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Indications and Contraindications for Pulp Revitalization in Mature Permanent Teeth: A Literature Review

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ABSTRACT

Evidence suggests that modified disinfection and mechanical enlargement of the apical foramen can facilitate pulp-like tissue ingrowth even in teeth with fully formed roots. In recent years, dentists have used Regenerative Endodontic Procedures (REPs) to restore vitality and neurovascular function of necrotic mature teeth. This study aims to distinguish between clinical conditions that provide predictable outcomes for pulp revitalization/revascularization in mature teeth and those that are deemed unfavourable. By analyzing the current literature, this work seeks to define the practical boundaries of REPs in a clinical setting. Studies found that REPs are indicated for single-rooted teeth, with success rates comparable to those of traditional Root Canal Treatments (RCTs). They are a highly effective alternative in arresting external infection-related resorption (EIRR) and internal infection-related resorption (IIRR). With surgical modifications, it is now possible to achieve revitalization in autotransplanted teeth. In many cases, complex root canal anatomy is a contraindication for regenerative procedures due to the threat of iatrogenic complications during apical preparation. The long-term interaction between revitalized teeth and orthodontic forces is unpredictable. Some evidence suggests a risk of late resorption. Using REPs in mature teeth is a reliable treatment in specific scenarios. It is a predictable treatment for single-rooted teeth and infection-related resorptions. Regenerative endodontics is a rapidly changing field that needs attention from practitioners. Recent advancements show potential, but more studies are required to make this treatment the new standard.

Keywords: pulp revitalization; Regenerative Endodontic Procedures; mature permanent teeth; root resorption; autotransplantation

1. INTRODUCTION

Dental caries and traumatic injuries can lead to dental pulp necrosis, requiring clinicians to carry out RCT (Rotstein and Ingle, 2019). The procedure inevitably compromises the tooth's natural nourishment and reduces its structural integrity. A tooth without its blood supply does not have its immune defense systems. Its dentin

and enamel lose their source of nutrition, resulting in reduced mechanical resistance and increased risk of bacterial re-infection. The absence of nerves in teeth after RCT allows dental caries to progress asymptomatically (Morotomi et al., 2019). While it was once the only available treatment, in the early 2000s revolutionary findings demonstrated that infected immature teeth are capable of healing and can develop longer and thicker roots (Chueh and Huang, 2006). These results were first considered limited to immature teeth with open apices. This phenomenon has since been known as revitalization/revascularization of the pulp. In the past researchers thought that teeth with fully formatted roots do not have necessary blood supply to allow revascularization. New research in fully matured teeth shows that enlarging the apical foramen can allow new tissue to enter the root canal system. This tissue is histologically and functionally similar to pulp (Eldessoky et al., 2023; Saad et al., 2024). Regenerative Endodontic Procedures (REPs) actively utilize tissue engineering principles such as stem cells, scaffolds, and growth factors to replace damaged dentin and restore the neurovascular system (Liang et al., 2021; Saad et al., 2024; Salah et al., 2025; Shi et al., 2025). This new approach aims to bring back the biological vitality and immune response in once necrotic mature teeth.

REPs are a promising therapeutic alternative, but need good success rates and clear indications to be a clinical standard that can compete with traditional RCTs. Evidence found in systematic reviews shows that the success rate of this treatment is comparable to RCTs (Kawthar et al., 2025). This paper explores the indications and contraindications for pulp revitalization in mature teeth. This is a topic that remains significantly underexplored. By analyzing current literature, it seeks to define its practical use and highlight cases where uncertainty is still present. This work aims to distinguish between conditions that ensure predictable outcomes and those that require further investigation.

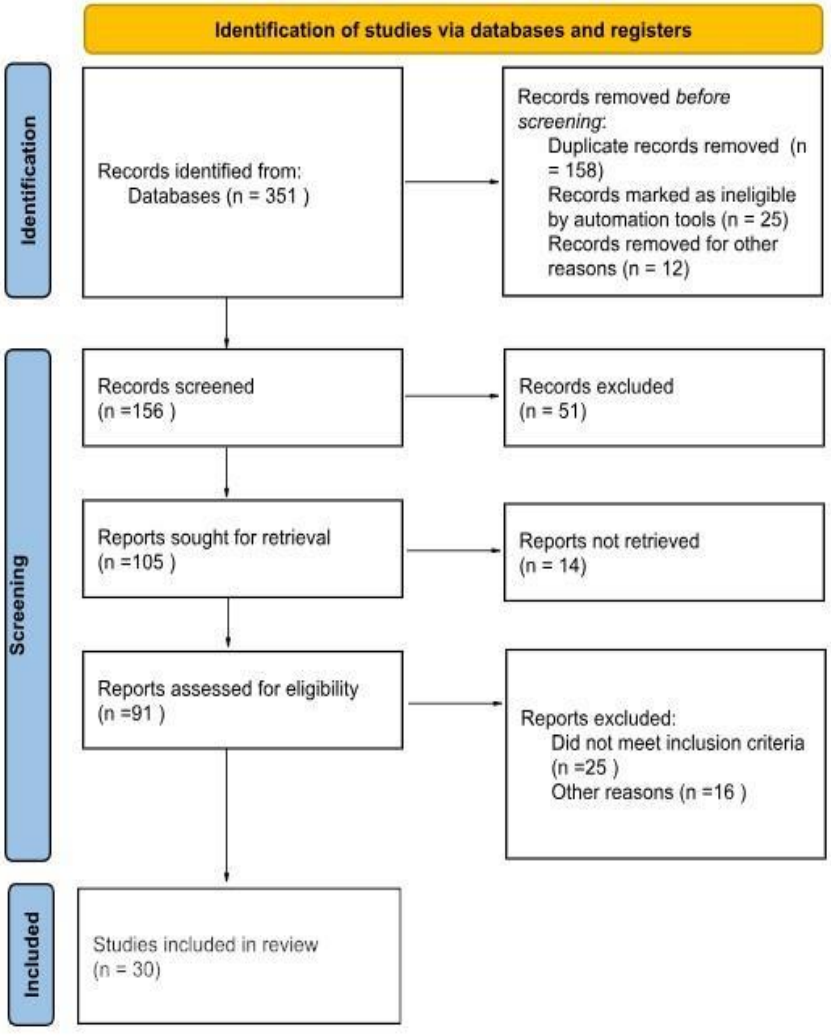

Figure 1. PRISMA 2020 flow diagram of study selection.

2. REVIEW METHODS

This study is a narrative literature analysis. Scientific publications were identified through database searches, including PubMed and Google Scholar repositories. Keywords used in the search included: "pulp revitalization", "mature permanent teeth", "regenerative endodontic procedures", and "procedural risks". Articles were included if they were published in peer-reviewed journals, focused on the indications and contraindications for revitalization in teeth with fully formed roots, and provided clinical or experimental evidence. Authors excluded: articles which focussed solely on immature roots, in vitro studies, opinions, letters to the editor and articles without full peer review. A total of 30 publications were selected for analysis (Figure 1).

3. RESULTS AND DISCUSSION

The Impact of Root Canal Complexity on REPs

Endodontic procedures require multiple precise steps to thoroughly disinfect the canals of the tooth. However, the root canal is a complex system rather than a single channel. A system containing lateral components, such as isthmuses, fins, and accessory canals. This nuanced morphology presents a great challenge for the cleaning required to disinfect canals. Factors like curvatures and narrow roots increase the risk of accidents, including ledge formation and perforations. Clinical outcomes in traditional endodontics are thus heavily influenced by the nature of the interaction between the infection and these complex spaces (Versiani et al., 2023). Ultimately, good anatomical knowledge is necessary for clinicians to treat persistent periapical disease (Mamat and Nik Abdul Ghani, 2023).

Clinicians question whether biological procedures are contraindicated when dealing with complex root canal systems. Some perspectives suggest that Vital Pulp Therapy (VPT), such as pulpotomy or pulpectomy, could be a better alternative when RCT is affected by anatomical complexities like aggressive curvatures and narrow canals. In such cases where there is a high risk of procedural errors such as instrument separation, VPT can reduce the need for aggressive mechanical shaping in deep, irregular spaces (Asgary et al., 2022). Biological procedures offer a way to manage teeth that are technically difficult to treat with standard filling methods. Unfortunately, these methods apply only to cases with partial irreversible pulpitis (Duncan, 2022).

REPs can be used to treat irreversible pulpitis and necrotic pulp with apical radiolucencies (Garrido-Parada et al., 2022). Root canal complexities are a major obstacle to rigorous disinfection. Furthermore, enlarging the apical foramen, which is required for the procedure, remains a challenge. Aggressive instrumentation used in REPs may be contraindicated in teeth with reduced dentinal thickness. Furthermore, complex canal configurations, including C-shaped canals and deep radicular grooves in mandibular premolars, need a more conservative approach (Versiani et al., 2022). Yet to fully determine characteristics of anatomical contraindications for revascularisation, there is a need for precise guidelines in terms of apical foramen enlargement. Published guidelines vary regarding the ideal final instrument size used in the procedure (Youssef et al., 2022).

Nevertheless, limited evidence of REPs being as successful as RCT in multirooted teeth exists. For the treatment to rival the gold standard, it must exhibit this statistic in systematic reviews and meta-analyses, which, if available, concern mainly single rooted teeth (Ahmed et al., 2023).

Revitalization for the Treatment of Root Resorption

Pathologic root resorption occurs when the natural homeostasis between teeth and the alveolar bone is disrupted. Under normal conditions, permanent teeth remain immune to osteoclasts because of the presence of cementoblast and odontoblast cells. When physical or chemical factors damage these protective barriers, the RANK-RANKL/OPG system is activated. That leads to the differentiation of macrophage progenitor cells into active osteoclasts. These cells destroy dental hard tissues by dissolving mineral components with acids and then breaking down organic structures (Rotstein and Ingle, 2019).

In cases of external infection-related resorption (EIRR), microbial toxins from a necrotic pulp diffuse through exposed dentinal tubules to the periodontal ligament. This triggers a rapid and progressive loss of tooth structure. The condition is especially dangerous due to its usual lack of symptoms. In most cases, only tooth discolouration can lead to the diagnosis (Rotstein and Ingle, 2019).

The other, rarer type important to this review is referred to as internal infection-related resorption (IIRR). It involves granulation tissue located between necrotic and healthy pulp, which undergoes pathological resorption that expands within the pulp space. This process, fueled by necrotic coronal tissue if left untreated, eventually leads to root perforation (Rotstein and Ingle, 2019).

While traditional endodontic therapy can effectively inhibit these inflammatory processes by eliminating the infection, current standard treatment can not replace the mineralized dentin lost during the pathologic process. This limitation has led to the exploration

of revitalization as a regenerative alternative. The novel treatment can restore the integrity of mature teeth affected by these conditions (Dadpe et al., 2023).

Recent clinical evidence suggests that REPs are a practical and potentially beneficial alternative for managing EIRR and IIRR (Table 1). One broad systematic review found that revitalization successfully arrested these conditions and resolved clinical symptoms in almost all cases, achieving a stable and functional tooth (Dadpe et al., 2023). It also suggested that REPs may be the only prospect to inhibit replacement resorption, yet this aspect needs more clinical research.

Another review showed that REPs require significantly shorter time between visits than the standard protocol. This is an advantage that could improve patient compliance (Lin et al., 2022). Newer case reports and clinical series provide evidence for successful treatment of EIRR and IIRR using REPs with longer follow-up periods (Lu et al., 2026; 2023). Use of i-PRF and disinfection assisted by laser is worth noting. These methods show up frequently in recent studies (Lu et al., 2026).

The results are promising, but more studies are needed. Only a single systematic review and no meta-analyses exist on this topic. Current research consists of case reports and series. These types of articles mainly report successful outcomes and are susceptible to publication bias. Another issue is the lack of a standard disinfection protocol for REPs. Some practitioners use high concentrations of NaOCl (5.25-6%) that could damage stem cells, and others follow the more conservative approach (Dadpe et al., 2023). Most studies are limited to anterior teeth and resorption from trauma. The effectiveness of REPs in posterior teeth or resorption due to caries needs more attention from the scientific community.

Based on the available literature, anterior teeth with EIRR appear as an indication for revitalization and rival the classic Cvek's protocol. Promising but lacking broad verification is its use for IIRR. Application of REPs in yet untreatable replacement resorption could be groundbreaking, but that remains a hopeful contemplation. There are other types of resorption that do not involve pulp, thus are out of consideration for revitalization (Rotstein and Ingle, 2019). Invasive Cervical Resorption (ICR) with pulpal involvement has not been explored under the scope of REPs which could be a nuance or a potentially new area to explore.

Table 1. Selected resorption types treatment options.

Resorption Type	Standard Treatment	Treatment with Regenerative Endodontic Procedures (REPs)	Notes
External Infection-Related Resorption (EIRR)	Root Canal Treatment (RCT)	Positive results	i-PRF + laser assisted disinfection advised
Internal Infection-Related Resorption (IIRR)	Root Canal Treatment (RCT)	Positive results	i-PRF + laser assisted disinfection advised
Replacement Resorption	No treatment option	Suggested possibility	Eventually extraction is necessary
Invasive Cervical Resorption (ICR) class 3	Topical trichloracetic acid + prophylactic RCT	Not explored	Pulpal involvement suggest possible use of REPs
Invasive Cervical Resorption (IRC) class 4	No treatment option (optionally the same as in class 3)	Not Explored	Pulpal involvement suggest possible use of REPs

Revitalization in Autotransplanted Mature Teeth

Autotransplantation is a procedure closely related to traumatic replantation. Both involve repositioning a tooth in a socket. The goal of the procedures is to achieve the return of the neurovascular supply (Plakwicz et al., 2023). The clinical environment in which the two procedures take place is the most important difference. The success of traumatic replantation is affected by unpredictable extra-alveolar time and by the way the tooth was stored (Marton et al., 2025). Autotransplantation involves precise preoperative planning to minimize extra-alveolar time and surgical trauma (Rugani et al., 2023).

A central determinant for revitalization in these procedures is the apical diameter. (Marton et al., 2025; Plakwicz et al., 2023). Historically, it was believed that successful pulp repair was unpredictable if the foramen was smaller than 1 millimeter. However, more

recent histological data suggest that this threshold is not absolute, as apical diameters as narrow as 0.32 mm have successfully allowed for the ingrowth of vital tissue into the majority of the pulp chamber (Jakse et al., 2018).

Recent advancements in dental traumatology have questioned the assumption that autotransplantation of mature teeth inevitably results in root canal treatment (RTC). Teeth with an immature apex have a high potential for pulp revitalization. Replanting mature teeth, however, has low success rates. It usually leads to pulp necrosis and inflammatory root resorption. Authors found that extraoral root-end resection (EORER) allows the pulp to be revitalized in mature replanted teeth (Jakse et al., 2018; Marton et al., 2025; Rugani et al., 2023). EORER involves extraction of the tooth, followed by extraoral resection of 2 to 4 mm. The resection is done using a rotary instrument with irrigation (Marton et al., 2025; Plakwicz et al., 2023). The intentional resection of the apical region of the root makes the apical foramen larger and eliminates the apical constriction. After the procedure, the tooth is left with no natural barrier against neurovascular tissue infiltration (Plakwicz et al., 2023; Rugani et al., 2023). The next step is to relocate the tooth to a new place in the alveolar bone. Then the last step is to ligate it with the remaining teeth. This modification widens the opening for blood vessel migration into the canal space. It also shortens the distance that regenerating tissue must travel to reach the pulp chamber (Plakwicz et al., 2023).

The clinical benefits of achieving successful revascularization with this method are significant when compared to standard treatment (Table 2). RCT as a protocol to prevent inflammatory complications in a transplanted tooth results in a non-vital tooth. The lack of blood supply weakens the transplanted tooth. RCT is an option that also raises the costs of the whole procedure (Marton et al., 2025; Plakwicz et al., 2023; Rotstein and Ingle, 2019; Rugani et al., 2023). Successful revitalization can restore vitality and proprioception of the tooth, both of which are important for the future function of the tooth (Jakse et al., 2018; Marton et al., 2025; Rugani et al., 2023). Evidence of successful healing is often characterized by canal obliteration seen on a radiograph. This sign indicates the replacement of necrotic tissue with fibrovascular connective tissue similar to bone (Jakse et al., 2018). Its deposition over time progresses steadily and starts on the inside of root canal walls. This leads to complete canal obliteration (Plakwicz et al., 2023). Four weeks after surgery, revascularization of the pulp can be confirmed by pulse oximetry or magnetic resonance (Marton et al., 2025; Rugani et al., 2023).

Case reports demonstrate that this modification can be a biological alternative to traditional endodontic protocols (Jakse et al., 2018; Marton et al., 2025; Plakwicz et al., 2023; Rugani et al., 2023). Criticism of autotransplantation has been motivated by shortcomings in research and dependence on the surgical skills of the operator (Ong et al., 2016). Skill dependence is negligible if extraoral apicoectomy is performed, yet this needs to be further backed up by broad studies. Before 2018, only animal studies were conducted on this topic, and since then, a surge in research interest has been noted. At this stage, it is too early to call for replantation of mature teeth as an indication for pulp revitalization. Nevertheless, this approach is very promising, and advancements in this topic are worth observing with great interest.

Different from the described method, Yoshihashi (2025) very recently introduced a novel therapy that utilizes cell-based regenerative endodontic therapy following the transplantation of a mature tooth without the need for apicoectomy. While this method can revitalize the pulp-dentin complex and uniquely reverse ankylosis, it remains significantly more expensive, time-consuming, and technically complex than the surgical EORER technique, which also preserves an untouched pulp.

Table 2. Autotransplantation protocols comparison.

Autotransplantation protocol	Tooth vitality after treatment	Coronal hard tissue loss	Costs	Duration of treatment	Specific instruments needed
Root Canal Treatment (RCT)	Non-vital	Yes	Moderate	2-3 visits over a course of 2 months	RCT instruments
Jakse's Extraoral Root-End Resection (EORER)	Vital	No	Low	One visit + controls	Diamond bur, 3000 rpm handpiece, saline solution
Yoshihashi's Cell Based Therapy	Vital	Yes	High	3 visits over a course of 2 months + controls	RCT instruments, liquid culture media incubator, Atelocollagen Implant containing G-CFS

Orthodontic Treatment Following Regenerative Endodontic Procedures

Clinicians use REPs to treat necrotic teeth but there is a lack of evidence on the complications of orthodontic tooth movement after these interventions (Stefopoulos et al., 2023). Only a small number of mostly case reports and series explore this interaction (Chaniotis and Chanioti, 2022; Stefopoulos et al., 2023; Yoshpe et al., 2025). There is even less data focusing on mature teeth. One recent case report shows the successful orthodontic movement of a mature permanent tooth after a nine-month healing period following revitalization. The authors suggested that the newly formed tissue in the canal space can protect mature roots from resorption. Other researchers reported varied and sometimes contradictory outcomes. This conflict in research should raise high levels of caution. A case series investigated whether orthodontic treatment has an effect on immature revascularized teeth. It showed that in more than 50% of cases external root resorption happens after orthodontic treatment (Stefopoulos et al., 2023). Another report documented late complications that appeared several years after the application of orthodontic forces. Invasive cervical resorption and internal resorption were the complications observed by the authors (Chaniotis and Chanioti, 2022; Yoshpe et al., 2025). Conflicting findings indicate that the dental community still does not fully understand the long-term interaction of REPs and orthodontic forces (Stefopoulos et al., 2023).

Before applying orthodontic forces, authors suggest waiting between 9 to 12 month after performing REPs. The forces should be possibly light and short acting (Stefopoulos et al., 2023; Yoshpe et al., 2025). The use of clear aligners was proposed as beneficial for its ability to apply minimal forces (Yoshpe et al., 2025). At this moment, it is impossible to deduce whether REPs are contraindicated if the need for orthodontic treatment will be present in the future. What is known is that regular clinical and radiographic monitoring remains essential to detect late failures like necrosis or resorption, which can emerge up to eleven years later. During orthodontic treatment planning, dentists should consider excluding teeth that underwent REPs. Before treatment, patients should know about the risk associated with moving such teeth (Chaniotis and Chanioti, 2022; Stefopoulos et al., 2023; Yoshpe et al., 2025).

4. CONCLUSION

While in recent years pulp revitalization in mature teeth became better understood, its indications and contraindications remain a vague topic. The newest literature provided evidence for some to emerge while others remain a topic that needs to be further explored. Indications for RETs in mature teeth that could be deduced from this study include: single-rooted necrotic teeth, teeth affected by external infection-related resorption, teeth affected by internal infection-related root resorption, and cases with complex anatomy or high risks of iatrogenic complications. Surgical modifications like extraoral root-end resection offer a promising solution for revitalizing autotransplanted mature teeth.

At this state of knowledge, it is hard to distinguish between contraindications and areas that require elevated caution. These cases include teeth with specific anatomical vulnerabilities, such as reduced dentinal thickness in mandibular molars or maxillary premolars. Such thin root canal walls are predisposed to iatrogenic complications during the necessary apical enlargement. Resorptions that do not involve the pulp are outside the current scope of this therapy. The role of REPs in replacement resorption remains a field with possible potential, but lacking any guidelines or research. Finally, while not a definitive contraindication, the future requirement for orthodontic movement demands high clinical caution and regular monitoring due to the risk of resorption in the long term.

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All authors have read and agreed to the published version of the manuscript.

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Data and materials availability
All data associated with this study will be available based on the reasonable request to corresponding author.

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