The role of intracanal medication in root canal treatment

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Summary
The role of intracanal medication as a root canal dressing is re-examined. In pulpectomy and some root canal treatments, where the root canal contains vital pulp tissue, it is doubtful whether a routine intracanal medicament is needed.

In infected root canals, intracanal medication has been advocated for many purposes. An intracanal medicament is used to:

(i) eliminate any remaining bacteria after canal instrumentation;
(ii) reduce inflammation of periapical tissues and pulp remnants;
(iii) render canal contents inert and neutralize tissue debris;
(iv) act as a barrier against leakage from the temporary filling;
(v) help to dry persistently wet canals.

However, most of the indications for intracanal medicaments are questionable.

Intracanal medicaments should only be used for root canal disinfection as part of controlled asepsis in infected root canals, and their role is secondary to cleaning and shaping of the root canal. Thorough canal debridement and adequate canal preparation are more pertinent, and their importance is emphasized. Bacteriological sampling may be necessary if a tooth does not respond to treatment, to help in the choice of intracanal medicament.

Keywords: bacteria, calcium hydroxide, medication, periapical inflammation, root canal treatment.

Introduction
The properties required of an ideal intracanal medicament in conventional root canal treatment are well documented (Martin 1979, Harty 1982, Grossman et al. 1988). To date, the ideal intracanal medicament has not been found. As a result, many different types of medicament have been used as root canal dressings (Spångberg 1985, Grossman et al. 1988, Heithersay et al. 1990).

Despite conflicting claims, no medicament appears superior to any other, and their usefulness has been questioned (Walton 1984, Seltzer 1988, Weine 1989). Some of the arguments for the use of intracanal medicaments are empirical but have persisted. Therefore it is time to re-evaluate the role and indications of intracanal medication in root canal treatment.

Vital teeth
The important role of bacteria in the pathogenesis of pulpal and periapical disease has been established by many studies (Kakehashi et al. 1965, Paterson 1976, Möller et al. 1981, Fabricius et al. 1982, Paterson & Watts 1987). In the absence of bacteria, there is no pulpal or periapical inflammatory reaction, and damaged tissues can heal (Möller et al. 1981, Fabricius et al. 1982). The severity of the inflammatory response of the pulp and periapical tissues can be related to the quantity of microorganisms present, the number of strains involved and the duration of exposure to the micro-organisms (Korzen et al. 1974).

As early as 1919, Henrici & Hartzell (1919) reported that the normal, vital pulp is sterile. When pulpectomies were performed under aseptic conditions on vital teeth in dogs, there was no, or only a mild, reaction in the periapical tissues, and bacteriological sampling after 1 and 2 months was negative (Allard & Strömberg 1979). Normal periapical tissues and an absence of inflammation were observed around teeth where root canal treatment was carried out under aseptic conditions and no intracanal medicament was used (Pitt Ford & Rowe 1989).

When a vital pulp has recently become exposed to the oral flora, it is usually only superficially invaded by bacteria (Paterson & Watts 1987). If pulpectomy is performed under controlled, aseptic conditions, the superficial bacterial flora and affected pulp will be removed, leaving a bacteria-free canal. Therefore, in root canal treatment of teeth where vital pulp tissue exists, it is
questionable whether an intracanal medicament is needed (Foreman & Barnes 1990).

Many intracanal medicaments are irritant and highly toxic (Massillomani el al. 1981, Spängberg 1982, Barnett et al. 1984). Of those that are biocompatible, it is always questionable whether the desirable properties may be extrapolated from the laboratory to the clinical situation (Walton 1984). Since intracanal medicaments have the potential to do more harm than good, they are not indicated in vital teeth, where a bacteria-free canal is achievable by controlled asepsis without the need for medicaments.

**Infected teeth**

In infected root canals, intracanal medication has been advocated for many reasons. An intracanal medicament is used to:

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(iv) act as a barrier against leakage from the temporary filling;
(v) help to dry persistently wet canals.

The use of intracanal medication for these purposes will now be examined.

(i) *As an antibacterial agent to eliminate any remaining bacteria in the root canal after canal instrumentation*

Antibacterial intracanal medication is used to eliminate any residual bacteria that have not been removed by canal preparation. During the period between appointments, bacteria surviving instrumentation and irrigation have been shown to increase rapidly in number in empty root canals (Byström & Sundqvist 1981, 1983, 1985). Controlled asepsis, including effective root canal disinfection, was shown to be important for successful healing of periapical lesions (Byström & Sundqvist 1987).

The antibacterial properties of intracanal medicaments have been well researched (Spånberg 1985), but the choice of medicament remains controversial. To justify the use of these medicaments, their antibacterial activity must be significantly greater than their cytotoxic effect (Messer & Feigal 1985). Antibacterial agents that are toxic and potent enough to eliminate bacteria may damage periapical tissues.

There are other problems to consider when using antibacterial medicaments. To be effective, the medicament must be in contact with the residual bacteria in sufficient concentration. Vapour-forming medicaments are considered to work at 'long-distance'. Unfortunately, the superior diffusibility of these medicaments may have adverse effects. The penetration of cytotoxic vapour-forming medicaments into the periodontium with undesirable consequences has been reported (Cambruzzi & Greenfeld 1983, Kopczyk et al. 1986). Formaldehyde- and phenol-type medicaments have the potential to be distributed widely in the body (Pashley et al. 1980, Block et al. 1983, Fager & Messer 1986, Hata et al. 1989). In addition, formaldehyde-type medicaments have mutagenic and carcinogenic potential (Lewis & Chestner 1981). Sipes & Binkley (1986) reviewed the use of formocresol in dentistry and concluded that there was little justification for its continued application in root canal therapy.

An antibacterial intracanal medicament must have a wide spectrum of activity and a reasonable duration of action to eliminate all the bacteria in the root canal. Since no intracanal medicament is active against the whole spectrum of root canal microbes, cocktails of polyantimicrobials were devised to overcome this shortcoming. However, combinations of antibacterial agents have not been shown to be active against the complex mixed flora that is found in root canals. Furthermore, the use of polyantibiotic medicaments is not recommended because of the possible risk of allergic reaction, sensitization and production of resistant bacterial strains (Seltzer 1988).

With regard to the duration of effectiveness of intracanal medicaments, the effectiveness of those based on phenol has been shown to decrease rapidly after insertion (Messer & Chen 1984, Koongtongkaew et al. 1988). Contact with tissue fluids will also render the medicament inactive within a short period of time. To overcome this problem, a controlled-release delivery system has been suggested (Tronstad et al. 1985), but the use of a quaternary ammonium compound in this delivery system was not found to give significantly better results (Barnett et al. 1986, Tronstad et al. 1988). Recently, the use of chlorhexidine in a controlled-release delivery system was proposed (Cervone 1990).

With the problems of selective activity, limited spectrum and short duration of effectiveness, there is the theoretical danger that bacteria not affected by the intracanal medicament will become selectively bred in the root.
canal. Instead of controlling the bacterial population, a recalcitrant infection could be created.

The choice of medicament should be judged with caution in view of these problems. The indiscriminate use of potent antibacterial agents should be discouraged, and every case should be decided individually. The choice of an intracanal medicament should be one that will support treatment and not delay healing. In infected root canals, an antibacterial intracanal medicament may be used as part of overall controlled sepsis, which should include the use of an antibacterial irrigant. Ørstavik et al. (1991) reported that, in the absence of an antibacterial irrigant, predictable asepsis was not achieved even when an antibacterial intracanal medicament was used. There were more bacteria to be killed by the intracanal medicament when an antibacterial irrigant was omitted (Cvek et al. 1976a, Byström & Sundqvist 1983, 1985). In a clinical study by Sjögren et al. (1991), half of the infected root canals were rendered bacteria-free when an antibacterial irrigant was used during root canal instrumentation. The bacteria that survived were eliminated by applying an antibacterial intracanal medicament.

Calcium hydroxide has emerged as a popular choice of intracanal medicament. It was shown to be superior to camphorated paramonochlorophenol and camphorated phenol in antibacterial activity in a clinical study of 65 single-rooted teeth with periapical lesions (Byström et al. 1985). When compared with 2% iodine-potassium iodide solution, calcium hydroxide-dressed root canals yielded fewer culture reversals (Safavi et al. 1985). However, Stevens & Grossman (1983) found that calcium hydroxide was inferior to camphorated chlorophenol in eliminating Enterococcus faecalis in experimentally infected root canals of cats. The failure of calcium hydroxide to eliminate enterococci effectively has also been reported by other workers (Byström et al. 1985, Haapasalo & Ørstavik 1987, Ørstavik & Haapasalo 1990, Safavi et al. 1990). This serves to highlight the potential problem and danger of relying upon intracanal medicaments, as no medicament is effective against all the bacteria found in the root canal. Calcium hydroxide, although suitable as an intracanal medicament, cannot be considered as a universal intracanal medicament (Reit & Dahlén 1988).

Intracanal medication does not 'sterilize' the root canal (Treanor & Goldman 1972), and is no substitute for thorough canal cleaning and adequate canal preparation. There are reports that, even with controlled asepsis, bacteria can become established outside the root canal in the periapical tissues (Byström et al. 1987, Tronstad et al. 1987, 1990a,b, Sjögren et al. 1988, 1990), which are inaccessible to conventional root canal treatment, and bacteria can even persist in filled root canals (Pitt Ford 1982).

Although bacteriological sampling of root canals may not be necessary routinely, it should be undertaken when a tooth is not responding to treatment. The information obtained from bacteriological sampling will enable a better choice of intracanal medicament, and the appropriate treatment can then be provided. Bacteriological sampling remains as an important adjunct in root canal treatment.

(ii) As an anti-inflammatory agent, to reduce inflammation of pulp remnants or periapical tissues, particularly when time does not permit complete removal of the pulp contents

The reduction of inflammation is primarily aimed at alleviation of pain and any acute exacerbation. Unfortunately, the use of intracanal medication has been found by many investigators to have no effect on interappointment and post-treatment pain (Maddox et al. 1977, Harrison et al. 1979, 1981, 1983, Kleier & Mullaney 1980, Torabinejad et al. 1988). The incidence of postoperative 'flare-ups' was also found to be independent of the intracanal medication used (Trope 1990).

However, the incidence of postoperative pain was found to be related to the preoperative state of the pulp and the presence of preoperative pain (Genet et al. 1987). The incidence of 'flare-ups' has also been reported to be related to the state of the pulp (Barnett & Tronstad 1989) and radiographic signs of apical periodontitis (Trope 1990). It was shown that, even with time limitations, when vital pulp contents were not completely removed, the removal of caries, emergency pulpotomy and sealing of the cavity were reliable means of relieving pain (Hasselgren & Reit 1989).

A treatment regime derived from Buckley's formocresol technique has recommended medication of non-vital teeth at the first appointment, rather than complete canal preparation, on the premise that it produced fewer acute exacerbations (Pearson & Goldman 1964, 1966). However, Balaban et al. (1984) found that such a premedication technique did not decrease the likelihood of acute exacerbations, and was therefore ineffective.

Topical corticosteroids have been used specifically as anti-inflammatory agents in root canal therapy.
An intracanal solution of corticosteroid has been claimed to be an effective anodyne in inflamed teeth, provided that the teeth are not infected (Moskow et al. 1984). A clinical trial of intracanal corticosteroid found that it was only effective in reducing the incidence of postoperative pain in teeth with vital pulps, but was ineffective when the pulp was necrotic (Chance et al. 1987). Therefore, corticosteroids cannot be advocated as a medicament in teeth with infected or necrotic pulps. The application of corticosteroid preparations in whatever form and by whatever route may lead to changes in the regulation of endogenous steroid secretion (Hartmann 1981), and it is not impossible that corticosteroids may cause unwanted systemic side-effects.

Some corticosteroids are combined with antibiotics to help combat any infection. The pharmacodynamics of such combinations are dependent on several factors, including the size of the apical foramen and the presence or absence of a smear layer (Abbott et al. 1988, 1989a). The range and duration of antimicrobial activity of a combined preparation may be limited (Abbott et al. 1988, 1990). The periapical tissue response to such a preparation may be favourable when the root canal contains vital, uninfected pulp tissue (Barker & Lockett 1972). However, in infected root canals, the periapical reaction is unpredictable and less favourable, and this combination cannot be relied upon to eradicate bacteria from infected root canals (Barker & Lockett 1971).

Trope (1990) compared the effect of formocresol, a corticosteroid/antibiotic formulation and calcium hydroxide on the incidence of post-instrumentation 'flare-ups', and found no significant difference in the 'flare-up' rate between the three intracanal medicaments. Watts & Paterson (1988) found that the topical application of corticosteroid to the exposed pulp enhanced bacterial dissemination, and they warned against the use of these anti-inflammatory compounds as root canal dressings. There was even a suggestion that ineffectively removed petroleum and water-based corticosteroid medicaments could affect the apical seal of root canals obturated with gutta-percha and zinc oxide–eugenol sealer (Harris & Wendt 1987). On the other hand, in teeth that had been dressed with calcium hydroxide and then obturated, there was significantly less dye leakage compared with unmedicated controls, but the improvement in the apical seal might be temporary (Porkaew et al. 1990).

A corticosteroid-antibiotic mixed with calcium hydroxide has also been advocated as an intracanal medicament (Heithersay et al. 1990). The mixing of these two medicaments altered the release and diffusion of the active components of the corticosteroid-antibiotic (Abbott et al. 1989b), but did not decrease their individual antibacterial potency when tested on Lactobacillus casei and Streptococcus mutans (Taylor et al. 1989). However, when tested on Streptococcus sanguis and Staphylococcus aureus, it was reported that the addition of calcium hydroxide to the corticosteroid-antibiotic decreased their individual antibacterial effectiveness (Seow 1990). It was concluded that the combination of two medicaments did not produce any additive or synergistic effects, and should not be used in combination, since the antibacterial activity of the individual components may be affected. The contrasting results obtained by these two studies (Taylor et al. 1989, Seow 1990) highlight the dissimilar response of different bacteria to antibacterial agents. The infected root canal contains a complex mixed flora, and combinations of antibacterial agents may not produce the desired synergism to eliminate all the bacteria in a root canal. It is therefore a fallacy to rely on antibacterial agents for this purpose.

The suppression of inflammation is also intended to circumvent anaesthetic difficulties with acutely inflamed teeth. Formocresol and corticosteroids have been used to this end. Unfortunately, the effectiveness of formocresol remains untested in controlled clinical studies (Walton 1984). Formocresol is in itself very cytotoxic (Jeng et al. 1987) and adverse reactions have been reported (Cambru & Greenfeld 1983, Kopczyk et al. 1986). The use of paraformaldehyde devitalizing paste in a case where there was difficulty in obtaining adequate anaesthesia has resulted in complications (Tal et al. 1978).

The difficulties encountered with an acutely inflamed tooth are often due to failure to obtain adequate anaesthesia (Fluery 1990). Some studies have suggested that inflammation affected satisfactory anaesthesia (Najjar 1977, Brown 1981, Rood & Pateromichelakis 1981, Wallace et al. 1985). Inadequate anaesthesia may be better managed by employing supplementary anaesthetic techniques (Malamed 1986, Dumsha & Gutmann 1988), instead of hoping to calm the inflamed tooth by leaving the cause of the inflammation and applying medicaments that do not achieve the desired effect. Once adequate anaesthesia has been obtained, thorough canal cleansing can take place. This removes the cause of the inflammation and allows the periapical reaction to resolve, thereby decreasing the total treatment time.
Intracanal medicaments have been used for chemical fixation of tissue remnants remaining after canal preparation. The concept of using chemical fixatives was the treatment modality when endodontic instruments and techniques were less well developed.

By their very action, fixatives are self-limiting and tissue penetration is limited (Simon & Van Mullem 1978). A wide surface area of contact and a sufficient amount of intracanal medicament is necessary for effective fixation. The tags of pulpal tissues in the anatomical ramifications of the root canal are not easily accessible, and may not be affected by the limited action of intracanal fixatives. Formaldehyde-based medicaments, for example, are poor fixatives in the amounts used as intracanal medicaments (Wemes et al. 1982a), and may irritate periapical tissues (Simon et al. 1979, Wemes et al. 1982b). Bone sequestration and dentine resorption following the use of a formaldehyde-containing preparation have been reported (Tal et al. 1978). In paediatric dentistry, where fixatives are still commonly utilized for pulpotomies, their continuing use has aroused concern (Judd & Kenny 1987), not least because of their mutagenic and carcinogenic potential.

Fixed necrotic tissues have also been found to be more resistant to dissolution by sodium hypochlorite solution, used as an irrigant (Thé 1979). In addition, questions have been raised as to whether fixed tissues are inert. Many studies on experimental animals have shown the irritancy of fixed tissues (Thoden van Welzen & Feltkamp-Vroom 1977, Thoden van Welzen & van den Hoof 1977, Wesselink et al. 1977, Makkes et al. 1978a,b,c,d, Brian et al. 1980). Intracanal fixatives can act as haptens and, when combined with pulp tissue, may act as an immunogen. Nishida et al. (1971) and Block et al. (1977, 1978a,b, 1979, 1981) have demonstrated immunological responses to pulp tissue of experimental animals, altered by various intracanal medicaments. Fixatives can also provoke allergic reactions in presensitized animals (Van Mullem et al. 1983), so the use of intracanal fixatives should be discontinued since, in clinical practice, previous sensitization cannot be ruled out. Some studies have suggested that sensitization via the root canal occurs only rarely (Rölling & Thulin 1976, Longwill et al. 1982), but this does not mean that a relationship does not exist (Wu et al. 1989). Recent studies have explored the immunological response to modified pulp tissues and serum albumins (Shinoda et al. 1986a,b). The potential toxicity and immunological reactions to altered pulp tissue remain as theoretical risks.

As a barrier against leakage or breakdown of the temporary filling

Intracanal medicaments are intended to act as a second front to prevent invasion of oral micro-organisms into the root canal in the event of leakage or breakdown of the temporary filling. To prevent canal contamination, a substantial amount of intracanal medicament will be required. This is because the percolation of oral fluids through a defective temporary filling will dilute and neutralize the medicament. Most intracanal medicaments, as they are toxic, are used sparingly, and so it is inconceivable that the limited amount of medicament used can prevent the ingress of micro-organisms through an inadequate temporary filling. In addition, the effectiveness of a phenol-type medicament, for example, decreases rapidly, so it is a poor barrier against canal contamination.

In order to prevent canal contamination, attention to provision of a bacteria-tight temporary filling is more appropriate than dependence on the intracanal medicament. After all, if a canal becomes contaminated, it will still need to be re-cleaned and re-disinfected, regardless of the presence of an intracanal medicament. The integrity of the temporary filling is vital during all stages of root canal treatment. Even with completed root fillings, coronal leakage may jeopardize the success of root canal treatment (Swanson & Madison 1987, Madison & Wilcox 1988, Torabinejad et al. 1990). Therefore, it is important to ensure that the temporary filling and the existing coronal restoration of the tooth under treatment are sound and caries free. The basic principle of caries control also applies to root canal access cavity preparation, so caries must be removed. If a filling or crown is carious, deficient or leaky, it must be replaced as appropriate. It is pointless to place a good temporary filling over an inadequate coronal restoration that allows leakage.

There are many reports on the sealing ability of temporary filling materials (Friedman et al. 1986, Teplitzky & Meimaris 1988, Anderson et al. 1989, Bobotis et al. 1989, Noguera & McDonald 1990). Conflicting results have emerged because of differing experimental protocols. Certain intracanal medicaments have been found to be incompatible with temporary filling materials. Formocresol, camphorated parachlorophenol and metacresyl-acetate have a softening effect on temporary filling
Intracanal medicaments may affect the seal of temporary filling materials (Blaney et al. 1981, Keller et al. 1981). In a brief report, endodontic medicaments were also found to have a softening effect on resin filling materials (Lorencki & Astiz 1981).

Since prevention of microbial microleakage into the root canal is the desired property of a temporary restoration, a material that possesses antibacterial properties would be appropriate. Most restorative materials possess some antibacterial properties when freshly mixed (Tobias et al. 1985, 1988). However, there is considerable variation in the antibacterial properties of different materials and between different formulations of similar materials. A good choice for a temporary restoration would be a zinc oxide–eugenol cement, because of its prolonged antibacterial activity (Tobias et al. 1985). In an early study, Möller (1966) found that a bacteria-tight seal could be achieved with zinc oxide cements. The antibacterial effect of zinc oxide–eugenol cement prevents colonization of bacteria, and is effective in preventing bacterial microleakage (Browne & Tobias 1986, Hume 1988). The level of release of eugenol from zinc oxide–eugenol mixtures by progressive hydrolysis of the cement surface is sufficient to kill oral micro-organisms. When testing the biocompatibility of dental filling materials, zinc oxide–eugenol cements have been used to surface seal the test cavities to prevent bacteria from entering the restoration/dentine interface (Brännström & Vojinovic 1976, Brännström et al. 1979, Browne & Tobias 1986, Cox 1987). In teeth that had been rendered bacteria-free and sealed with a zinc-oxide eugenol temporary cement, no bacteria could be recovered when resampled 1–5 weeks later, even in the absence of an intracanal medicament (Sjögren et al. 1991). Therefore the prevention of canal contamination is best tackled by ensuring a good temporary filling with a zinc oxide–eugenol cement. The use of intracanal medication to prevent canal recontamination is ineffective.

(v) To control persistent abscesses and the persistent ‘weeping/wet’ canals

A persistently ‘weeping/wet’ canal results from seepage of apical fluids into the root canal. Calcium hydroxide is widely used as an intracanal medicament to control this continuous exudation (Heithersay 1975, Martin & Crabb 1977). The elimination of exudation facilitates permanent filling of the root canal. The exact mechanism of action of calcium hydroxide is unknown, but it may be due to its antibacterial properties. Another possible explanation is that the release of hydroxyl ions and the pH shift in the process of alkaliization of calcium hydroxide (Staehle et al. 1989) provides an environment that favours repair and calcification (Tronstad et al. 1981). Other suggested mechanisms of action include the contraction of capillaries (Heithersay 1975), the formation of a fibrous barrier (Rasmussen & Mjör 1971), or formation of an apical plug by calcium hydroxide. This material also has the ability to dissolve tissues and eliminate necrotic debris (Cvek et al. 1976b). The tissue-dissolving effect of sodium hypochlorite was shown to be enhanced when tissues were pretreated with calcium hydroxide paste (Hasselgren et al. 1988), but calcium hydroxide solution used alone as an irrigant was an ineffective solvent of pulp tissue (Morgan et al. 1991).

The actual mechanism of action of calcium hydroxide is still not fully understood, but it possesses many of the properties required of an ideal intracanal medicament. Calcium hydroxide has good antibacterial activity, but its duration of action is short. It is not equally effective against all the bacteria that are found in the root canal, and it is not a universal intracanal medicament (Reit & Dahlén 1988). The biochemical actions, dental formulations and uses of calcium hydroxide have been reviewed by Foreman & Barnes (1990).

Conclusions

After reviewing the indications for use of intracanal medicaments, it can be concluded that most of these indications are questionable. It is doubtful whether an intracanal medicament is routinely needed in root canal treatment of teeth containing vital pulp tissue. When the root canal is extensively infected and when interappointment time periods are long, there is merit in using an antibacterial intracanal medicament as part of controlled asepsis. However, this must be combined with an antibacterial irrigant, thorough cleaning and adequate shaping of the root canal. Intracanal medicaments play a secondary role, and should not be used as an alternative to thorough cleaning and adequate shaping of the root canal.

A good temporary filling should prevent canal recontamination instead of the need to use an intracanal medicament. Zinc oxide–eugenol temporary restorative materials have a proven record of preventing bacterial microleakage, and will provide the required bacteria-tight coronal seal.

Postoperative pain is better controlled by analgesics than by potent intracanal medicaments. Severe, acute infections are better managed with systemic antibiotics.
The use of topical corticosteroids is debatable. Intracanal medicaments have the potential to do more harm than good.

Intracanal medicaments with fixative action should not be used as dressings, as they are unlikely to be effective and there are questions regarding the safety of using them.

Calcium hydroxide has much to commend it as a root canal dressing for drying wet canals, and as an anti-bacterial intracanal medicament. However, it is not equally effective against all the bacteria that are found in the root canal. It is not a panacea, and its injudicious use should be avoided.

When a tooth does not respond to root canal treatment, bacteriological sampling may be needed to determine the bacteria present in the root canal system. This will aid the choice of intracanal medicament and monitoring of the progress of treatment. Every case should be judged on the advantages and disadvantages of using an intracanal medicament. After all, what is removed from the root canal is of greater significance with regard to the success of root canal treatment than what is placed in the root canal system.

References


