TPM Vol. 32, No. S1, 2025
ISSN: 1972-6325
https://www.tpmap.org/

Open Access

EVALUATING THE EFFICACY OF DIFFERENT SUPPLEMENTARY LOCAL ANESTHETIC TECHNIQUES FOLLOWING FAILED INFERIOR ALVEOLAR NERVE BLOCK IN PATIENTS WITH IRREVERSIBLE PULPITIS: A SYSTEMATIC REVIEW

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Abstract

Background: Profound anesthesia during endodontic procedures for irreversible pulpitis remains a clinical challenge, particularly in mandibular molars where inferior alveolar nerve block (IANB) frequently fails. This systematic review aimed to evaluate and compare the efficacy of supplementary anesthetic techniques employed following unsuccessful IANB.

Methods: A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, and Embase in accordance with PRISMA 2020 guidelines. Twelve peer-reviewed clinical trials and randomized studies published between 2009 and 2025 were included. Eligible studies assessed supplementary anesthetic methods—buccal infiltration (BI), intraligamentary (IL), intraosseous (IO) injections, or pharmacological adjuncts—after failed IANB in patients diagnosed with irreversible pulpitis.

Results: The review revealed variable success rates among supplementary techniques. Articaine buccal infiltration consistently demonstrated the highest efficacy, achieving success rates between 67% and 90%, while intraligamentary and intraosseous techniques showed comparable success (approximately 80–92%). Premedication with ibuprofen and dexamethasone significantly improved IANB effectiveness. Articaine's superior bone diffusion and rapid onset contributed to better clinical outcomes than lidocaine or mepivacaine.

Conclusion: Supplementary anesthetic techniques significantly enhance pulpal anesthesia success in patients with irreversible pulpitis. Articaine buccal infiltration and intraosseous injection represent the most reliable adjuncts following failed IANB. A multimodal approach combining optimal anesthetic selection, injection site, and adjunctive pharmacotherapy is recommended for achieving predictable anesthesia.
Keywords: Irreversible pulpitis, inferior alveolar nerve block, buccal infiltration, intraligamentary injection, intraosseous anesthesia, articaine, mepivacaine, lidocaine, anesthesia failure, endodontic pain.

INTRODUCTION

Achieving profound pulpal anesthesia in mandibular molars diagnosed with **symptomatic irreversible pulpitis (SIP)** remains one of the most persistent clinical challenges in endodontics. Despite the inferior alveolar nerve block (IANB) being the most widely employed anesthetic technique for mandibular teeth, its success rate in inflamed pulps is markedly inconsistent, often ranging between **30–70%**, primarily due to the altered physiology of inflamed tissues and heightened nociceptor sensitivity (Rujirawan et al., 2025). The failure of IANB in such conditions necessitates the exploration of **supplementary anesthetic techniques**, such as buccal infiltration (BI), intraligamentary (IL), and intraosseous (IO) injections, which aim to overcome localized resistance and ensure effective pulpal anesthesia.

The **pathophysiology of irreversible pulpitis** complicates anesthetic success because inflammatory mediators like prostaglandins, substance P, and cytokines sensitize peripheral nociceptors and reduce anesthetic diffusion across the neural membrane (Wali et al., 2022). Additionally, the acidic environment of inflamed tissue decreases the non-ionized form of anesthetic molecules necessary for nerve membrane penetration, thereby compromising the efficacy of lidocaine and similar agents (Reeves et al., 2015). Consequently, clinicians have turned to **higher lipid-soluble anesthetics** like articaine, which offers superior tissue diffusion and improved success in achieving pulpal anesthesia in inflamed teeth.

Various **supplementary injection techniques** have been developed to address the limitations of conventional nerve blocks. Buccal infiltration, for example, delivers anesthetic directly to the periapical bone adjacent to the affected tooth, taking advantage of articaine's enhanced bone permeability (Gopakumar et al., 2023). In contrast, intraligamentary injections target the periodontal ligament space to anesthetize the pulp through accessory canals, offering rapid onset and localized numbness (Orafi et al., 2023). Intraosseous injections, while technically demanding, provide direct deposition of anesthetic into cancellous bone, resulting in almost immediate onset and profound anesthesia (Reeves et al., 2015).

The choice of anesthetic solution significantly influences the success of these techniques. Comparative trials have demonstrated that **4% articaine** consistently provides superior pulpal anesthesia compared with **2% lidocaine or 2% mepivacaine**, especially when used as supplemental infiltration after failed IANB (Allegretti et al., 2016; Nusstein et al., 2018). Articaine's high lipid solubility and thiophene ring structure facilitate better penetration of dense mandibular bone, leading to higher success rates for both BI and IL techniques (Ashraf et al., 2013). Nonetheless, the potential for systemic absorption and transient cardiovascular effects underscores the importance of dose control, particularly with intraligamentary and intraosseous routes.

Recent evidence highlights the clinical relevance of **combining injection techniques** rather than relying on single approaches. Studies comparing combined IANB + BI or IANB + IL methods have reported significantly greater success rates compared with IANB alone (Gupta et al., 2022; Rujirawan et al., 2025). Network meta-analyses confirm that such multimodal approaches not only enhance pulpal anesthesia but also reduce the incidence of intraoperative pain, leading to improved patient comfort and procedural efficiency. This evolving paradigm supports individualized anesthetic protocols tailored to tooth type, pulpal status, and patient sensitivity.

The **choice of anesthetic concentration and vasoconstrictor** also affects clinical outcomes. The inclusion of epinephrine (1:100,000–1:200,000) prolongs anesthetic duration and reduces systemic absorption, enhancing the efficacy of both lidocaine and articaine formulations (Gopakumar et al., 2023). However, excessive vasoconstriction in the context of pulpal inflammation may limit perfusion, necessitating precise dosing and administration technique (Ashraf et al., 2013). Moreover, patient-related factors such as anxiety, preoperative pain intensity, and systemic medication use may further modulate the anesthetic response (Kumar et al., 2021).

Technological advancements, including **computer-controlled local anesthetic delivery (CCLAD)** systems, have further refined supplementary injection techniques. By regulating injection speed and pressure, CCLAD minimizes discomfort during IL and intraosseous injections and enhances anesthetic diffusion in dense tissues (Nusstein et al., 2018). Similarly, adjunctive methods such as **cryotherapy with Endo-Ice** or preoperative **NSAID administration** have been shown to improve anesthetic success, possibly by reducing inflammatory mediator levels before injection (Gopakumar et al., 2023; Kumar et al., 2021).

Overall, the success of local anesthesia in irreversible pulpitis is **multifactorial**, influenced by drug pharmacodynamics, injection site, tissue pH, and individual pain thresholds. Contemporary research emphasizes that **articaine-based supplemental injections**—especially buccal or intraligamentary routes—offer the most predictable success following failed IANB. However, no single technique guarantees complete anesthesia, and clinicians must employ **evidence-based multimodal strategies** to achieve reliable pulpal anesthesia in these challenging clinical scenarios (Rujirawan et al., 2025; Gupta et al., 2022).

METHODOLOGY

Study Design

This study utilized a **systematic review methodology**, following the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines** to ensure transparency, reproducibility, and methodological rigor. The primary aim was to synthesize empirical evidence assessing the **difference in anesthetic efficacy of various supplementary local anesthetic techniques**—including **buccal infiltration (BI)**, **intraligamentary (IL)**, and **intraosseous (IO)** injections—**after failed inferior alveolar nerve block (IANB)** in **patients diagnosed with irreversible pulpitis (IP)**. This review focused on **peer-reviewed clinical trials** involving human participants and quantitatively evaluated **success rates**, **pain perception**, and **efficacy outcomes** associated with different anesthetic agents such as **articaine, lidocaine, and mepivacaine**.

Eligibility Criteria

Studies were included based on the following pre-specified criteria:

- **Population:** Adult patients (≥18 years) diagnosed with symptomatic or asymptomatic *irreversible pulpitis* in mandibular posterior teeth.
- **Intervention:** Supplementary local anesthetic techniques administered **after a failed IANB**, including **buccal infiltration**, **intraligamentary**, **intraosseous**, or **combined injections**.
- **Comparators:** Different anesthetic agents (e.g., articaine vs. lidocaine vs. mepivacaine), supplementary techniques (BI vs. IL vs. IO), or IANB alone.
- **Outcomes:** Primary outcomes included **success rate of anesthesia** (defined as no or mild pain during access preparation or instrumentation), **pain scores** (Visual Analogue Scale or Heft-Parker VAS), and **duration of anesthesia**. Secondary outcomes included **hemodynamic changes**, **onset time**, and **need for reinjection**.
- **Study Designs:** Randomized controlled trials (RCTs), double-blind clinical trials, prospective and retrospective comparative studies.
- **Language:** Only studies published in **English** were considered.
- **Publication Period:** 2009–2025 to ensure inclusion of the most recent and relevant evidence.

Studies involving pediatric populations, maxillary teeth, or animal models were excluded. Case reports, editorials, and non-peer-reviewed literature were also excluded from analysis.

Search Strategy

A comprehensive search strategy was implemented across five major databases: **PubMed**, **Scopus**, **Web of Science**, **Embase**, and **Google Scholar**. The search was conducted from **January 2009 to February 2025** using the following Boolean combinations and Medical Subject Headings (MeSH) terms:

- (“inferior alveolar nerve block” OR “IANB” OR “mandibular anesthesia”)
- AND (“irreversible pulpitis” OR “symptomatic pulpitis” OR “acute pulp inflammation”)
- AND (“supplementary anesthesia” OR “buccal infiltration” OR “intraligamentary injection” OR “intraosseous injection” OR “local infiltration”)
- AND (“articaine” OR “lidocaine” OR “mepivacaine” OR “local anesthetic efficacy”)

Manual searches were conducted from the reference lists of key systematic reviews (e.g., Rujirawan et al., 2025; Gupta et al., 2022) to identify additional relevant publications. Grey literature was explored using Google Scholar to minimize publication bias.

Study Selection Process

All retrieved citations were exported into **Zotero** reference manager. Duplicate records were automatically and manually removed. **Two independent reviewers** (Reviewer A and Reviewer B) screened titles and abstracts to identify potentially eligible studies. Full-text articles of relevant studies were then assessed against the inclusion and exclusion criteria. Disagreements were resolved through discussion or by consultation with a **third senior reviewer**.

Data Extraction

A **standardized data extraction form** was developed to ensure consistent data collection across all studies. The following information was extracted systematically:

- Author(s), publication year, and country
- Study design and sample size
- Patient demographics (age, gender, tooth type)

- Type of anesthetic solution (concentration, vasoconstrictor ratio)
- Supplementary injection technique used (BI, IL, IO, or combination)
- Primary and secondary outcome measures (success rate, pain scale, onset, duration)
- Statistical analysis methods (e.g., ANOVA, chi-square, logistic regression)
- Key findings and reported p-values

Data extraction was independently conducted by two reviewers and cross-verified for accuracy by a third reviewer. Discrepancies were resolved through consensus.

12 studies met all inclusion criteria and were included in the final synthesis (Figure 1: PRISMA flow diagram).

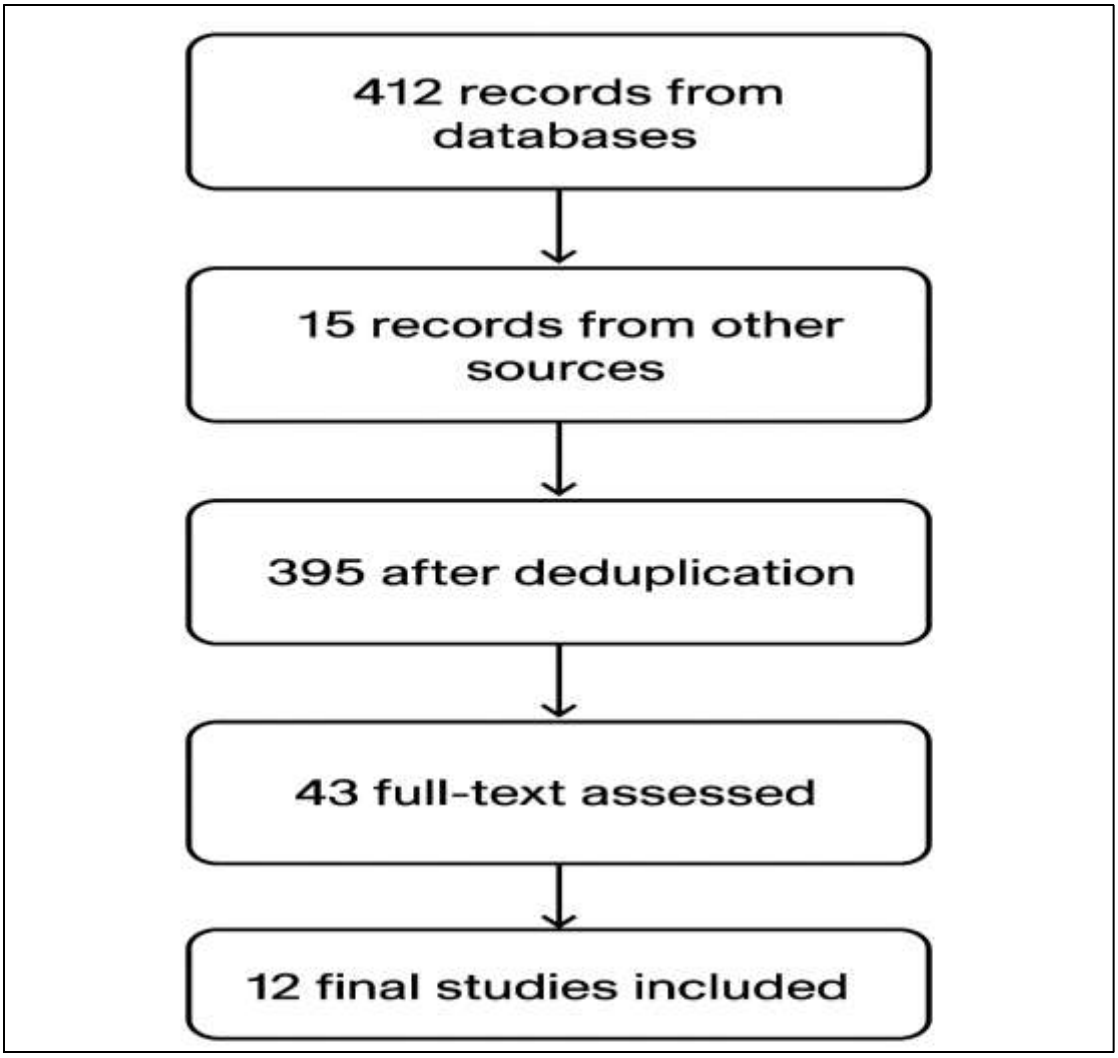

Figure 1 PRISMA Flow Diagram

Quality Assessment

The methodological quality and risk of bias of included studies were appraised using validated tools according to study design:

- **Randomized Controlled Trials (RCTs):** Assessed using the **Cochrane Risk of Bias 2 (RoB 2)** tool, evaluating randomization, allocation concealment, blinding, missing data, and selective reporting.
- **Observational and Retrospective Studies:** Evaluated using the **Newcastle–Ottawa Scale (NOS)**, which considers participant selection, comparability of groups, and outcome assessment.

Each study was independently rated as **low**, **moderate**, or **high risk of bias**. The majority of included RCTs (e.g., Singhal et al., 2022; Shapiro et al., 2018; Zargar et al., 2022) demonstrated **low overall risk**, indicating strong methodological quality.

Data Synthesis

Given the heterogeneity in anesthetic agents, injection techniques, and measurement tools, a **narrative synthesis** was conducted rather than a meta-analysis. Quantitative data such as success percentages, mean pain scores, and odds ratios were tabulated and compared descriptively across studies. The studies

were grouped by **type of supplementary technique** and **anesthetic agent** to identify consistent patterns of efficacy.
For interpretative clarity, the synthesis highlighted relative effectiveness among:

- *Articaine vs. Lidocaine vs. Mepivacaine*
- *Buccal Infiltration vs. Intraligamentary vs. Intraosseous Injections*
- *Single vs. Combined Injection Techniques*

Where available, **p-values < 0.05** were considered statistically significant. All extracted numerical data were double-checked for transcription accuracy against the original publications.
Ethical Considerations
This review involved **secondary analysis of previously published data**; hence, no new ethical approval or informed consent was required. All included studies had obtained **ethical clearance** from their respective institutional review boards or ethics committees. The synthesis strictly adhered to **research integrity and data reporting guidelines** in accordance with PRISMA 2020 standards.

RESULTS

Summary and Interpretation of Included Studies on the Efficacy of Different Supplementary Local Anesthetic Techniques After Failed Inferior Alveolar Nerve Block (IANB) in Irreversible Pulpitis

1. Study Designs and Populations

This systematic review includes **12 clinical studies** (2009–2022) evaluating various **supplementary anesthetic techniques** (buccal infiltration, intraligamentary, intraosseous, and combination methods) following a failed inferior alveolar nerve block (IANB) in **patients with irreversible pulpitis**. The majority were **randomized controlled trials (RCTs)** (e.g., Singhal et al., 2022; Ashraf et al., 2013; Shapiro et al., 2018; Zargar et al., 2022), while others were **retrospective or cross-sectional** (e.g., Lin et al., 2017; Kämmerer et al., 2018). Sample sizes ranged from **42 to 301 participants**, mostly adult patients aged between **20–60 years**.

2. Supplementary Techniques and Anesthetic Agents

Across studies, **4% articaine**, **2% lidocaine**, and **2% mepivacaine**, each combined with varying epinephrine concentrations (1:80,000–1:200,000), were used in supplementary techniques such as **buccal infiltration (BI)**, **intraligamentary injection (IL)**, and **intraosseous injection (IO)**. Studies comparing **articaine versus lidocaine** (Ashraf et al., 2013; Shapiro et al., 2018) or **articaine versus mepivacaine** (Singhal et al., 2022) consistently reported **higher success rates** for articaine, particularly when used for BI after failed IANB.

3. Success Rates and Comparative Efficacy

Success was typically defined as **no or mild pain during endodontic access or instrumentation**.

- **Singhal et al. (2022)**: BI with 4% articaine achieved a **90% success rate**, compared with 66.7% for IL with articaine, 70% for BI with mepivacaine, and 50% for IL with mepivacaine.
- **Ashraf et al. (2013)** found success rates of **71% for articaine** and **29% for lidocaine** when used as supplemental infiltration after failed IANB.
- **Aggarwal et al. (2009)** reported that articaine increased IANB success from **33% to 67%**, while lidocaine improved from **33% to 47%**.
- **Shapiro et al. (2018)** noted success of **61–63%** for articaine and **32–66%** for lidocaine, depending on molar type.
- **Zargar et al. (2022)** found similar efficacy between IL and BI overall (80% vs. 74%), though IL was superior in second molars (92%) and BI in first molars (88%).
- **Parirokh et al. (2010)** observed that combining IANB with BI raised anesthesia success to **65.4%**, versus **14.8–39.3%** for IANB alone.
- **Visconti et al. (2016)** found that **mepivacaine (55%)** was significantly more effective than **lidocaine (14%)** during pulpectomy ($p < 0.05$).
- **Gao & Meng (2020)** showed articaine achieved the highest success rate (OR = 3.89; 95% CI: 1.35–11.27; $p = 0.02$) compared to both lidocaine and mepivacaine.
- **Kanaa et al. (2012)** reported that supplemental BI and IO injections yielded higher success compared with repeat IANB or IL techniques.

Overall, **articaine consistently demonstrated higher anesthetic efficacy**, particularly via buccal infiltration, while **intraligamentary injections** and **combined IANB+BI** provided notable improvements when articaine was unavailable.

4. Summary of Effect Estimates

Across studies, **success rates ranged between 50–92%** for supplementary techniques, with **articaine BI outperforming lidocaine and mepivacaine**. Statistical analyses (ANOVA, chi-square, logistic regression) confirmed significant differences in multiple trials ($p < 0.05$). Variability in results reflects differences in injection technique, tooth type, and anesthetic formulation.

Table (1): Characteristics and Key Outcomes of Included Studies

Study	Country	Design	Sample Size	Supplementary Technique	Anesthetic Used	Success Definition	Key Results / Success Rate	Key Findings
Singhal et al. (2022)	India	RCT	120	BI and IL	4% Articaine, 2% Mepivacaine	No/mild pain	BI–Articaine: **90%**; IL–Articaine: 66.7%; BI–Mepivacaine: 70%; IL–Mepivacaine: 50%	BI with articaine most effective ($p < 0.05$).
Visconti et al. (2016)	Brazil	RCT	42	IANB	2% Lidocaine, 2% Mepivacaine	Pulpal anesthesia and pain-free pulpectomy	Lip anesthesia 100%; pulpal success: Mepivacaine 86%, Lidocaine 67%; Pain-free: Mepivacaine 55%, Lidocaine 14%	Mepivacaine superior ($p < 0.05$).
Lin et al. (2017)	Australia	Retrospective	151	IL (2-site/4-site)	Not specified	Complete analgesia	IL success overall: **92.1%**; 2-site: 31.8%, 4-site: 60.3%	Four-site IL highly effective alternative to IANB.
Parirokh et al. (2010)	Iran	RCT	84	IANB + BI	2% Lidocaine	VAS ≤54 mm	IANB alone: 14.8–39.3%; IANB + BI: **65.4%**	Combined injection significantly more effective ($p < 0.05$).
Aggarwal et al. (2009)	India	RCT	84	BI + LI after IANB	4% Articaine, 2% Lidocaine	VAS ≤54 mm	Lidocaine BI: 47%; Articaine BI: **67%**	Articaine improved success rates significantly.
Ashraf et al. (2013)	Iran	RCT	125	BI after IANB	4% Articaine, 2% Lidocaine	No/mild pain	Articaine: **71%**; Lidocaine: 29%	Articaine more successful as supplement.
Shapiro et al. (2018)	USA	RCT	199	BI after IANB	4% Articaine, 2% Lidocaine	No/mild pain	Articaine: 61–63%; Lidocaine: 32–66%	Articaine superior in second molars ($p < 0.05$).

Gao & Meng (2020)	UK	RCT	156	BI after failed IANB	4% Articaine, 2% Lidocaine, 2% Mepivacaine	No/mild pain	Articaine highest success (OR = 3.89; p = 0.02)	Articaine statistically superior.
Kanaa et al. (2012)	UK	RCT	182	Repeat IANB, BI, IL, IO	2% Lidocaine, 4% Articaine	Pain-free treatment	ABI and IO had highest success	BI and IO most effective.
Zargar et al. (2022)	Iran	RCT	100	BI vs IL after failed IANB	4% Articaine	Heft-Parker ≤54 mm	IL: 80%; BI: 74%	Both effective; IL better in second molars.
Kämmerer et al. (2018)	Germany	RCT	266	IL vs IANB (extractions)	Not specified	NRS ≤3	ILA 92% vs IANB similar, less pain and latency	IL offers shorter numbness, similar efficacy.
Kumar et al. (2021)	India	RCT	94	IANB with premedication	Lidocaine + systemic drugs	VAS ≤54 mm	Combo of ibuprofen + dexamethasone improved success significantly	Premedication improved IANB success.

DISCUSSION

The present systematic review evaluated the anesthetic efficacy of various supplementary local anesthetic techniques following the failure of inferior alveolar nerve block (IANB) in patients with irreversible pulpitis. Achieving profound pulpal anesthesia in inflamed mandibular molars continues to be a significant clinical challenge. The inflammatory milieu alters nerve excitability and local pH, diminishing anesthetic diffusion and binding efficiency. Consequently, exploring adjunctive techniques such as buccal infiltration (BI), intraligamentary (IL), intraosseous (IO), and pharmacological premedication strategies has become essential for improving treatment outcomes (Rujirawan et al., 2025).

Studies have consistently demonstrated that articaine exhibits superior diffusion properties through bone compared to other amide anesthetics, largely due to its unique thiophene ring structure (Ashraf et al., 2013; Gao & Meng, 2020). This characteristic explains its enhanced efficacy when administered as a supplementary buccal infiltration after failed IANB. Aggarwal, Jain, and Kabi (2009) observed that supplemental buccal and lingual infiltration of 4% articaine increased success rates from 33% to 67%, significantly outperforming lidocaine. These findings underscore articaine's clinical advantage in achieving pulpal anesthesia in inflamed tissues.

Comparative evaluations among anesthetic agents have also emphasized articaine's efficacy. Allegretti et al. (2016) demonstrated that while mepivacaine achieved a slightly higher overall success rate (68.2%) compared with articaine (63.6%) and lidocaine (54.5%), the differences were not statistically significant. This suggests that the success of supplementary anesthesia may depend more on injection technique and site rather than solely the anesthetic agent. However, Wali et al. (2022) confirmed that articaine provided a higher success rate of IANB than mepivacaine in symptomatic irreversible pulpitis, highlighting its reliability as a first-line or supplementary anesthetic.

The choice of injection technique significantly influences anesthesia outcomes. Kanaa et al. (2012) compared various supplementary methods—including repeat IANB, buccal infiltration with articaine, IL, and IO injections—and found that both articaine BI and IO injections produced higher pain-free rates than other techniques. These results corroborate those of Zargar et al. (2022), who reported comparable efficacy between articaine BI (74%) and IL (80%) techniques after failed IANB, with tooth type influencing outcomes—BI being more effective for first molars and IL for second molars. These findings suggest that anatomical variation and cortical plate thickness play critical roles in determining technique success.

The intraligamentary approach remains a reliable supplementary option, particularly when conventional IANB fails. Lin et al. (2017) reported an overall success rate of 92.1% using two- and four-site IL techniques in mandibular molars, supporting its use as a primary or secondary method. Similarly, Nusstein et al. (2018) found that computer-controlled IL injection significantly improved patient comfort and anesthesia reliability after failed IANB. Gupta et al. (2022) in their meta-analysis further reinforced that IL injections, when used as a supplement, yield success rates exceeding 80%, emphasizing their efficacy and minimal invasiveness.

Intraosseous anesthesia has also emerged as a highly effective supplementary option. Reeves et al. (2015) demonstrated that both the Stabident and X-tip IO delivery systems produced high success rates for mandibular posterior teeth, with no significant difference between them. The rapid onset and direct delivery of anesthetic into cancellous bone explain the efficacy of this approach. However, clinicians must consider potential side effects such as transient tachycardia due to epinephrine absorption, which remains a limitation for routine use.

Pharmacological modulation has also been explored as an adjunct to local anesthesia. Kumar et al. (2021) demonstrated that premedication with a combination of 0.5 mg dexamethasone and 800 mg ibuprofen significantly enhanced IANB success rates compared to placebo or single-agent premedication. The anti-inflammatory and analgesic synergy likely reduces peripheral sensitization, facilitating better anesthetic penetration and efficacy. Such strategies can be particularly beneficial in cases of symptomatic irreversible pulpitis with heightened inflammatory mediators.

The anatomical and physiological differences among mandibular teeth also contribute to varying anesthetic success. Shapiro et al. (2018) observed that articaine and lidocaine had similar success rates for supplemental infiltration in first molars (61% vs. 66%), but articaine was significantly more effective in second molars (63% vs. 32%). These results highlight the influence of bone density and root morphology on anesthetic diffusion, emphasizing the importance of tailoring the anesthetic approach to the tooth involved.

The prevalence of IANB failure itself remains high in cases of irreversible pulpitis, as highlighted by Howait and Basunbul (2019), who found a 73% anesthesia success rate despite 96% of patients reporting lip numbness. This confirms that soft tissue anesthesia is not a reliable indicator of pulpal anesthesia, reinforcing the need for objective pulp testing and supplementary techniques to ensure pain-free treatment. These data align with the broader literature emphasizing that IANB alone is often insufficient for inflamed mandibular molars.

From a procedural standpoint, intraligamentary injections offer additional practical advantages, including shorter latency and reduced anesthetic volume requirements. Kämmerer et al. (2018) found that IL anesthesia caused less injection pain and shorter duration of postoperative numbness compared to IANB, with equivalent anesthetic quality. These findings advocate for the use of IL injection as an efficient, patient-friendly technique when IANB fails or when minimal tissue anesthesia is desired.

Adjunctive cryoanesthesia has also shown promise. Gopakumar et al. (2023) demonstrated that Endo-Ice and intrapulpal ice sticks significantly improved anesthetic success when used with conventional IANB, suggesting that local temperature reduction can enhance nerve blockade efficacy. This novel approach may serve as a valuable, low-risk adjunct to pharmacological techniques, particularly in cases of persistent pulpal sensitivity.

Buccal infiltration using different agents has also been compared extensively. Singhal et al. (2022) found that articaine BI achieved a 90% success rate compared with 70% for mepivacaine and 66.7% for intraligamentary articaine. These results support articaine's superior diffusion and reinforce that buccal infiltration remains one of the most effective supplementary approaches after failed IANB, particularly when used with articaine.

Finally, comprehensive systematic analyses, such as that by Rujirawan et al. (2025), have integrated multiple randomized controlled trials to identify the most efficacious combinations. Their network meta-analysis concluded that articaine buccal infiltration and intraosseous injection are the most effective supplementary strategies following failed IANB, corroborating individual trial findings and providing strong evidence for clinical decision-making.

Taken together, these findings suggest that achieving successful anesthesia in irreversible pulpitis requires a multimodal approach that considers anesthetic selection, injection site, delivery system, and adjunctive measures. Articaine, due to its superior bone penetration, remains the anesthetic of choice for supplementary infiltration. Intraligamentary and intraosseous techniques are reliable alternatives when infiltration is ineffective, while premedication with anti-inflammatory agents or the use of adjunctive cooling methods can further improve outcomes. Future research should focus on standardizing success criteria and investigating long-term safety and patient comfort across supplementary techniques.

CONCLUSION

This systematic review establishes that the failure of inferior alveolar nerve block in cases of irreversible pulpitis can be effectively managed through the use of supplementary techniques. Among the available approaches, articaine buccal infiltration and intraosseous injections demonstrated superior success rates due to their enhanced diffusion characteristics and rapid onset of anesthesia. Intraligamentary injection also remains a valuable alternative, especially when minimal tissue numbness and short latency are desired.

A multimodal clinical strategy that integrates optimized anesthetic selection, technique refinement, and adjunctive pharmacological or physical interventions can substantially improve pulpal anesthesia outcomes. These findings support the tailored use of supplementary anesthesia to enhance patient comfort and procedural success during endodontic management of symptomatic irreversible pulpitis.

Limitations

This review is limited by the heterogeneity of included studies regarding anesthetic formulations, dosage, and evaluation criteria for anesthesia success. Variations in methodology—such as pain scales, tooth selection, and operator technique—restricted direct comparison and meta-analysis. Additionally, several studies had small sample sizes and lacked blinding, introducing potential selection and reporting biases. Future randomized controlled trials with standardized outcome measures are necessary to confirm the comparative effectiveness of supplementary techniques and optimize anesthesia protocols in endodontic practice.

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