & Heft, M.W. (2005) Heft M (2005) Orofacial pain: patient satisfaction and delay of urgent care. *Public Health Reports*, 120, 140–149.

Rogers, M.J., Johnson, B.R., Remeikis, N.A. & BeGole, E.A. (1999) Comparison of effect of intracanal use of ketorolac tromethamine and dexamethasone with oral ibuprofen on post treatment endodontic pain. *Journal of Endodontics*, 25, 381–384.

Rosenberg, P.A., Babick, P.J., Schertzer, L. & Leung, A. (1998) The effect of occlusal reduction on pain after endodontic instrumentation. *Journal of Endodontics*, 24, 492–496.

Scarpelli, D.G., Burrows, W., Robbins, S.L. & Robbins, J.H. (2020) Human disease. Britannica, 1 Apr. 2020, www.britannica.com/science/human-disease/Classifications-of-diseases [Accessed 9 September 2021]

Schroeder, A. (1965) Corticosteroids in endodontics. *Journal of Oral Therapeutics and Pharmacology*, 21, 71–79.

Schroeder, A. (1968) Indirect capping and the treatment of deep carious lesions. *International Dental Journal*, 18, 381–391.

Schroeder, A. (1972) The problem of direct pulp capping. *Journal of the British Endodontic Society*, 6, 72–79.

Simecek, J.W. (2008) Estimation of non-preventable dental emergencies in U.S. Marine Corps Personnel. *Military Medicine*, 173, 1104–1107.

Sjögren, U., Hägglund, B., Sundqvist, G. & Wing, K. (1990) Factors affecting the long-term results of endodontic treatment. *Journal of Endodontics*, 16, 498–504.

Skucaite, N., Peciuliene, V., Vitkauskiene, A. & Machiulskiene, V. (2010) Susceptibility of endodontic pathogens to antibiotics in patients with symptomatic apical periodontitis. *Journal of Endodontics*, 36, 1611–1616.

Sundqvist, G. (1976) Bacteriological studies of necrotic dental pulps. Odontological Dissertations No. 7. Umeå University, Sweden.

Sundqvist, G. (1990) Endodontic microbiology. In: Spångberg, L.S.W. (Ed.) *Experimental endodontics*. Boca Raton, FL: CRC Press Inc., pp. 131–153.

Torabinejad, M., Kettering, J.D., McGraw, J.C., Cummings, R.R., Dwyer, T.G. & Tobias, T.S. (1988) Factors associated with endodontic inter-appointment emergencies of teeth with necrotic pulps. *Journal of Endodontics*, 14, 261–266.

Torres, C.R.G., Gomes, A.P.M., Balducci, I., Tiradentes, N., dos Santos, I.S.S., de Vasconcelos, R.A. et al. (2012) Patient attendance for emergency care in a Brazilian dental school. *World Journal of Dentistry*, 3, 11–17.

Touré, B., Faye, B., Kane, A.W., Lo, C.M., Niang, B. & Boucher, Y. (2011) Analysis of reasons for extraction of endodontically treated teeth: a prospective study. *Journal of Endodontics*, 37, 1512–1515.

Tronstad, L. (1991) *Clinical endodontics. A textbook*, 2nd edition. Stuttgart, Germany: Thieme, pp. 76–83.

Trope, M. (1998) Root resorption of dental and traumatic origin: classification based on etiology. *Practical Periodontics and Aesthetic Dentistry*, 10, 515–522.

Tsesis, I., Faivishevsky, V., Fuss, Z. & Zukerman, O. (2008) Flare-ups after endodontic treatment: a meta-analysis of literature. *Journal of Endodontics*, 34, 1177–1181.

Vickers, E.R. & Cousins, M.J. (2000) Neuropathic orofacial pain part 1–prevalence and pathophysiology. *Australian Endodontic Journal*, 26, 19–26.

Vire, D.E. (1991) Failure of endodontically treated teeth: classification and evaluation. *Journal of Endodontics*, 17, 338–342.

Walker, R.T. (1984) Emergency treatment—a review. *International Endodontic Journal*, 17, 29–35.

Walton, R. & Fouad, A. (1992) Endodontic interappointment flare-ups: a prospective study of incidence and related factors. *Journal of Endodontics*, 18, 172–177.

Watkins, C.A., Logan, H.L. & Kirchner, H.L. (2002) Anticipated and experienced pain associated with endodontic therapy. *Journal of the American Dental Association*, 133, 45–54.

Whitten, B.H., Gardiner, D.L., Jeansonne, B.G. & Lemon, R.R. (1996) Current trends in endodontic treatment: report of a national survey. *Journal of the American Dental Association*, 127, 1333–1341.

Widström, E., Pietilö, I., Piironen, P., Nilsson, B.O. & Savola, I. (1988) Analysis of patients utilizing emergency dental care in two Finnish cities. *Acta Odontologica Scandinavia*, 46, 105–112.

Wilmowsky, C., Kiesewetter, M.R. & Moest, T. (2014) Dental treatment on a German warship during a three-month deployment. *Journal of the Royal Army Medical Corps*, 160, 42–45.

Wolcott, J., Rossman, L. & Hasselgren, G. (2011) Management of endodontic emergencies. In: Hargreaves, K.M. & Cohen, S. (Eds.) *Pathways of the pulp*, 10th edition. St Louis, MO: Mosby Elsevier, pp. 40–48.

Wong, M. & Lytle, W.R. (1991) A comparison of anxiety levels associated with root canal therapy and oral surgery treatment. *Journal of Endodontics*, 17, 461–465.

York, A.K., Moss, D.L. & Martin, G. (2008) A longitudinal study of dental experience during the first four years of military experience. *Military Medicine*, 173, 38–41.

Zadik, Y., Sandler, V., Bechor, R. & Salehrabi, R. (2008) Analysis of factors related to extraction of endodontically treated teeth. *Oral Surgery Oral Medicine Oral Pathology Oral Radiology & Endodontics*, 106, e31–e35.

**How to cite this article:** Abbott, P.V. (2022) Present status and future directions: Managing endodontic emergencies. *International Endodontic Journal*, 55(Suppl. 3), 778–803. Available from: https://doi.org/10.1111/iej.13678