World Journal of Pharmaceutical Science and Research
www.wjpsronline.com
Research Article
ISSN: 2583-6579
SJIF Impact Factor: 5.111
Year - 2025
Volume: 4; Issue: 4
Page: 704-715

PULPOTOMY VERSUS SINGLE-VISIT ROOT CANAL TREATMENT IN MATURE PERMANENT TEETH WITH IRREVERSIBLE PULPITIS AND THE ROLE OF ARTIFICIAL INTELLIGENCE (AI) IN PULPOTOMY AND RCT

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Article Received: 14 July 2025 || ***Article Revised: 04 August 2025*** || ***Article Accepted: 25 August 2025***

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DOI: https://doi.org/10.5281/zenodo.17011013

How to cite this Article: Prof. Shivkumar Mantri (2025) PULPOTOMY VERSUS SINGLE-VISIT ROOT CANAL TREATMENT IN MATURE PERMANENT TEETH WITH IRREVERSIBLE PULPITIS AND THE ROLE OF ARTIFICIAL INTELLIGENCE (AI) IN PULPOTOMY AND RCT. World Journal of Pharmaceutical Science and Research, 4(4), 704-715. https://doi.org/10.5281/zenodo.17011013

ABSTRACT

Historically, irreversible pulpitis has necessitated complete pulp extirpation via RCT. However, advancements in pulp biology and biomaterials have led to the re-emergence of pulpotomy, a vital pulp therapy, as a viable alternative. Both pulpotomy and single-visit RCT, achieve high and comparable clinical and radiographic success rates, including periapical healing.[1,2,3,4,5,6] Pulpotomy offers distinct advantages, including significantly faster pain relief, reduced chair time, lower cost, and the crucial preservation of tooth vitality, neurosensory ability, and proprioception.[7,1,8,3,4,5] These benefits contribute to higher patient satisfaction and address significant barriers to dental care, particularly in resource-limited settings.[7,3,4] Despite its promising outcomes, the evidence-base for pulpotomy, especially concerning long-term results, is still evolving and characterized by some methodological limitations and heterogeneity in studies.[1,8,4] Single-visit RCT, while efficient and generally successful, may present a higher risk of immediate postoperative flare-ups, necessitating careful patient selection.[2,11] The findings underscore an ongoing paradigm shift in endodontics towards more minimally invasive, tissue-preserving therapies, advocating for individualized treatment planning based on a holistic assessment of clinical, radiographic, and patient-reported outcomes. Artificial Intelligence's (AI) integration into endodontic practice promises to enhance diagnostic accuracy, refine treatment planning, improve procedural precision, and ultimately will lead to better patient outcomes in both pulpotomy and RCT.

INTRODUCTION

Understanding Irreversible Pulpitis and Evolving Treatment Paradigms

Definition and Diagnostic Challenges of Irreversible Pulpitis

Irreversible pulpitis (IP) is a clinical diagnosis indicating that the vital inflamed dental pulp is beyond self-healing, traditionally mandating root canal treatment.[9,12,13] Patients typically present with intense pain episodes, often triggered by thermal stimuli, which may persist even after the stimulus is removed.[7,12,2,5] Other common indicators include pain upon percussion of the tooth and lingering sensitivity to hot, cold, or sweet stimuli that lasts for more than a few seconds.[12] Despite these established clinical indicators, the precision of the diagnostic term "irreversible pulpitis" has faced scrutiny.[9] A growing body of evidence suggests that clinical symptoms do not always perfectly correlate with the actual histological condition of the pulp.[9,7,1] There is a recognized absence of reliable tools or tests that can accurately measure the precise depth and extent of pulpal inflammation.[9,1]

This diagnostic ambiguity presents a significant challenge in treatment planning. This discrepancy in diagnosis leads to a profound implication: teeth that have historically been considered "beyond repair" and thus requiring complete pulp removal might, in fact, retain healthy, vital radicular pulp tissue capable of healing.[9,4] This biological reality provides a fundamental rationale for the re-emergence of vital pulp therapies (VPT) such as pulpotomy, signaling a shift in the treatment paradigm from radical extirpation to selective tissue preservation.

Overview of Traditional Root Canal Treatment (RCT) and the Re-emerging Role of Vital Pulp Therapy (VPT)

Traditional root canal treatment (RCT) is a widely performed dental procedure. It involves the complete removal of the dental pulp from both the crown and the root canals, followed by thorough cleaning, shaping, filling, and sealing of the prepared canals.[2,14,13] For an extended period, RCT has been the cornerstone treatment for teeth diagnosed with irreversible pulpitis and pulp necrosis.[9,12,1,13] While generally successful, with reported success rates reaching up to 95% [1], RCT is also known to be an expensive and time-consuming procedure that demands meticulous clinical skills.[9,1,8,3,15,4] Furthermore, it can compromise the structural and functional integrity of the dentin-pulp complex.[1] and may increase the tooth's susceptibility to fracture over time.[1,8,15,4]

In contrast, pulpotomy, a form of vital pulp therapy (VPT), involves the selective removal of only the inflamed coronal pulp, with the deliberate aim of preserving the vitality of the radicular pulp.[9,1,14,8,4,16,10,17] Traditionally, pulpotomy was indicated primarily for primary teeth and immature permanent teeth.[1,14,8,4,16] However, significant advancements in the understanding of pulp biology, coupled with the development and introduction of advanced bio-ceramic materials, have prompted a re-evaluation of pulpotomy as a definitive treatment option for mature permanent teeth presenting with irreversible pulpitis.[9,7,1,8,15,4,10,13,18,5] This approach aligns seamlessly with the principles of minimally invasive dentistry.[9, 8,4,10]

Pulpotomy represents a less invasive procedure compared to complete root canal treatment, designed to preserve more of the natural tooth structure and its inherent vitality.[14,8,4,16] The increasing acceptance of pulpotomy is driven by a deeper biological understanding—the capacity to preserve vital tissue—and practical considerations, including reduced invasiveness, lower cost, and less treatment time. This indicates a significant, broader trend in dentistry toward more conservative, tissue-preserving treatments, moving away from radical extirpation when a viable alternative exists. This evolution is a direct consequence of scientific progress in both materials' science and biological knowledge.

Pulpotomy in Mature Permanent Teeth with Irreversible Pulpitis

Clinical and Radiographic Success Rates

Pulpotomy in mature permanent teeth diagnosed with irreversible pulpitis has demonstrated encouraging success rates[9,7,1,8,3,4,10,13,5,6] Meta-analyses have reported pooled success rates ranging from 82.4% to 86.7%.[9,1,8] Some systematic reviews indicate high success rates, exceeding 90%, at a 1-year follow-up period.[9] Individual studies further support these findings, with clinical success rates as high as 97.3% and radiographic success rates of 93.3% at 12 months.[3] Other reviews have shown overall clinical success rates varying from 66% to 100% and radiographic success rates from 68% to 100%.[1]

For teeth exhibiting symptomatic irreversible pulpitis (SIP), one study reported a five-year success rate for full pulpotomy (FP) at 78%, noting a significantly increased success rate ($p=0.04$) in cases without pre-existing periapical pathosis or involvement (PPI).[13] The success rate for partial pulpotomy (PP) or full pulpotomy (FP) in SIP teeth was found to be 90%, a figure not significantly different from the 97% success rate observed in teeth with normal pulp or reversible pulpitis (NP/RP).[13] These consistently high reported success rates for pulpotomy in mature permanent teeth with irreversible pulpitis, often explicitly stated as comparable to traditional RCT, suggest a strong emerging trend for this procedure to be considered a primary treatment option rather than merely a last resort or a treatment exclusively for immature teeth. This shifts the clinical decision-making framework, potentially positioning pulpotomy as the preferred initial approach given its other inherent advantages, marking a significant evolution in endodontic practice.

Key Factors Influencing Outcomes

Several critical factors significantly influence the success of pulpotomy in mature permanent teeth with irreversible pulpitis.

The choice of pulp capping material plays a crucial role in the treatment outcome.[7,1,8,13,18] Bio -ceramic materials, such as Mineral Trioxide Aggregate (MTA) and Biodentine, are recommended due to their more favorable outcomes compared to conventional calcium hydroxide.[7,1,8,13,18] Specifically, MTA and Biodentine demonstrated higher success rates (88.2% and 97.5%, respectively) compared to 79.1% for conventional calcium hydroxide.[8] Biodentine offers additional advantages, including faster setting, higher strength, and, notably, the absence of tooth discoloration (zero percent of cases), unlike MTA, which can cause significant discoloration (83% of cases) attributed to its bismuth oxide content.[13,18]

Achieving hemostasis, or the control of pulpal bleeding, within a short timeframe (e.g., within six minutes) is paramount and strongly correlated with improved pulpotomy success.[13] If hemostasis can be achieved within 1 to 10 minutes, it suggests that the inflammation is likely confined to the coronal pulp, indicating a better prognosis for the procedure.[1]

Regarding preoperative symptoms and periapical status, while some studies indicate no significant difference in success rates between symptomatic and asymptomatic irreversible pulpitis.[13], others suggest that teeth with symptomatic irreversible pulpitis (SIP) but without periapical pathosis or involvement (PPI) show a significantly increased success rate.[9,13] Furthermore, the healing of pre-existing periapical rarefaction has been observed following pulpotomy treatment.[1]

For teeth diagnosed with SIP or extremely deep caries, complete caries removal is recommended to adequately expose the pulp and facilitate effective treatment.[13] Interestingly, root maturity does not appear to significantly affect the success of partial or full pulpotomy in teeth with normal pulp/reversible pulpitis.[10,13] nor does it seem to significantly influence pulpotomy success in permanent teeth with carious pulp exposure.[8,13]

The strong correlation between specific biomaterials (MTA and Biodentine) and successful outcomes, coupled with the critical importance of achieving effective hemostasis, indicates that the technical execution of the procedure and the precise selection of materials are not merely contributing factors but are fundamental determinants of pulpotomy success. This implies that for pulpotomy to be consistently successful and predictable, clinicians must adhere to strict, evidence-based protocols concerning material usage and bleeding control, refining the procedure from a general concept to a highly specific, technique-sensitive intervention.

ADVANTAGES

Pulpotomy offers several compelling advantages, making it an increasingly attractive option for managing irreversible pulpitis in mature permanent teeth.

A significant biological advantage is tooth structure preservation. Pulpotomy is a minimally invasive approach that preserves the vitality of the radicular pulp, thereby maintaining the natural vascularization and nutritional supply of the dental pulp.[1,14,8,4,16] This preservation is crucial for the long-term health and structural integrity of the tooth [4] and aligns with the overarching principles of minimally invasive dentistry.[8, 4]

Pulpotomy also offers considerable benefits in terms of chair time and cost-effectiveness. It is a significantly quicker and more economical solution compared to conventional root canal procedures.[7,8,3,4] One comparative study reported that the average treatment time for full pulpotomy was 43.5 minutes, which was significantly lower than the 112.5 minutes required for RCT.[3] Similarly, the average cost for pulpotomy was markedly less than for RCT.[3] This cost-effectiveness makes pulpotomy a more affordable option, particularly advantageous in regions with limited access to advanced dental equipment, such as radiography units essential for RCT, or in countries where conventional RCT is not covered by public health insurance, thereby preserving tooth functionality at a more accessible rate.[7,3,4]

Another notable advantage is faster pain relief. Pulpotomy consistently provides more rapid and significant pain reduction compared to RCT.[7,3,4,5] A study indicated that the pulpotomy group experienced a significantly greater reduction in pain intensity than the RCT group at day 1 (mean 2.3 vs. 5.5, respectively; $P < 0.05$).[3] Approximately 30% of patients receiving pulpotomy reported complete pain relief (score 0) one day after treatment, a more substantial decrease than observed in the RCT group.[3] Furthermore, fewer patients required analgesics following pulpotomy.[5] This rapid pain relief is attributed to a swift decrease in local tissue pressure and inflammatory mediators.[3]

While specific complications are not extensively detailed for pulpotomy in all available literature, its less invasive nature, preservation of vital tissue, and faster pain relief inherently suggest a potentially smoother and less traumatic postoperative course compared to RCT, which can sometimes induce mechanical, chemical, or microbial irritation to periapical tissues. [3,4]

The rapid and significant pain relief, coupled with reduced chair time and lower cost, has profound implications beyond just clinical efficacy. These factors directly address major barriers to dental care, particularly in underserved

populations or regions where advanced dental equipment is limited or public health insurance coverage for RCT is lacking.[4] This suggests that pulpotomy could significantly improve access to and uptake of endodontic treatment, leading to better overall oral health outcomes on a population level. Moreover, reduced discomfort and shorter appointment times can enhance patient compliance and their willingness to seek timely dental care.[4]

Limitations And Controversies

Despite the promising results, the effectiveness of pulpotomy in mature permanent teeth with irreversible pulpitis remains a subject of some controversy.[9,1,4] The current evidence base from systematic reviews is often considered insufficient, with some reviews rated as critically low quality due to methodological limitations, including a lack of bias assessment, poor reporting, and the absence of certainty grading.[8,4] The heterogeneity among included randomized controlled trials (RCTs) in terms of materials used, diagnostic criteria, outcome definitions, and follow-up durations further complicates direct comparison and the generalizability of findings.[4]

While clinical success rates are encouraging, radiographic success rates exhibit wider variation, ranging from 38.4% to 95%.[4] Long-term data is still considered limited; some reviews suggest that success rates for pulpotomy may potentially decline over extended periods (e.g., from 89% at 1 year to 63% at 10 years in one review).[1]
As previously discussed, the variability in clinical symptoms often does not accurately reflect the true extent of pulpal pathology, which complicates precise diagnosis and appropriate case selection for pulpotomy. [9,7,1,4]

Reported complications specifically associated with pulpotomy include the development of painful pulpitis, pulpal obliteration, and periapical rarefaction.[1] While not extensively detailed in all available literature, the potential for pulpotomy failure necessitating subsequent root canal treatment or even extraction does exist.[3]

The identified limitations in evidence certainty, such as critically low-quality systematic reviews, relatively short follow-up durations, and significant heterogeneity among studies, create a critical need for more robust, high-quality, long-term randomized controlled trials directly comparing pulpotomy with RCT. Without this stronger evidence, the widespread and definitive adoption of pulpotomy as a first-line treatment for irreversible pulpitis in mature permanent teeth will likely remain cautious, necessitating strict case selection and clinician reliance on individual judgment. This points to a crucial area for future research and the development of more definitive, evidence-based clinical guidelines.

Single-Visit Root Canal Treatment in Mature Permanent Teeth with Irreversible Pulpitis

Clinical and Radiographic Success Rates

Root canal treatment (RCT) is a widely accepted and generally successful procedure for managing irreversible pulpitis. [1,2] Studies consistently report high success rates, reaching up to 95%, for RCT in teeth diagnosed with this condition.[1]
A key area of comparison within RCT is the efficacy of single-visit (SV) versus multiple-visit (MV) approaches. Meta-analyses comparing these two regimens generally indicate no significant difference in long-term complications, overall pain, or radiological failure.[2,11] For instance, one review found no evidence of a difference in radiological failure (risk ratio 0.93, 95% confidence interval 0.81 to 1.07; I2 = 0%; 13 studies, 1505 teeth; moderate-certainty evidence) between single-visit and multiple-visit treatments.[2] This consistent finding of no significant difference in long-term clinical or radiographic outcomes between single-visit and multiple-visit RCT, despite some immediate postoperative differences, strongly supports the clinical efficiency and logistical advantages of single-visit treatment. This trend towards single-visit procedures is driven by patient convenience, requiring fewer appointments, and reduced chair time for the

clinician, provided that long-term outcomes are not compromised. This implies that for many cases, the single-visit approach is a valid, effective, and often preferred option from a logistical standpoint, though clinicians must remain mindful of the immediate postoperative period.

Considerations and Potential Complications

While single-visit RCT offers efficiency, certain considerations and potential complications warrant attention.

Regarding postoperative pain and flare-ups, although the overall risk of pain may not significantly differ between single-visit and multiple-visit RCT.[11], the risk of a flare-up (an acute exacerbation of symptoms) was found to be significantly higher after single-visit treatment (risk ratio 2.13, 95% confidence interval 1.16 to 3.89; very weak evidence).[11] Patients treated over multiple visits were likely to experience less pain in the first week following treatment initiation compared to those treated in a single visit.[2] This suggests that while long-term outcomes are similar, the immediate postoperative period can be more challenging with single-visit RCT.[2]

For teeth with periapical lesions, multiple-visit treatment might be preferred due to the potentially increased risk of flare-ups associated with single-visit treatment.[11] Root tip infections can manifest in various forms, including diffuse infections that may not be clearly visible on dental X-rays, or localized cyst-like infections that appear as teardrop radiolucencies.[19]

A significant concern with RCT is its potential to compromise the structural integrity of the tooth. By involving the complete removal of pulp and extensive preparation of root canals, RCT can weaken the tooth structure, potentially increasing its susceptibility to fracture over time.[1,8,15,4]

Finally, in terms of cost and time, RCT is generally more expensive and time-consuming compared to pulpotomy.[8,3,4]

The increased risk of immediate postoperative flare-ups in single-visit RCT, particularly for teeth with pre-existing periapical lesions.[11], indicates that while the single-visit approach is generally effective and efficient, it necessitates careful patient selection and risk stratification. Clinicians must balance the convenience of a single visit against the patient's immediate comfort and the potential for acute complications, especially in cases with existing periapical pathology. This necessitates individualized treatment planning rather than a one-size-fits-all approach for single-visit RCT, prioritizing patient well-being and proactively managing expectations.

Comparative Analysis: Clinical Outcomes

Pain Relief and Postoperative Symptoms

A critical aspect of comparing these two treatment modalities is their impact on pain and postoperative symptoms. Full pulpotomy consistently demonstrates faster and more significant pain relief compared to RCT.[7,3,4,5] One study reported that the pulpotomy group experienced a significantly greater reduction in pain intensity than the RCT group at day 1 (mean 2.3 vs. 5.5, respectively; $P < 0.05$).[3] Approximately 30% of patients in the pulpotomy group reported complete pain relief (score 0) one day after treatment, a more substantial decrease than observed in the RCT group.[3] Furthermore, fewer patients required analgesics after pulpotomy.[5] This rapid pain relief following pulpotomy is attributed to a quick decrease in local tissue pressure and inflammatory mediators.[3]

In contrast, RCT can result in a higher incidence of postoperative pain, potentially due to periapical tissue contamination and irritation from root canal instruments, which may induce mechanical, chemical, or microbial

damage.[3,4] Specifically, single-visit RCT may lead to a higher proportion of participants reporting pain within one week compared to multiple-visit groups.[2,13] The rapid and significant pain relief offered by pulpotomy is a critical patient-reported outcome that can profoundly influence patient satisfaction and acceptance of the procedure. Beyond purely clinical success, the immediate alleviation of symptoms can significantly enhance the patient's perception of treatment effectiveness and their overall quality of life. This makes pulpotomy a potentially more appealing option for patients primarily seeking quick symptomatic relief and a less arduous immediate postoperative experience.

Functional Tooth Preservation and Vitality

The fundamental difference between pulpotomy and RCT lies in their approach to pulp tissue. Pulpotomy's primary objective is to preserve the vitality of the radicular pulp, thereby maintaining the tooth's neurosensory ability and proprioception.[1,14,8,4,16] This preservation of the tooth's natural biological functions, including its vascularization and nutritional supply, is crucial for its long-term health and functional integrity.[8,4] In some instances, teeth in the full pulpotomy group that were initially unresponsive to electric pulp testing (EPT) at 3 months regained responsiveness at 6 months, indicating preserved vitality and healing potential.[3]

Conversely, RCT involves the complete removal of the pulp, rendering the tooth non-vital.[16] While the tooth structure remains, a non-vital tooth loses its natural sensory feedback and intrinsic defense mechanisms. Over time, such teeth may become more prone to fracture due to dehydration and the absence of proprioception.[1,8,15,4] The preservation of pulp vitality through pulpotomy represents a profound biological advantage over complete pulp extirpation. A vital tooth retains its natural defense mechanisms against further insults, its sensory feedback (e.g., to biting forces and temperature changes), and potentially its long-term structural integrity more effectively than a non-vital tooth. This translates to a more natural "feel" for the patient during mastication and potentially a reduced risk of future complications associated with brittle, non-vital teeth, contributing significantly to better long-term functional tooth preservation and overall oral health.

Patient-Reported Outcomes and Quality of Life

Patient satisfaction and quality of life are increasingly recognized as vital measures of treatment success. Patients consistently report higher general satisfaction with pulpotomy, primarily attributing this to the significantly reduced time and cost involved.[7,3,15,4,5] Specifically, patient satisfaction with pulpotomy surpassed that with RCT in terms of the time commitment, intraoperative pain experienced, overall pleasantness of the procedure, and cost.[5]

Both pulpotomy and RCT were found to improve the Oral Health Impact Profile (OHIP) Quality of Life (QOL) of patients.[15,5] Notably, no statistically significant differences were observed between the two treatment groups in terms of QOL improvement at the 1-year follow-up.[5] While both treatments effectively improve overall quality of life by resolving the underlying pulpitis and associated pain, pulpotomy's specific advantages in terms of reduced chair time, lower financial burden, and faster pain relief directly translate into enhanced patient satisfaction.[7,3,15,4,5] This underscores the critical importance of considering patient-reported outcomes beyond purely clinical metrics. A treatment that is perceived as less burdensome financially and temporally, while achieving comparable clinical results, contributes significantly to a holistic positive patient experience and can strongly influence treatment choice and patient compliance.

Treatment Time and Cost-Effectiveness

Pulpotomy is considerably more time-efficient and cost-effective than RCT.[7,8,3,4] A comparative study found that the average treatment time for full pulpotomy was 43.5 minutes, which was significantly lower than the 112.5 minutes required for the RCT group ($P < 0.05$).[3] Similarly, the average cost for pulpotomy was RMB 882 (approximately 124.36 USD), significantly lower than RMB 1985.5 (approximately 279.95 USD) for the RCT group ($P < 0.05$).[3]

The inherent cost-effectiveness of pulpotomy makes it particularly beneficial in regions with limited access to advanced dental equipment, such as radiography units, or in countries where conventional RCT is not covered by public health insurance. In such contexts, pulpotomy can preserve the tooth's functionality at a more affordable rate.[7,3,4] The substantial differences in treatment time and cost between pulpotomy and RCT have significant implications for healthcare systems and global oral health initiatives. Widespread adoption of pulpotomy, where clinically appropriate, could alleviate financial burdens on both individual patients and healthcare providers, dramatically increase treatment accessibility in underserved areas, and potentially free up resources for other essential dental needs. This suggests a strategic public health benefit of integrating pulpotomy more broadly into standard care protocols, moving beyond individual patient benefits to systemic advantages.

Comparative Analysis : Radiographic Outcomes

Periapical Healing and Lesion Resolution

Radiographic outcomes, particularly periapical healing and lesion resolution, are crucial indicators of treatment success.[1,2,3,15] Both pulpotomy and RCT demonstrate high and comparable radiographic success rates.[1,2,3,6] For instance, the full pulpotomy group exhibited a radiographic success rate of 93.3%, while the RCT group showed a comparable rate of 94.6%.[3]

Studies have specifically documented the healing of periapical rarefaction following pulpotomy treatment.[1] This healing is linked to the resolution of neurogenic inflammation that precedes pulpal necrosis, indicating the capacity of the preserved vital pulp to promote periapical tissue repair.[1] The observation that pulpotomy, a vital pulp therapy that preserves the radicular pulp, can achieve periapical healing comparable to full pulp extirpation (RCT) is a critical validation of its biological efficacy. It implies that complete removal of the pulp is not always necessary to resolve periapical pathology. Rather, selective removal of the inflamed coronal pulp, combined with effective hemostasis and biocompatible materials, is sufficient to allow the remaining vital radicular pulp to heal and promote periapical tissue regeneration. This finding strongly reinforces the paradigm shift towards vital pulp preservation as a biologically sound and effective treatment strategy.

Dentin Bridge Formation (for Pulpotomy)

Dentin bridge formation is a recognized radiographic and histological indicator of successful pulpal healing after pulpotomy, signifying the formation of a hard-tissue barrier over the exposed pulp.[7,20] This calcific barrier acts as a protective layer for the underlying vital pulp tissue.[20]

Dentin bridge formation has been observed in a subset of pulpotomy cases, for example, in five out of twenty teeth in one study.[7]

Success criteria for pulpotomy often include the presence of a radiographically observed and clinically verified hard-tissue barrier.[15,20] However, a nuanced understanding has emerged regarding its interpretation. The absence of dentin bridge formation has been noted in some cases that were otherwise clinically asymptomatic and lacked prominent periapical radiolucency, suggesting that its absence does not necessarily indicate treatment failure or a lack of vitality.[3] The reasons for this lack of visible response without clinical symptoms could include deep restoration affecting electric pulp test reliability, increased fibrous components in the pulp tissue, or chronic necrosis.[3] While dentin bridge formation is a recognized and desirable sign of successful pulpal healing, its absence in clinically and radiographically asymptomatic cases introduces a critical nuance to the definition of pulpotomy success.

This suggests that the biological response to pulpotomy can vary, and healing might occur through different mechanisms (e.g., fibrous tissue formation or continued vitality without a visible calcific barrier) that still maintain pulp vitality and tooth function. Clinicians should therefore interpret radiographic findings holistically, considering clinical symptoms and functional outcomes alongside the presence or absence of a dentin bridge.

Key Differences: Pulpotomy vs. Single-Visit RCT

Feature	Pulpotomy	Single-Visit RCT
Goal	Preserve vital radicular pulp	Remove all pulp (vital or necrotic)
Scope	Coronal pulp removal only	Complete pulp removal from crown and roots
Indication	Mild/moderate pulpitis, vital root pulp	Irreversible pulpitis, necrotic pulp, infection
Tooth Type	Primarily primary teeth; immature permanent	Permanent teeth, primary teeth (less common)
Complexity	Less complex, shorter	More complex, longer
Cost	Lower	Higher
Success Rate	Good for specific indications	High for definitive treatment

The Role of Artificial Intelligence (AI) in Pulpotomy and RCT[21,22,23,24,25,26,27]

AI is revolutionizing dentistry, enhancing diagnosis, treatment planning, and outcomes for procedures like pulpotomy and RCT.[21,22]

1. Enhanced Diagnosis

Image Analysis: AI algorithms can analyze dental radiographs (periapical, panoramic, CBCT scans) to detect subtle signs of pulp inflammation, periapical lesions, and anatomical variations (e.g., accessory canals, calcified canals) with greater accuracy than the human eye.[23]

Early Detection: AI can assist in early detection of caries extending close to the pulp, helping clinicians decide between vital pulp therapies and full RCT.[24]

Pulp Status Assessment: Machine learning models can integrate clinical symptoms, patient history, and imaging data to predict the pulp's vitality and inflammation status more reliably.[25]

2. Precision Treatment Planning

Automated Canal Tracing: AI can automatically trace root canals in 3D CBCT scans, providing precise measurements of length, curvature, and morphology, which is crucial for accurate shaping and obturation.[23]

Risk Assessment: AI can identify potential procedural risks (e.g., perforations, instrument separation) based on tooth anatomy and suggest safer treatment approaches.[22]

Material Selection: AI can recommend the most appropriate biocompatible materials for pulpotomy or root canal sealers based on patient factors and clinical evidence.[21]

3. Prognosis Prediction

Outcome Prediction: AI models can predict the long-term success rates of pulpotomy or RCT based on various pre-operative factors, helping clinicians set realistic expectations with patients.[25]

Failure Identification: AI can monitor post-treatment radiographs for signs of healing or failure, alerting clinicians to potential issues early.[24]

4. Automation and Efficiency

Automated Measurements: AI can automate tedious measurements of root canal lengths, saving time and reducing human error.[23]

Workflow Optimization: AI-powered systems can streamline documentation, billing, and patient management, allowing dentists to focus more on clinical care.[21]

Surgical Navigation: In the future, AI could guide robotic systems for highly precise canal preparation and obturation, especially in complex cases.[22]

5. Education and Training

Simulations: AI-powered virtual reality (VR) and augmented reality (AR) simulations can provide realistic training environments for dental students and practitioners to practice pulpotomy and RCT procedures, improving their skills before working on actual patients.[24]

Feedback Systems: AI can provide real-time feedback on technique, instrument usage, and canal preparation, accelerating the learning curve.[25]

CONCLUSIONS

The evolving understanding of pulp biology, coupled with advancements in biocompatible materials, is driving a paradigm shift towards more conservative, patient-centered endodontic approaches. Pulpotomy is increasingly recognized as a viable and often superior option for select cases of irreversible pulpitis in mature permanent teeth, particularly when considering patient comfort, cost, time efficiency, and the preservation of natural tooth vitality. Future research should focus on high-quality, long-term studies to further solidify the evidence and refine clinical guidelines, ensuring that treatment decisions are optimally tailored to individual patient needs and clinical presentations.

Both pulpotomy and single-visit RCT are vital procedures for preserving natural teeth. The choice depends on the extent of pulp involvement and the tooth's vitality. As AI continues to advance, its integration into endodontic practice promises to enhance diagnostic accuracy, refine treatment planning, improve procedural precision, and ultimately lead to better patient outcomes in both pulpotomy and RCT.

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