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Intracanal Medicaments and Root Canal Sealers in Contemporary Endodontics: From Ideal Requirements to Evidence-Based Selection – A Comprehensive Narrative Review

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ABSTRACT

Background: Successful root canal treatment depends on elimination of intraradicular infection and on a durable three-dimensional seal. Intracanal medicaments (ICMs) and root canal sealers are two adjuncts whose selection remains inconsistent in practice.

Objective: To review the properties, mechanisms, clinical performance and limitations of commonly used ICMs (calcium hydroxide, Ledermix and related agents) and obturation sealers (zinc oxide–eugenol, epoxy resin and calcium silicate/bioceramic), and to rank them against ideal requirements.

Methods: A narrative review of laboratory, animal and clinical literature, with emphasis on systematic reviews and randomised or prospective clinical studies, was performed.

Results: Calcium hydroxide remains the reference ICM because of its availability, biocompatibility and alkaline antimicrobial action, yet culture-based syntheses show it does not reliably render canals bacteria-free. Ledermix, a corticosteroid–tetracycline paste, is valuable for controlling inflammation, pain and inflammatory resorption, but is not a long-term antimicrobial dressing and carries a risk of discolouration. Among sealers, epoxy resin (AH Plus) retains its status as the benchmark for physicochemical stability, whereas premixed bioceramic sealers offer bioactivity, hydrophilicity and simplified single-cone protocols, with clinical outcomes that are broadly comparable to resin sealers and possibly less postoperative pain.

Conclusions: No ICM or sealer is ideal. Selection should be guided by the clinical scenario, the diagnosis and the available evidence, with disinfection quality and coronal restoration remaining the principal determinants of outcome.

Keywords: intracanal medicament; calcium hydroxide; Ledermix; root canal sealer; bioceramic sealer; obturation

1. Introduction

Apical periodontitis is an infectious disease, and bacteria that persist after chemo-mechanical preparation are a principal cause of treatment failure [1]. Outcome is influenced by a range of pre-, intra- and post-operative factors, among which the quality of disinfection, the quality of the root filling and the quality of the coronal restoration are the most modifiable [2,3]. Two materials sit at either end of the treatment sequence: the intracanal medicament, placed between appointments to supplement disinfection, and the sealer, which fills the irregularities that gutta-percha alone cannot [4–6].

Intracanal medicaments are intended to eliminate residual micro-organisms, reduce inflammation and pain, neutralise tissue remnants and act as a physical barrier against re-contamination [4,5]. Obturation sealers are expected to bond the core material to dentine, fill voids and accessory anatomy, and remain stable and biocompatible for the life of the tooth [6]. Over the past decade, premixed calcium silicate ("bioceramic") sealers have challenged the long-held position of epoxy resin sealers, and the clinical consequences of this shift are still being clarified [7].

Despite a large body of literature, clinicians are presented with a confusing array of products, and individual claims are often drawn from laboratory studies of limited clinical relevance. **The objective of this review** is to describe, in order from ideal requirements to the best currently available options, the properties, mechanisms and clinical evidence for commonly used intracanal medicaments (with emphasis on calcium hydroxide and Ledermix) and obturation sealers (with emphasis on epoxy resin and bioceramic materials), and to offer a practical framework for selection.

2. Materials and Methods

Study design. This is a narrative, evidence-informed review. It is not a registered systematic review and no meta-analysis was undertaken by the author; pooled estimates quoted are those reported by the cited systematic reviews.

Search strategy. Literature was identified in October 2026 through electronic searches of PubMed/MEDLINE-indexed journals, publisher databases and Google Scholar. Search terms combined "intracanal medicament", "intracanal dressing", "calcium hydroxide", "Ledermix", "triamcinolone", "demeclocycline", "triple antibiotic paste", "root canal sealer", "epoxy resin sealer", "AH Plus", "calcium silicate sealer" and "bioceramic sealer". Reference lists of key reviews were hand-searched.

Eligibility and selection. English-language systematic reviews, randomised and non-randomised clinical studies, animal studies and laboratory studies addressing antimicrobial efficacy, anti-inflammatory action, physicochemical properties, biocompatibility, sealing ability and clinical outcome were considered. Seminal historical studies were included where they established a mechanism or concept. Evidence was weighted by design, with systematic reviews and clinical trials given priority over in vitro reports.

Synthesis. Findings were grouped by material, appraised against the ideal requirements for each category, and summarised narratively and in comparative tables.

Ethical considerations. This work is a review of published literature and involved no human participants, animal experimentation or patient data. Ethical approval and informed consent were therefore not required.

3. Results and Discussion

1. Ideal requirements

An ideal intracanal medicament should be broadly antimicrobial (including against *Enterococcus faecalis* and *Candida albicans*), able to diffuse through dentinal tubules, effective over days to weeks, biocompatible, non-staining, inexpensive, easy to place and easy to remove, and should neutralise bacterial endotoxin [3–5]. No current medicament meets all of these criteria.

An ideal sealer should adhere to dentine and the core material, provide a hermetic and dimensionally stable seal, be radiopaque, non-staining, insoluble in tissue fluids, bacteriostatic, non-mutagenic, biocompatible, and retrievable should retreatment be needed [6,8]. Again, no available sealer fulfils all criteria; current materials are best viewed as compromises with different strengths [6,7].

2. Calcium hydroxide

Mechanism of action. Calcium hydroxide dissociates into calcium and hydroxyl ions. The resulting high pH (around 12.5) damages bacterial cytoplasmic membranes, proteins and DNA, and the paste also hydrolyses bacterial lipopolysaccharide and promotes hard-tissue repair [9,10]. Its action is contact- and diffusion-dependent, and dentine buffers its alkalinity, which limits penetration [9,10].

Antimicrobial efficacy. Calcium hydroxide proved more reliable than camphorated phenols in classical clinical work [11] and was effective as a short-term dressing in canals with a documented infection [12]. However, culture-based syntheses temper this picture. The meta-analysis by Sathorn et al., covering eight studies and 257 cases, reported considerable heterogeneity and a pooled risk difference of –21% (95% CI –47% to 6%), and concluded that calcium hydroxide has limited effectiveness in eliminating bacteria from infected canals [5]. Related evidence-based analyses have reached comparable conclusions [13,14]. *E. faecalis* and *C. albicans* tolerate the alkaline environment, partly through proton-pump activity and dentine buffering [9]. Comprehensive reviews of in vitro and in vivo work indicate that antimicrobial effect is improved when calcium hydroxide is combined with other agents [15,16], and chlorhexidine has been explored for this purpose [17].

Clinical use and limitations. Calcium hydroxide is the reference medicament for multi-visit treatment of necrotic teeth with apical periodontitis, and a one-week dressing is generally regarded as adequate. It does not reliably control inflammatory pain, and the data on whether intracanal medicaments reduce inter-appointment pain are inconsistent [18]. Evidence does not show that completing treatment in one visit yields clearly better periapical healing than treatment over two visits, which supports the continued use of a dressing when a case cannot be completed at one sitting [19,20]. Long-term use in immature teeth has been associated with a greater risk of cervical root fracture [21], and experimental data show reduction in dentine fracture strength after prolonged exposure [22]. Residual paste can also interfere with sealer penetration and adhesion if not completely removed [4,5].

3. Ledermix and corticosteroid–antibiotic pastes

Composition and release. Ledermix paste combines a corticosteroid (triamcinolone acetonide, approximately 1%) and a tetracycline (demeclocycline hydrochloride, approximately 3%) in a polyethylene-glycol base. Both components diffuse through dentinal tubules and cementum to reach periradicular tissues, with release highest in the first days and declining thereafter [23,24]. This makes the paste suitable as a short-term dressing rather than a sustained antimicrobial.

Anti-inflammatory and anti-resorptive effects. The principal value of Ledermix is control of inflammation. In experimental replantation models, immediate intracanal Ledermix reduced inflammatory root resorption and improved healing [25,26]. In a dog study of teeth replanted after 60 minutes of dry time, favourable healing was 75.8% with Ledermix, 69.8% with triamcinolone alone and 52.4% with demeclocycline alone, compared with none in

the gutta-percha and sealer control. This indicates that the corticosteroid component is largely responsible for the benefit [27]. Clinical studies of postoperative pain after root canal treatment have reported favourable pain outcomes with corticosteroid-containing dressings [18].

Limitations. Ledermix has limited antimicrobial potency as a stand-alone dressing and the tetracycline component can cause tooth discolouration, particularly with prolonged placement [27,28]. Mixing it with calcium hydroxide is sometimes advocated to extend its antimicrobial range, although this alters release characteristics of the active components [5]. It is therefore best reserved for symptomatic teeth, traumatic injuries with risk of resorption, and short inter-appointment periods.

4. Other medicaments

Chlorhexidine gel offers broad antimicrobial activity and substantivity but does not dissolve necrotic tissue [17]. Triple antibiotic paste (ciprofloxacin, metronidazole, minocycline) is potent against infected dentine [29] and is widely used in regenerative endodontics [30], but its minocycline component is associated with crown discolouration, which has led to modified formulations [28,30]. These agents are generally reserved for specific indications rather than routine disinfection.

Table 1. Comparison of commonly used intracanal medicaments

Property	Calcium hydroxide	Ledermix	Triple antibiotic paste
Main action	Alkaline, broad antimicrobial	Anti-inflammatory plus antibiotic	Potent polymicrobial antibiosis
Duration	Days to weeks	Short (first days)	Days to weeks
Major strength	Biocompatible, inexpensive, well documented	Inflammation and resorption control	Regenerative protocols, resistant infections
Major limitation	Limited bacterial elimination; <i>E. faecalis</i> tolerance	Discolouration; limited antimicrobial effect	Discolouration; resistance concerns
Evidence base	Extensive	Moderate (largely experimental and trauma)	Moderate (in vitro and regenerative)

5. Root canal sealers: from ideal to better

5.1 Zinc oxide–eugenol (ZOE).

Zinc oxide–eugenol sealers have a long clinical history, good radiopacity and antibacterial effect, but they are soluble in tissue fluids and release eugenol, which is cytotoxic and may cause tissue irritation [6]. They are considered to be inferior to modern materials for long-term seal [6,7].

5.2 Epoxy resin sealers (AH Plus).

AH Plus has been widely accepted as the benchmark sealer because of its low solubility, good flow, adhesion to dentine and long track record [31,32]. Disadvantages include limited bioactivity, hydrophobicity (it prefers a dry canal), and early cytotoxicity of freshly mixed material that declines as it sets [33]. Compared with powder–liquid and premixed calcium silicate sealers, epoxy resin shows lower solubility and favourable dimensional stability [31,32].

5.3 Calcium silicate (bioceramic) sealers.

These are hydraulic materials derived from the chemistry of mineral trioxide aggregate [34]. On setting they release calcium ions and generate an alkaline pH, and are hydrophilic, so they set using canal moisture [35,36]. This allows premixed, ready-to-use formulations and single-cone protocols with hydraulic condensation [7,37]. Reported benefits include biocompatibility, apatite formation and a favourable cellular response [38,39]. Limitations include higher solubility and water sorption than epoxy resin, and a literature review concluded that despite meeting ISO physical requirements, they had not clearly overcome resin sealers in actual practice [32,40]. Antibacterial activity of many sealers is greatest in the freshly mixed state and diminishes once set [41].

5.4 Clinical evidence.

Early clinical series using a bioceramic sealer in single-cone obturation reported high healing rates [42], and a non-randomised trial of a calcium silicate sealer reported periapical healing comparable to conventional filling [43]. The most comprehensive synthesis to date, a systematic review and meta-analysis of premixed bioceramic versus standard sealers, reported similar survival and success outcomes despite heterogeneity in protocols and operator experience [7]. For postoperative pain, a systematic review with meta-analysis of randomised trials found less pain at 24 and 48 hours with bioceramic than resin-based sealer techniques [44]. Retreatment of bioceramic-filled canals is feasible in laboratory studies, but residual material is a recognised concern [40,45].

5.5 Technique.

Sealer choice interacts with obturation technique. Epoxy resin sealers are well suited to warm vertical compaction and carrier-based techniques, whereas premixed calcium silicate sealers are suited to single-cone and hydraulic condensation approaches, although warm techniques have been described [37,46]. Overheating and the film thickness of the sealer affect properties and should be considered [46].

Table 2. Comparison of root canal sealer categories

Property	Zinc oxide–eugenol	Epoxy resin (AH Plus)	Calcium silicate / bioceramic
Solubility	High	Low	Higher than epoxy resin
Bioactivity	Minimal	Minimal	Present (ion release, apatite formation)
Biocompatibility	Eugenol cytotoxicity	Early cytotoxicity, improves on setting	Favourable
Moisture tolerance	Moderate	Hydrophobic	Hydrophilic (uses canal moisture)
Technique	Cold or warm	Cold, warm, carrier-based	Single-cone, hydraulic condensation, warm variants
Clinical evidence	Long history, outdated	Extensive, benchmark	Growing; outcomes comparable to resin

6. Clinical synthesis: ranking from ideal to better

Taken together, the evidence supports the following practical positions. For intracanal medication, calcium hydroxide remains the first-line agent in necrotic teeth with apical periodontitis that require multiple visits, with Ledermix or another corticosteroid–antibiotic paste reserved for acute symptomatic cases and for resorption risk after trauma, and with a combination or alternative agent chosen only for a specific indication. For sealers, epoxy resin remains the benchmark for physical stability, whereas bioceramic sealers are a reasonable and arguably preferable option where bioactivity, moisture tolerance, simplified technique or lower postoperative pain are priorities. The distinction between the two sealer categories should not be overstated, because clinical outcomes appear largely similar [7].

7. Limitations of the evidence and future directions

Many claims about medicaments and sealers rest on in vitro studies whose relevance to clinical outcome is uncertain. Culture-based end-points underestimate the role of molecular and biofilm persistence [1]. Bioceramic sealer trials vary in brand, technique and follow-up, and long-term outcomes beyond several years remain limited [7]. As a narrative review, this article is also subject to selection bias. Future research should prioritise adequately powered randomised trials with standardised outcomes, direct clinical comparisons of medicaments, and long-term follow-up of bioceramic obturation.

8. Conclusion

Calcium hydroxide remains the standard intracanal medicament despite its limited ability to render canals bacteria-free, and Ledermix is best used selectively for inflammation and resorption control. Epoxy resin sealers retain benchmark status for physical stability, while bioceramic sealers provide bioactivity and procedural simplicity with comparable clinical outcomes. Neither medicament nor sealer compensates for inadequate disinfection or a poor coronal restoration, and material selection should be individualised to the diagnosis and clinical scenario.

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Conflict of Interest

The author declares no conflict of interest.

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