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# Entombing Theory in Endodontics: Biological Basis, Clinical Implications, and Contemporary Perspectives

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**Abstract**

**Background:** The entombing theory holds that residual microorganisms remaining within the root canal system after chemomechanical preparation can be rendered biologically inert if deprived of the nutrients, space, moisture, and physicochemical conditions necessary for continued survival by a well-adapted, three-dimensional obturation. This concept underlies much of the biological rationale for single-visit root canal treatment and for the emphasis placed on obturation and restorative quality in modern endodontic practice.

**Aim:** This narrative review synthesises the biological basis of the entombing theory, examines the microbiological and material factors that determine its clinical reliability, and situates the theory within the broader, and at times conflicting, contemporary endodontic literature.

**Methods:** A narrative, non-systematic approach was used. Relevant literature was identified through targeted searches of PubMed and Google Scholar using terms including "entombing theory," "residual bacteria root canal," "single-visit endodontics," "coronal leakage," "extraradicular infection," and "endodontic biofilm," supplemented by hand-searching reference lists of key articles. Foundational bacteriologic and outcome studies were prioritised alongside more recent histobacteriological, microbiological, and materials-science literature.

**Results and Conclusion:** The entombing theory offers a coherent and broadly supported explanation for the comparable clinical success of single- and multiple-visit root canal treatment, and is anchored by decades of bacteriologic and outcome research. However, its clinical validity is conditional: it depends on the quality of the coronal and apical seal, the antimicrobial and physical properties of the obturation materials used, the resilience of particular microbial species — most notably Enterococcus faecalis and Candida albicans — and the anatomical complexity of the canal system. Extraradicular infection and established biofilm communities represent recognised limits to the theory's reach. Entombment is therefore best regarded as one of several interacting determinants of endodontic outcome, rather than a stand-alone guarantee of success, and should inform — but not replace — meticulous chemomechanical preparation, attentive material selection, and timely definitive restoration.

**Keywords**: entombing theory; root canal obturation; endodontic microbiology; single-visit endodontics; residual bacteria; coronal seal; biofilm; apical periodontitis

## Introduction

The elimination, or at minimum the effective control, of microorganisms within the root canal system is central to the biological objective of endodontic therapy. Apical periodontitis, in the overwhelming majority of cases, is a consequence of microbial invasion and colonisation of the pulp space, and successful treatment depends on interrupting the supply of bacterial antigens and metabolic by-products to the periapical tissues. For much of the twentieth century, this objective was framed in near-absolute terms: instrumentation and irrigation were expected to sterilise the canal, and any residual bacterial presence was viewed as a direct threat to healing.

Empirical bacteriologic research conducted from the 1960s onward complicated this picture considerably. Careful culture-based sampling demonstrated that even meticulous chemomechanical preparation, performed by experienced clinicians under controlled research conditions, reduces the intracanal bacterial population by several orders of magnitude but rarely eliminates it entirely. Residual organisms persist within dentinal tubules, isthmuses, fins, accessory canals, and apical ramifications — anatomical spaces that instruments cannot reach and that irrigants penetrate only partially, if at all. This reality raised an uncomfortable question for a discipline whose success had, until then, been implicitly premised on sterilisation: if bacteria routinely survive treatment, why do the great majority of treated teeth nonetheless heal?

The entombing theory offers one of the most influential answers to this question. Rather than requiring complete eradication, the theory proposes that surviving microorganisms can be rendered clinically irrelevant if they are physically and chemically isolated from the nutrients, moisture, and space required for continued metabolic activity and proliferation. In this framework, obturation ceases to be merely a mechanical filling procedure and becomes an active biological intervention — one that starves, desiccates, and confines any bacteria that instrumentation and irrigation failed to remove. The theory reframes the clinical objective from sterilisation to biological containment, a distinction with substantial implications for how treatment protocols, materials, and restorative sequencing are understood.

This narrative review has five principal aims: first, to describe the biological basis and proposed mechanisms of the entombing theory; second, to examine the microbiological evidence that both supports and complicates the theory, including the behaviour of specific resilient organisms and the role of extraradicular infection; third, to explore the clinical implications of the theory, with particular attention to single-visit root canal treatment and the technical factors that determine entombment reliability; fourth, to critically appraise contemporary perspectives, including molecular microbiological findings and the evolving role of bioceramic materials, that refine or challenge the theory's scope; and fifth, to situate the entombing concept within the broader restorative literature, where an analogous logic underlies contemporary approaches to selective caries removal and indirect pulp capping. The review closes with a discussion of current limitations and directions for future research.

It is worth noting at the outset that the entombing theory, although most fully developed and most rigorously tested within endodontics, did not emerge in isolation. Its central logic — that residual microorganisms, if physically and biochemically isolated from the substrate and conditions required for continued activity, need not be completely eliminated to achieve a favourable clinical outcome — echoes a broader shift across restorative dentistry away from an absolute, sterilisation-based model of caries and infection control and toward a more nuanced, containment-based model. This parallel is explored further in Section 9, following the core endodontic discussion.

## 2. Historical Background

Understanding of intracanal infection, and of what constitutes an adequate clinical response to it, has evolved substantially over the past century, and this evolution is inseparable from the development of the entombing theory. Table 1 summarises the principal milestones discussed below.

Early twentieth-century dental and medical thinking was strongly influenced by the focal infection theory, which held that chronic, low-grade infection at any bodily site — including root-filled or infected teeth — could seed distant, clinically significant disease



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through haematogenous spread of bacteria or their toxins. Under this paradigm, a tooth harbouring any residual infection, however well obturated, was regarded as an unacceptable systemic risk, and wholesale extraction of endodontically involved teeth was common practice in many settings. This view left little conceptual space for a theory premised on the acceptability of residual, contained bacteria.

The mid-twentieth century saw growing clinical and epidemiological scepticism toward the focal infection theory, as evidence failed to substantiate the scale of systemic risk originally proposed and as case series demonstrated favourable long-term outcomes for retained, root-filled teeth. This shift allowed endodontic therapy to be re-established on more defensible scientific footing, and created the intellectual space in which questions about the biological fate of residual intracanal bacteria could be pursued on their own terms rather than being pre-empted by a presumption of systemic danger.

From the 1960s through the 1980s, a body of careful bacteriologic research — most notably the work of Byström and Sundqvist — quantified the reduction in cultivable bacteria achieved by mechanical instrumentation and irrigation, using both conventional and antimicrobial irrigating solutions. These studies established, with a rigour that earlier clinical impressions could not match, that substantial but incomplete bacterial reduction is the realistic and consistent outcome of even well-performed chemomechanical preparation. This finding was foundational: it transformed the question from whether residual bacteria exist (they demonstrably do) to what becomes of them after the canal is obturated.

The 1990s produced the study most directly credited with articulating the modern entombing theory in something close to its current form. Sjögren and colleagues followed a cohort of teeth with apical periodontitis, correlating bacteriologic culture status immediately prior to obturation with long-term radiographic healing outcome. Canals that were culture-negative at obturation showed the highest rates of complete healing, as might be expected. Critically, however, a substantial proportion of culture-positive canals also healed successfully when obturation was technically adequate — a finding difficult to reconcile with a strict sterilisation-based model, but readily explained if residual bacteria were being rendered biologically inert by an effective seal. This single body of work remains the empirical anchor most frequently cited in support of the entombing theory.

Subsequent decades brought a series of important refinements. Histobacteriological and confocal laser scanning microscopy studies, notably by Ricucci, Siqueira, and Nair, characterised the persistence of organised biofilm communities within treated canals and documented the existence of extraradicular infection — bacterial colonisation of the external root surface or periapical tissue, lying beyond the physical reach of any intracanal seal. These findings did not overturn the entombing theory so much as delineate its boundaries, clarifying the circumstances under which physical and chemical containment can and cannot be expected to succeed. More recently, advances in bioceramic sealer chemistry, micro-computed tomography for quantifying voids and sealer adaptation, and culture-independent molecular microbiological techniques have continued to refine the picture, situating entombment as one contributor among several to long-term treatment success rather than a complete explanatory model in itself.

Table 1. Historical milestones relevant to the development of the entombing theory

| Period | Development | Significance |
|---|---|---|
| Early–mid 20th c. | Focal infection theory dominates dental thinking; teeth harbouring any residual bacteria are regarded as a systemic hazard. | Extraction is favoured over conservative endodontic treatment; the biological premise for retaining root-filled teeth is weak. |

| Period | Development | Significance |
|---|---|---|
| 1930s–1950s | Growing clinical and epidemiological scepticism toward the focal infection theory; endodontics gradually re-establishes credibility. | Shifts the professional question from "should the tooth be saved" to "how can the canal be adequately treated and sealed." |
| 1965–1985 | Quantitative bacteriologic studies (e.g., Byström & Sundqvist) measure the reduction in cultivable bacteria achieved by instrumentation and irrigation. | Establishes that near-complete elimination, not sterilization, is the realistic ceiling of mechanical and chemical disinfection. |
| 1990–1999 | Sjögren and colleagues correlate pre-obturation culture status with long-term healing outcome; the entombing concept is articulated more formally to explain healing in culture-positive cases with adequate obturation. | Provides the central empirical anchor for the entombing theory and reframes obturation as a biologically active step, not merely a mechanical seal. |
| 2000–2010 | Histobacteriological and confocal microscopy studies (Ricucci, Siqueira, Nair) characterise biofilm persistence and extraradicular infection. | Introduces important qualifications: entombment may fail against biofilm communities and cannot address infection beyond the root canal system. |
| 2010–present | Bioceramic sealers, micro-CT quantification of voids, and molecular (next-generation sequencing) microbiology refine understanding of seal quality and microbial viability. | Repositions entombment as one of several interacting determinants of outcome, alongside host response, restorative timing, and canal anatomy. |

## 3. Biological Basis of the Entombing Theory

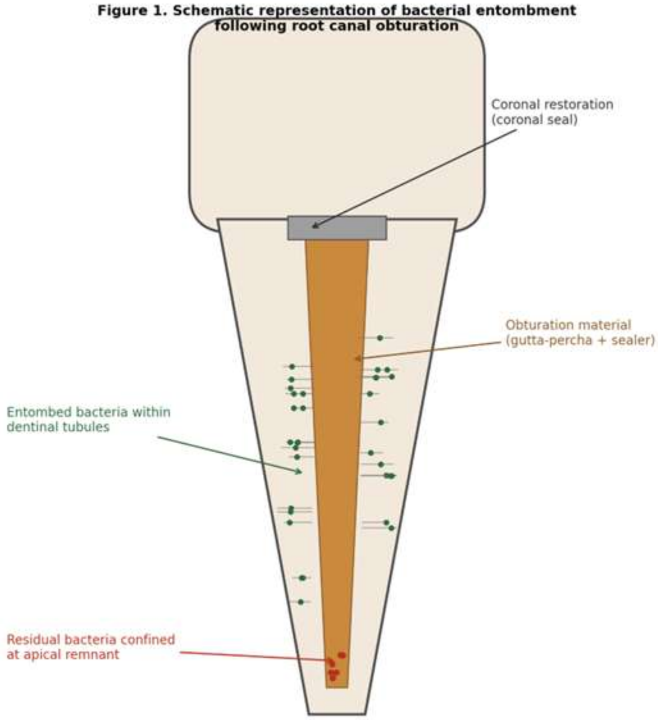
### 3.1 Core Ecological Principle

At its foundation, the entombing theory rests on a straightforward ecological premise: microbial survival and proliferation depend on continued access to nutrients, moisture, an appropriate redox potential, and physical space in which to replicate. Chemomechanical preparation substantially reduces the intracanal bacterial load and disrupts the architecture of any pre-existing biofilm within the main canal space, but — as established by decades of bacteriologic research — cannot be relied upon to achieve complete elimination. The subsequent placement of a dense, well-adapted, three-dimensional obturation is proposed to physically isolate any surviving organisms from the periapical tissues and from any residual source of nutrients or fluid, effectively arresting further metabolic activity and, over time, leading to microbial dormancy or death.

Two structural features of the root canal system are particularly relevant to this principle. First, dentinal tubules — typically ranging from roughly 1 to 3 micrometres in diameter near the pulp chamber and narrowing toward the periphery — are of comparable or smaller scale to many oral bacteria, meaning that tubular bacteria are, in principle, amenable to physical confinement if the tubule orifices at the canal wall can be sealed. Second, obligate versus facultative anaerobic status varies considerably among the bacterial species implicated in root canal infection, and this variation predicts differential vulnerability to the altered, sealed microenvironment created by obturation: strict anaerobes dependent on syntrophic metabolic partnerships within a mixed community are, in general, far less tolerant of isolation and nutrient restriction than facultative organisms capable of independent survival.

**Figure 1 illustrates this concept schematically, depicting entombed bacteria confined within dentinal tubules and residual canal remnants following three-dimensional obturation.**

Figure 1. Schematic representation of bacterial entombment following root canal obturation




(Conceptual illustration; not to anatomical scale)

### 3.2 Proposed Mechanism

The mechanism proposed by the entombing theory can be conceptualised as a sequential process, depicted in Figure 2. Chemomechanical preparation first achieves a marked reduction in intracanal bacterial load through the combined mechanical action of instrumentation and the chemical action of irrigants such as sodium hypochlorite and chlorhexidine. Despite this reduction, residual microorganisms persist in anatomical locations that remain inaccessible to both instruments and irrigant penetration — dentinal tubules, isthmuses, and fine ramifications of the canal system. Three-dimensional obturation, comprising a semi-solid or solid core material together with a sealer cement, is then placed to fill the prepared and unprepared spaces alike, as completely as the material's handling properties and the canal's anatomy allow. This obturation physically seals residual bacteria away from the source of nutrients and fluid exchange that would otherwise sustain them, and the resulting deprivation of nutrients, space, and moisture is proposed to culminate in bacterial dormancy, metabolic arrest, or outright death — the state described as "entombment."



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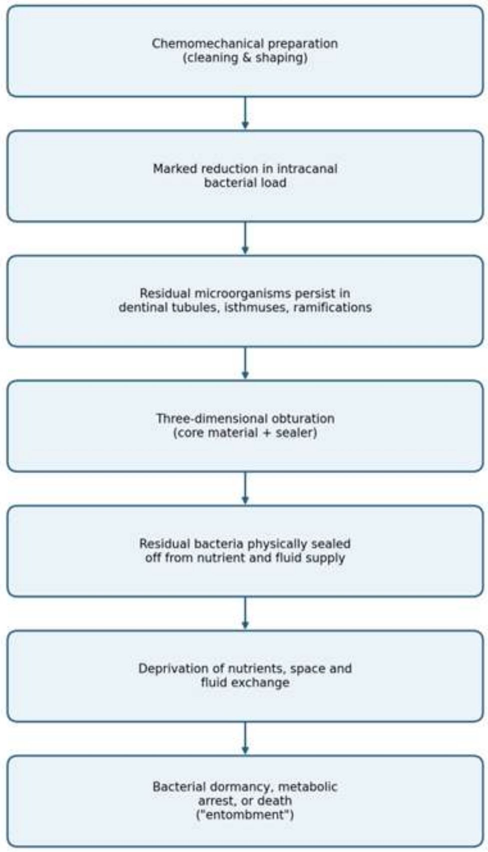
Figure 2. Conceptual sequence underlying the entombing theory




A distinction worth drawing out is that entombment, as originally conceived, is primarily a physical mechanism — the creation of an impermeable barrier around residual organisms. In practice, however, many contemporary obturation materials also contribute a chemical dimension to this process. Calcium hydroxide–based sealers release hydroxide ions that raise local pH to levels incompatible with the survival of many bacterial species, while calcium silicate–based (bioceramic) sealers similarly generate a transient alkaline environment during setting and hydration. The clinical effect attributed to "entombment" is therefore, in many cases, better understood as a combination of physical confinement and ongoing low-grade chemical antimicrobial activity, rather than starvation and isolation alone.

### 3.3 Dormancy Versus Death: The Viable-but-Non-Culturable State

An important, and clinically consequential, nuance in the entombing theory concerns the distinction between bacterial death and bacterial dormancy. Classical culture-based bacteriology, which underlies much of the foundational research in this area, can only detect organisms capable of growth under the conditions provided by the culture medium; it cannot readily distinguish a truly dead organism from one that has entered a viable-but-non-culturable (VBNC) state — a well-documented survival strategy in which bacteria downregulate metabolic activity, alter cell wall and membrane composition, and persist for extended periods without dividing, while retaining the potential to resume active growth if favourable conditions return.

This distinction matters because a bacterial population that has been successfully entombed in the sense of being rendered dormant, rather than killed outright, remains a latent biological risk. Should the physical seal responsible for entombment later be compromised — through coronal restoration failure, recurrent caries, root fracture, or progressive sealer degradation — dormant organisms could, in principle, resume metabolic activity and proliferation, re-establishing an active infection long after the original treatment. Histobacteriological evidence that loss of coronal



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integrity is strongly associated with recolonisation of previously well-obturated canals is broadly consistent with this possibility, though it does not, on its own, establish that the recolonising organisms originated from a dormant entombed population rather than from fresh bacterial ingress.

### 3.4 The Complicating Role of Biofilm Architecture

Much of the classical bacteriologic literature underpinning the entombing theory was conducted using planktonic (free-floating) bacterial models or culture techniques not specifically designed to characterise biofilm communities. Subsequent histobacteriological work, notably by Ricucci and Siqueira, has demonstrated that bacteria within both untreated and treated root canals frequently exist as organised, structured biofilms rather than as dispersed individual organisms. This distinction is biologically significant: the extracellular polymeric substance (EPS) matrix that characterises biofilm architecture can buffer the local microenvironment against external changes, retain moisture, sequester nutrients released by ongoing tissue breakdown, and physically impede the penetration of antimicrobial agents and, potentially, of sealer-derived alkaline leachates.

The implication is that entombment may be considerably less reliable against organised biofilm communities than against dispersed planktonic bacteria, since a biofilm's own structural properties can partially offset the nutrient and moisture deprivation that the sealed canal environment is intended to impose. This tension — between a theory whose foundational studies were largely framed in terms of culturable, planktonic bacterial load and a more contemporary understanding of biofilm biology — represents one of the more substantive contemporary critiques of the entombing model, discussed further in Section 6.

### 3.5 Redox Potential and the Sealed Microenvironment

A further physicochemical dimension of entombment concerns the oxidation–reduction (redox) potential of the sealed canal environment. Many of the strict anaerobes characteristic of primary, untreated endodontic infection require a low (negative) redox potential to survive, a condition typically maintained by continuous microbial metabolic activity within a nutrient-rich, poorly oxygenated necrotic pulp space. Once the bulk of this necrotic substrate is removed by chemomechanical preparation and the canal is sealed, the conditions that previously sustained a low redox potential are largely eliminated, which is likely to contribute independently to the decline of strict anaerobes even where nutrient deprivation alone might not be immediately fatal. Facultative organisms such as Enterococcus faecalis, by contrast, are far less dependent on a specific redox state and can tolerate the comparatively oxidised, static conditions of a well-sealed, obturated canal for extended periods, offering a further biological explanation for the disproportionate representation of facultative species among organisms recovered from persistent or secondary infection.

## 4. Microbiological Considerations

Not all microorganisms respond identically to nutrient and space deprivation, and this variability has direct bearing on the reliability of entombment as a general therapeutic mechanism. Table 2 summarises key microorganisms relevant to this discussion, and the subsections below examine two categories of particular clinical importance: resilient intraradicular species, and extraradicular infection lying beyond the reach of intracanal entombment altogether.

**Table 2. Key microorganisms implicated in root canal infection and their relevance to entombment**

| Microorganism | Typical Niche | Relevance to Entombment |
|---|---|---|
| Enterococcus faecalis | Dentinal tubules, isthmuses; strongly associated with persistent/secondary infection after obturation. | Facultative anaerobe capable of surviving prolonged nutrient scarcity and alkaline stress, and of entering a viable-but-non-culturable state; frequently |



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| Microorganism | Typical Niche | Relevance to Entombment |
|---|---|---|
| | | recovered from failed, technically adequate root fillings. |
| Fusobacterium, Porphyromonas, Prevotella spp. | Necrotic pulp tissue and mixed anaerobic biofilm communities of primary infection. | Obligate anaerobes highly dependent on continuous nutrient supply and syntrophic partners; generally do not persist once effectively entombed. |
| Actinomyces spp. / Propionibacterium spp. | Capable of establishing cohesive colonies within periapical granulation tissue (periapical actinomycosis). | When extraradicular, these organisms lie outside the physical reach of intracanal obturation and cannot be entombed by canal sealing alone. |
| Candida albicans | Retreatment cases; dentinal tubules; occasionally therapy-resistant apical periodontitis. | A eukaryotic organism with metabolic versatility and morphological plasticity (yeast–hyphal transition) that may enhance survival under nutrient-poor, sealed conditions. |
| Mixed-species biofilm communities | Canal walls, isthmuses, apical ramifications, and — in some cases — the external root surface. | The extracellular polymeric matrix may buffer the local microenvironment and slow nutrient depletion, and can limit penetration of sealer-derived antimicrobial leachates, partially offsetting the intended effect of entombment. |

### 4.1 Resilient Intraradicular Species

Enterococcus faecalis occupies a particularly prominent position in this literature. It is a facultative anaerobic, gram-positive coccus capable of survival across a wide range of environmental conditions, including comparatively high pH, low nutrient availability, and monoculture conditions that would be inhospitable to many of the strict anaerobes typically associated with primary (untreated) endodontic infection. E. faecalis is disproportionately recovered from canals associated with persistent or secondary infection following root canal treatment, and has been proposed as a marker organism for treatment failure precisely because of its comparative resistance to the conditions that entombment is intended to create. Its capacity to penetrate dentinal tubules, adhere to collagen, and survive extended periods of starvation contributes to its clinical significance in this context.



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Candida albicans, though less frequently implicated than E. faecalis, presents an analogous concern from a different biological kingdom. As a eukaryotic organism with metabolic versatility and the capacity to switch between yeast and hyphal morphologies, C. albicans has been isolated from therapy-resistant apical periodontitis and from canals undergoing retreatment, and some evidence suggests it may tolerate nutrient-poor, sealed conditions more readily than many bacterial species. Its presence in retreatment cases in particular raises the possibility that organisms surviving an initial, unsuccessful attempt at entombment may be selected for precisely the resilience traits that make subsequent entombment less reliable.

### 4.2 Extraradicular Infection: A Boundary of the Theory

A conceptually important limitation of the entombing theory is that it addresses, by definition, only intraradicular infection — bacteria located within the confines of the root canal system that a well-adapted obturation can physically isolate. Extraradicular infection, in which microorganisms colonise the external root surface or the periapical tissues themselves, lies structurally beyond the reach of any intracanal seal, however technically excellent.

Histological and correlative electron microscopic work by Nair and colleagues has documented several circumstances in which extraradicular infection occurs: acute exacerbations of apical periodontitis, in which bacteria may transiently invade periapical tissue during abscess formation; periapical actinomycosis, in which cohesive colonies of Actinomyces or related organisms can persist independently of the intracanal environment; infection associated with periapical cysts that maintain an open communication with the root canal; and, less commonly, mineralised, calculus-like biofilm deposits on the external root surface. A recent systematic review of published case reports by Pérez and colleagues examined fifteen such cases in detail, finding that extraradicular biofilm was strongly associated with treatment failure and that, in most instances, apical surgical intervention — rather than further intracanal management — was required to resolve the infection once it was recognised.

Extraradicular infection of this kind is generally considered uncommon relative to the overwhelming predominance of intraradicular infection in apical periodontitis, and the majority of solid periapical granulation tissue is understood to be free of viable microorganisms once the intracanal source is controlled. Nonetheless, its existence is a genuine and structurally unavoidable limitation of the entombing model: no degree of obturation quality can entomb bacteria that are not located within the canal system to begin with, and cases of persistent apical periodontitis that fail to respond to technically excellent orthograde retreatment should prompt consideration of an extraradicular component.

## 5. Clinical Implications

### 5.1 Single-Visit versus Multiple-Visit Root Canal Treatment

The entombing theory provides much of the biological rationale for single-visit root canal treatment, in which obturation is performed immediately following instrumentation and irrigation, without an interappointment antimicrobial dressing. If residual bacteria can be reliably entombed by an adequate three-dimensional seal, the additional antimicrobial contribution of an interappointment medicament — most commonly calcium hydroxide — becomes less critical to achieving a favourable long-term outcome. This logic has been examined in a substantial body of clinical research, summarised in Table 3 and, for individual key studies, in Table 6.

**Table 3. Comparison of single-visit and multiple-visit root canal treatment in relation to the entombing theory**

| Parameter | Single-Visit RCT | Multiple-Visit RCT |
|---|---|---|
| Reliance on entombing theory | High — obturation is performed immediately after instrumentation, so residual organisms rely on the seal, rather | Lower — an interappointment intracanal medicament (typically calcium hydroxide) provides an |



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| Parameter | Single-Visit RCT | Multiple-Visit RCT |
|---|---|---|
| | than an interappointment medicament, for containment. | additional antimicrobial interval before the canal is sealed. |
| Reported healing outcomes | Systematic reviews and randomised trials generally report healing rates comparable to multiple-visit treatment for both vital and necrotic cases, including teeth with apical periodontitis. | Comparable healing rates overall; theoretically advantageous where canals remain grossly contaminated or exudative at the first appointment. |
| Postoperative pain / flare-up | Some meta-analyses report a modestly higher incidence of postoperative pain, though the clinical magnitude is generally small and inconsistent across studies. | Interappointment medication may reduce flare-up in selected high-risk cases, but exposes the canal to a period of temporary restoration, with its own leakage risk. |
| Clinical efficiency | Higher — fewer appointments, reduced risk of temporary restoration failure and interappointment recontamination. | Lower — requires an additional visit, coordination of a temporary restoration, and patient compliance between appointments. |
| Situations warranting caution | Extensive periapical pathology with persistent exudation, inability to achieve adequate debridement or apical dryness in one visit, or significant patient/operator time constraints. | Prolonged or repeated $Ca(OH)_2$ dressing carries its own risks, including dentin weakening with extended use and increased coronal leakage risk during the interappointment period. |

Several randomised trials and systematic reviews have examined this question directly. Trope, Delano, and Ørstavik compared single-visit treatment without an interappointment medicament to multiple-visit treatment with calcium hydroxide dressing in necrotic teeth with apical periodontitis, and reported comparable healing rates between the two protocols. Peters and Wesselink similarly found that periapical healing occurred even in canals with culturable bacteria detected at the time of obturation, provided the canal had been adequately filled — a finding that speaks directly to the entombment mechanism rather than to any inherent superiority of one visit-number protocol over another. At the level of systematic synthesis, Sathorn, Parashos, and Messer found no clinically significant difference in postoperative pain or flare-up incidence between single- and multiple-visit protocols, while Su, Wang, and Ye similarly found no statistically significant difference in healing rate across the pooled trials they examined. Taken together, this literature is broadly consistent with the entombing theory's central prediction: that obturation quality, rather than the number of treatment visits or the presence of an interappointment medicament, is the more important determinant of long-term outcome in most cases.

This body of evidence should not, however, be read as suggesting that visit number is clinically irrelevant in all circumstances. Clinical judgement remains important in cases involving extensive periapical pathology, persistent canal exudation or inability to achieve apical dryness at the first appointment, difficulty achieving thorough debridement due to canal complexity, or patient and operator constraints that make a single, extended appointment impractical. In such scenarios, an interappointment calcium hydroxide dressing may offer practical or psychological advantages even if the entombment-based rationale for single-visit treatment remains sound in principle.

**Table 6. Selected key studies informing the clinical evaluation of the entombing theory**

| Study | Design | Population / Focus | Key Finding |
|---|---|---|---|
| Sjögren et al., 1997 | Prospective cohort, bacteriologic culture correlated with outcome | Teeth with apical periodontitis undergoing primary treatment | Negative pre-obturation culture yielded the highest healing rate, but a substantial proportion of culture-positive canals also healed when well obturated — the empirical foundation of the entombing theory. |
| Trope, Delano & Ørstavik, 1999 | Randomised comparison | Necrotic teeth with apical periodontitis, single- vs multi-visit | Healing rates were comparable between one-visit treatment without medicament and treatment with interappointment calcium hydroxide. |
| Peters & Wesselink, 2002 | Randomised clinical trial | Teeth obturated with or without detectable residual microorganisms | Periapical healing occurred even in canals with culturable bacteria at obturation, provided the canal was adequately filled. |
| Sathorn, Parashos & Messer, 2008 | Systematic review / meta-analysis | Postoperative pain and flare-up, single- vs multi-visit | No clinically significant difference in flare-up incidence between protocols; minor variation across pooled studies. |
| Su, Wang & Ye, 2011 | Systematic review / meta-analysis | Healing rate and postoperative pain across multiple trials | No statistically significant difference in healing rate between single- and multiple-visit treatment of infected canals. |
| Vera et al., 2012 | Histobacteriologic study | Teeth undergoing one- vs two-visit treatment prior to extraction/retreatment | Residual intracanal bacteria persisted after instrumentation regardless of protocol; obturation quality, rather than |

| Study | Design | Population / Focus | Key Finding |
|---|---|---|---|
| | | | number of visits, correlated with bacterial containment. |
| Ricucci & Bergenholtz, 2003 | Histobacteriologic study | Root-filled teeth exposed to the oral environment by restoration loss | Loss of coronal seal was strongly associated with recolonisation of the canal space, illustrating the reversibility of entombment when the coronal barrier fails. |

### 5.2 Technical Factors Influencing Entombment Efficacy

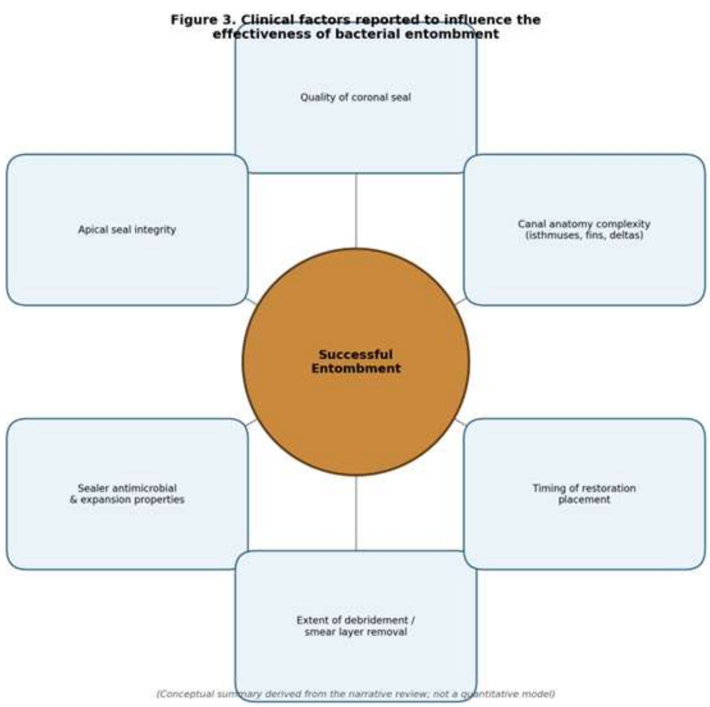
The clinical reliability of entombment is not absolute; it depends on a range of technical and biological factors that determine whether a genuinely impermeable, nutrient-excluding seal is achieved in practice. These factors are summarised in Table 4 and represented conceptually in Figure 3.

**Table 4. Factors influencing the effectiveness of bacterial entombment**

| Factor | Clinical Relevance |
|---|---|
| Quality of coronal seal | Classic radiographic studies found coronal restoration quality to be at least as strongly associated with periapical health as root filling quality, implicating coronal microleakage as a major route of reinfection that can defeat an otherwise adequate entombment. |
| Apical and lateral seal integrity | Voids, gaps, and poor sealer-to-dentine adaptation create pathways for fluid percolation that can resupply nutrients to residual organisms, undermining the physical basis of entombment. |
| Sealer composition and properties | Antimicrobial activity (e.g., calcium hydroxide–based or bioceramic, calcium silicate–based sealers), dimensional stability, minimal shrinkage, and favourable flow into irregularities influence the completeness of the seal and add a chemical dimension to entombment. |
| Canal system anatomy | Isthmuses, fins, deltas, and lateral canals are difficult to instrument and completely fill, leaving anatomical niches in which bacteria may evade both debridement and entombment. |
| Smear layer management | Removal (or intentional retention) of the smear layer affects sealer penetration into dentinal tubules and, by extension, the depth to which tubular bacteria can be physically or chemically entombed. |

| Factor | Clinical Relevance |
|---|---|
| Timing of definitive restoration | Delay between obturation and permanent coronal restoration lengthens the window during which a temporary restoration may fail, permitting coronal microleakage before the seal can be considered secure. |
| Presence of pre-existing biofilm | Organised biofilm, as opposed to planktonic bacteria, is inherently more resistant to both instrumentation and subsequent nutrient deprivation, reducing the reliability of entombment where biofilm is well established. |

**Figure 3. Clinical factors reported to influence the effectiveness of bacterial entombment (conceptual summary derived from the narrative review; not a quantitative model).**




Among these factors, the quality of the coronal seal deserves particular emphasis, as it has repeatedly been identified in the literature as at least as important as — and in some analyses more important than — the technical quality of the root filling itself. In a now-classic radiographic study of 1,010 endodontically treated teeth, Ray and Trope found that teeth with well-fitting, well-sealed coronal restorations showed significantly less periapical inflammation than teeth with poor coronal restorations, regardless of root filling quality, and that the combination of a good coronal restoration and a good root filling produced the most favourable periapical outcomes. This finding has been broadly corroborated by subsequent cross-sectional studies in different populations, and underscores that entombment, however well achieved at the time of obturation, is not a permanent or self-sustaining state: it depends on the continued integrity of the coronal barrier over the years and decades that follow treatment.

Complementary histobacteriological evidence reinforces this point directly. Ricucci and Bergenholtz examined root-filled teeth that had subsequently lost



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their coronal restoration through fracture, caries, or restorative failure, exposing the root filling to the oral environment, and found that loss of coronal integrity was strongly associated with recolonisation of the canal space by oral microorganisms. This provides a compelling illustration of the reversibility of entombment: a canal that was successfully entombed at the time of obturation can become recontaminated once the coronal seal — the barrier separating the entombed space from the oral cavity and its abundant nutrient and microbial supply — is breached.

### 5.3 Restorative Considerations

Because coronal microleakage can reintroduce both nutrients and bacteria into an otherwise adequately obturated canal, timely placement of a well-sealed definitive coronal restoration is best understood as an integral extension of the entombment principle, rather than as a separate or secondary consideration in treatment planning. Delays between obturation and definitive restoration — whether due to scheduling, cost, restorative complexity, or patient factors — prolong the period during which a temporary restoration, generally less resistant to marginal leakage than a definitive restoration, remains the sole coronal barrier. Restorations with poor marginal adaptation, inadequate material selection for the functional demands of the tooth, or insufficient remaining tooth structure to support a durable seal may all compromise an otherwise successful entombment. From a clinical protocol standpoint, this argues for minimising the interval between root canal obturation and definitive coronal restoration wherever feasible, and for treating restorative planning as inseparable from endodontic treatment planning rather than as a downstream, independently scheduled step.

### 5.4 Retreatment Considerations

The entombing theory carries somewhat different implications in the context of endodontic retreatment. By definition, a tooth requiring retreatment has already experienced a failure of either the original seal or the original disinfection protocol (or both), meaning that any bacteria recovered at retreatment have, in effect, already survived one attempt at entombment or elimination. This raises the possibility of a selection effect: organisms capable of surviving an initial round of instrumentation, irrigation, interappointment medication (where used), and obturation may be enriched for precisely the resilience traits — tolerance of nutrient deprivation, alkaline pH, and reduced moisture — that make subsequent entombment attempts less reliable. The disproportionate recovery of Enterococcus faecalis and Candida albicans from retreatment cases, noted in Section 4.1, is consistent with this interpretation, although a full mechanistic explanation for this pattern remains an active area of investigation. Clinically, this argues for particular attention to thorough removal of the previous filling material, extended or repeated chemomechanical disinfection, and careful consideration of an interappointment antimicrobial dressing in retreatment cases, even where single-visit protocols may be entirely appropriate for primary treatment of the same tooth type.

### 5.5 Special Clinical Scenarios

Certain clinical scenarios warrant additional consideration when applying the entombing framework. In teeth with extensive periapical radiolucency, the sheer volume of infected tissue and the likelihood of complex, ramified canal anatomy may reduce the probability of achieving a uniformly complete seal, even with meticulous technique, favouring careful case selection when deciding between single- and multiple-visit protocols. In medically compromised or immunosuppressed patients, it is important to note that entombment does not eliminate the need for an effective host response: while entombment may reduce the microbial antigenic and metabolic challenge presented to the periapical tissues, resolution of any periapical inflammation that has already been established still depends on host-mediated healing processes, which may be attenuated in patients with diabetes, immunosuppression, or other systemic conditions affecting wound healing. Finally, in teeth with cracked or fractured roots, or with restorations that provide a marginal or compromised coronal seal from the outset, the entombment achieved at obturation may be undermined from the moment of placement, and such cases warrant closer restorative follow-up than would otherwise be indicated.

### 5.6 Patient- and Operator-Related Factors

Beyond material and anatomical determinants, entombment reliability is also shaped by factors relating to the patient and the treating clinician. Patient-related considerations include the presence of parafunctional habits or heavy occlusal loading, which can predispose an otherwise adequate coronal



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restoration to microleakage-inducing marginal fracture over time; oral hygiene and caries risk, which influence the likelihood of secondary caries developing around, and eventually breaching, the coronal restoration; and attendance for recall and maintenance care, since asymptomatic restorative deterioration is often identified only through periodic clinical and radiographic review rather than through patient-reported symptoms. Operator-related considerations include adherence to a rubber dam or comparable isolation technique throughout treatment, which limits intraoperative contamination that could compromise the disinfection achieved prior to obturation; consistency and technique in obturation, since even an appropriate material will underperform if inconsistently condensed or compacted; and, importantly, the sequencing of care, given the demonstrated risks associated with delayed definitive restoration discussed in Section 5.3. None of these factors are unique to the entombing theory, but each bears directly on whether the theoretical mechanism of entombment is realised in a given clinical case, and their cumulative influence likely explains a meaningful proportion of the variability in outcome observed across published cohorts.

## 6. Contemporary Perspectives and Criticisms

While the entombing theory remains an influential and broadly supported framework, contemporary research has both refined and, in certain respects, challenged its scope. Table 5 juxtaposes supporting and critical perspectives drawn from the current literature, and the subsections below examine three areas of particular contemporary relevance: molecular microbiological insights, the evolving role of bioceramic materials, and the theory's structural limitations.

**Table 5. Supporting and critical perspectives on the entombing theory**

| Supporting Perspectives | Critical / Contrasting Perspectives |
| --- | --- |
| Systematic reviews generally show comparable outcomes between single- and multiple-visit treatment, consistent with effective entombment in the majority of cases. | Resilient species such as Enterococcus faecalis and Candida albicans demonstrate tolerance of nutrient deprivation, questioning the theory's universal applicability. |
| Histobacteriological outcome data (e.g., Vera et al.) show healing even when bacteria are detectable at obturation, provided the canal is well filled — direct support for the entombment mechanism. | Persistent extraradicular infection and mineralised apical biofilm, though uncommon, lie beyond the physical reach of intracanal entombment altogether. |
| Advances in bioceramic sealers improve marginal adaptation and add antimicrobial/alkaline activity, reinforcing the biological basis of the theory. | Complex canal anatomy (isthmuses, fins, deltas) limits achievement of a truly hermetic seal in a meaningful proportion of cases. |
| Supports simplified, patient-friendly single-visit protocols without compromising long-term success rates in most clinical scenarios. | Coronal microleakage occurring months to years after treatment can reintroduce nutrients, effectively "reopening" a previously entombed space. |
| Provides a coherent rationale for prioritising obturation and restorative quality over prolonged interappointment medication in most primary treatment cases. | Molecular (culture-independent) microbiology suggests a greater residual microbial diversity than culture-based studies indicate, raising the possibility that entombment success has been |



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| Supporting Perspectives | Critical / Contrasting Perspectives |
|---|---|
| | overestimated by earlier culture-dependent research. |

### 6.1 Molecular Microbiological Insights

Much of the foundational literature supporting the entombing theory relied on culture-based bacteriological techniques, which, by definition, can only detect organisms capable of growth under the specific conditions provided by the culture medium used. Culture-independent molecular techniques — including polymerase chain reaction (PCR)-based methods and, more recently, next-generation sequencing of bacterial 16S ribosomal RNA genes — have revealed substantially greater microbial diversity within both primary and persistent endodontic infections than culture-based studies alone had suggested, including organisms that are difficult or impossible to culture using standard laboratory techniques. This raises a methodologically important question for the entombing literature: if culture-based studies systematically underestimate the diversity, and potentially the residual viability, of intracanal microorganisms, then estimates of entombment "success" derived from such studies may themselves require reappraisal using contemporary molecular tools, ideally combined with viability-specific techniques (such as RNA-based assays or viability PCR) capable of distinguishing genuinely dormant or viable-but-non-culturable organisms from inert bacterial DNA.

### 6.2 Bioceramic Materials and the Evolving Concept of Obturation

The introduction and increasing clinical adoption of bioceramic, calcium silicate–based sealers over the past two decades has, in some respects, blurred the conceptual boundary between passive physical entombment and active antimicrobial treatment. These materials characteristically exhibit favourable flow and adaptation to canal wall irregularities, a degree of expansion during setting that may improve marginal sealing compared with some traditional sealers, and sustained release of calcium and hydroxide ions that generates a transient but clinically relevant antimicrobial and alkaline effect during the setting and early maturation period. Laboratory studies evaluating physicochemical properties of representative bioceramic sealers have documented measurable calcium ion release and sustained alkaline pH over extended observation periods, properties that plausibly extend the antimicrobial contribution of the obturation material well beyond the moment of placement. From this perspective, contemporary obturation may be better conceptualised as a hybrid intervention — combining physical entombment with an active, sustained chemical antimicrobial effect — rather than as pure physical containment in the sense originally described in the earlier entombing literature.

### 6.3 Structural Limitations of the Theory

Beyond the specific critiques already discussed — resilient microbial species, extraradicular infection, biofilm architecture, and the reversibility of entombment upon coronal seal failure — it is worth stating plainly that the entombing theory, however well supported empirically, is not and does not claim to be a complete explanatory model for endodontic treatment outcome. It does not, for instance, account for host immune and healing factors, which determine whether periapical tissue that has already been damaged by infection is capable of resolving inflammation and regenerating once the microbial challenge is controlled. It does not address cases in which anatomical complexity precludes adequate instrumentation and obturation in the first instance, regardless of the sealing properties of the material eventually placed. Nor does it offer guidance on the small but clinically important subset of cases involving genuine extraradicular disease. A balanced, contemporary application of the entombing theory therefore situates it as one important and evidence-supported contributor to treatment success, embedded within a broader model that also encompasses thorough chemomechanical debridement, appropriate case selection, restorative timing and quality, and host-related healing capacity.

## 7. Entombment as a Broader Concept: Parallels with Selective Caries Removal and Indirect Pulp Capping



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Although the entombing theory is most fully developed within endodontics, an analogous logic has come to underpin contemporary approaches to the management of deep dental caries in vital teeth, and a brief comparative discussion helps clarify both the generality and the limits of the underlying biological principle.

### 7.1 The Shift from Complete Caries Removal to Selective Removal

For much of the twentieth century, restorative dogma held that all caries-affected and caries-infected dentine had to be mechanically removed before a restoration was placed, on the assumption — closely paralleling the pre-entombment view of root canal treatment — that any residual bacteria left beneath a restoration would continue to progress and threaten pulp vitality. Contemporary cariology has moved substantially away from this position, particularly for deep lesions in close proximity to the pulp, in favour of selective (partial) caries removal, in which frankly infected, unsalvageable dentine is removed but a layer of caries-affected, bacterially colonised but structurally retained dentine is deliberately left in place and sealed beneath a well-adapted restoration.

The biological rationale for this shift mirrors the entombing theory closely: once the residual bacteria are deprived of a substrate supply from the oral environment and of the moisture and nutrient exchange that sustained their activity within an open, unsealed lesion, their metabolic activity and cariogenic potential decline substantially, and the residual dentine may even undergo a degree of remineralisation and sclerosis over time. Clinical and radiographic follow-up studies of selective and stepwise caries removal have generally reported low rates of subsequent pulp exposure or endodontic complication when the coronal seal is well maintained, an outcome pattern that closely echoes the entombing literature's central finding that residual bacteria, when adequately sealed away from their nutrient supply, need not compromise long-term treatment success.

### 7.2 Indirect Pulp Capping and Sealed Caries

Indirect pulp capping — the deliberate placement of a protective liner or base over a thin layer of retained, caries-affected dentine immediately overlying the pulp, followed by a well-sealed definitive restoration — represents perhaps the closest restorative analogue to root canal entombment. As in the endodontic context, success depends less on achieving a bacteria-free substrate than on achieving and maintaining a durable peripheral seal that isolates the residual bacterial population from the oral environment. And, just as coronal microleakage has been repeatedly identified as capable of undermining an otherwise successful root canal entombment, marginal breakdown of a restoration placed over sealed, caries-affected dentine can reintroduce nutrient supply and permit renewed bacterial activity, potentially precipitating the very pulpal pathology the procedure was intended to avoid.

### 7.3 Shared Principle, Distinct Contexts

The parallel between these two areas of practice — root canal obturation and selective caries removal with indirect pulp capping — should not be overstated, since the tissue substrates, bacterial ecology, and clinical objectives differ considerably. Root canal entombment addresses a necrotic or instrumented, largely avital canal space, whereas indirect pulp capping is performed with the explicit goal of preserving pulp vitality in living tissue with an active, potentially reparative host response immediately adjacent to the sealed bacterial layer. Nonetheless, the shared underlying principle — that a durable peripheral seal, rather than exhaustive substrate sterilisation, is the primary determinant of long-term clinical success — illustrates that the entombing concept reflects a more general biological pattern in restorative dentistry rather than an isolated, endodontics-specific phenomenon, and reinforces, from a different clinical direction, the central emphasis this review places on seal quality and restorative timing as determinants of outcome.

## 8. Future Directions

Several avenues of research could meaningfully advance understanding of the entombing theory and its clinical application. Quantitative imaging techniques, particularly micro-computed tomography, allow non-destructive, three-dimensional assessment of void volume, sealer-to-dentine adaptation, and residual unfilled canal space at a resolution far exceeding conventional radiography, and could be used to correlate objectively measured seal quality with bacteriologic and clinical outcome in prospective cohorts. Viability-specific molecular assays — capable of distinguishing genuinely dormant or viable



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organisms from inert bacterial DNA — would help resolve the important open question of how frequently entombment results in true bacterial death as opposed to a viable-but-non-culturable state with latent reactivation potential. Long-term prospective studies that combine such microbiological methods with standardised, blinded radiographic and clinical outcome assessment over follow-up periods of a decade or more would help clarify how durable entombment is under real-world conditions of coronal restoration wear, replacement, and occasional failure. Finally, continued development of bioactive and antimicrobially sustained sealer materials, together with standardised reporting of their physicochemical properties, may progressively shift the practical balance of obturation from passive physical containment toward active, sustained microbial control, a trajectory already visible in the bioceramic sealer literature discussed in Section 6.2.

## 9. Conclusion

The entombing theory offers a biologically coherent and empirically supported explanation for the clinical success of root canal treatment despite the near-impossibility of achieving complete intracanal sterilisation. Anchored by foundational bacteriologic research and reinforced by decades of clinical outcome studies, it supports the substantial and growing evidence base for single-visit treatment protocols and underscores the clinical importance of obturation quality and timely, well-sealed coronal restoration. At the same time, the theory's effectiveness is not universal or unconditional: resilient microbial species such as Enterococcus faecalis and Candida albicans, organised biofilm communities, complex and incompletely instrumentable canal anatomy, extraradicular infection, and eventual coronal restorative failure can all limit the degree to which residual bacteria are genuinely and durably rendered inert. Clinicians are therefore best served by treating entombment as one important, evidence-supported pillar of endodontic success — one that argues strongly for careful attention to three-dimensional obturation quality and prompt definitive restoration — rather than as a substitute for thorough chemomechanical debridement or as a guarantee applicable to every clinical scenario. Continued research employing advanced imaging, viability-specific molecular microbiology, and long-term outcome tracking will likely further refine the conditions under which entombment can be relied upon, and help translate the theory into progressively more precise clinical guidance. Recognising that an analogous seal-dependent, containment-based logic also underlies contemporary selective caries removal and indirect pulp capping protocols further suggests that the entombing principle, properly understood, is not a narrow endodontic curiosity but an instance of a broader and clinically important pattern in restorative dental biology.

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