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Needle-Free and Minimally Invasive Dental Anesthesia Versus Conventional Injection Anesthesia: Evidence-Based Comparison and Clinical Roles

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Abstract. Needle-based local anesthesia, the conventional approach, provides dependable pain control for many dental procedures. That said, the pain caused by needle insertion is a well-recognized source of dental anxiety, and this has driven increasing interest in needle-free and minimally invasive alternatives. Three such approaches are reviewed here: needle-free jet injection anesthesia, topical anesthetic application, and microneedle-assisted anesthesia. Each is compared against conventional injectable anesthesia, on an evidence-based basis, in four domains: anesthetic efficacy, patient experience, safety profile, and suitability across different patient populations. Jet injection and microneedle-assisted techniques cause little procedural pain, but both are constrained by shallow tissue penetration and relatively short-lasting analgesia. Topical anesthesia achieves only superficial analgesia and offers limited value on its own. Conventional injection remains the clinical standard because it can meet the demands of complex, prolonged procedures reaching deeper tissue layers. Needle-free jet injection and microneedle-assisted drug delivery may be workable options for selected superficial procedures and particular patient groups. Even so, the current evidence base is concentrated on pediatric populations, procedures involving maxillary primary teeth, and local infiltration anesthesia, and it does not suffice to justify fully replacing conventional injections. Taken together, needle-free jet injection may serve as an alternative in selected clinical scenarios, while topical and microneedle-assisted anesthesia presently act mainly as adjuncts to conventional injectable anesthesia. An important direction for future research remains the development of devices and anesthetic formulations that can deliver truly painless, deep-penetrating anesthesia.

Keywords: Dental anxiety, needle-free jet injection anesthesia, topical anesthesia, microneedle-assisted anesthesia, conventional injection anesthesia

1. Introduction

Pain control in dentistry rests largely on local anesthesia, which is used across restorative work, endodontic treatment, and tooth extraction. For decades, the standard approach has been needle-based injection, valued for its dependable clinical effect and the familiarity of its administration techniques among practitioners. Even so, the pain of needle insertion and the dental anxiety that

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accompanies it continue to trouble many patients — children and those with needle phobia in particular [1]. To make delivery easier on patients, various needle-free and minimally invasive methods have been introduced into practice over time. Because they promise administration that hurts less and invades tissue less, they have become a focal point for innovation beyond conventional injection-based anesthesia. The techniques now available fall roughly into three groups: needle-free jet injection, topical anesthetic application, and microneedle-assisted anesthesia [1]. What remains unsettled, however, is whether any of these can take the place of conventional injectable anesthesia altogether, or whether they are better confined to adjunctive use — there is no clinical consensus on this question. The clinical evidence reviewed here centers on dental infiltration anesthesia and routine pediatric dental procedures. How far these findings extend to procedures that involve deeper tissues or greater complexity is considered cautiously. Each technique's strengths and drawbacks are then taken up in turn, to judge whether it could stand in for conventional injection.

2. Conventional injectable local anesthesia: the clinical benchmark

Standard injectable dental anesthesia relies on sterile needles and syringes to deliver amide local anesthetics — lidocaine and articaine among them — via routine techniques such as mucosal infiltration and nerve blocks. The agents reach submucosal or subperiosteal sites in the operative area, or the tissue around a nerve trunk, where they interrupt nerve impulse conduction so that clinical procedures can be carried out painlessly. This approach is broadly accepted as the clinical benchmark for dental local anesthesia [2]. Its main advantages can be summarized as follows: 1. Onset is reliable, and the duration of action can be adjusted to clinical needs, so the analgesic demands of longer, moderately to highly invasive procedures — complex tooth extractions, root canal treatment, and periodontal flap surgery — are met. Used for suitable indications and given correctly, conventional injection anesthesia delivers fairly consistent, controllable local anesthesia in deeper tissues. 2. Enough anesthetic penetration allows pain control in deep soft tissue and bone, which makes the technique suitable for the great majority of dental procedures. There are, however, clear clinical limitations. One review notes that needle-related anxiety is fairly common among dental patients and may weaken cooperation during treatment in children as well as adherence in adults [3]. Taken together, the chief strengths of conventional injection anesthesia lie in its high efficacy, wide applicability, and dependable performance, and these characteristics supply the main criteria for the comparative evaluation of needle-free and minimally invasive techniques that follows.

3. Classification and characteristics of needle-free and minimally invasive dental anesthesia techniques

Needle-free and minimally invasive local anesthetic approaches in dentistry fall into three categories based on how they work, how the drug is delivered, and how much tissue trauma they cause: needle-free jet injection, topical anesthetic application, and microneedle-assisted anesthesia. These approaches differ considerably in their clinical roles, mechanisms of action, advantages, and limitations, so each is suited to different clinical settings. Their main characteristics are outlined below.

Jet injectors deliver anesthetic solutions into tissues under high pressure without needles. They are mainly used to achieve regional anesthesia [4]. Devices in common use include the INJEX and Comfort-In needle-free injection systems [5]. Among the advantages reported are avoidance of needle-puncture trauma and its complications, less fear of needles, even distribution of the

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anesthetic solution, rapid onset of anesthesia, control over the dose given, and reduced drug wastage [6]. Intraoperative pain scores have been reported as significantly lower than with conventional injection anesthesia. The technique does, however, have several limitations. Because penetration is limited, high-pressure jet injection achieves only superficial mucosal infiltration anesthesia and does not reach deeper bone tissue or nerve trunks. Anesthesia is also relatively short-lived, so supplemental dosing is needed in most clinical settings. Equipment acquisition and maintenance costs are comparatively high, and administration is relatively complex. For these reasons, the technique is unsuitable for prolonged, highly invasive dental surgery.

Among minimally invasive ways of achieving dental anesthesia, topical application is the simplest and most commonly used. Typical products are gels or sprays with a local anesthetic such as lidocaine or benzocaine. The agent is applied or sprayed straight onto the oral mucosa at the treatment site, penetrating the epithelium and blocking conduction in superficial nerve endings to produce surface analgesia. The procedure is easy to perform, noninvasive, and usually painless, and no special delivery equipment is needed. It can quickly relieve stinging pain on the mucosal surface and is well tolerated by patients, which makes it particularly useful as pretreatment before dental work in children and anxious patients. Its main drawback is that it generally cannot anesthetize the pulp, bone, or deeper soft tissues, so its use is mostly limited to easing the pain of needle insertion and superficial procedures. Local and systemic adverse reactions are uncommon, yet careful dose control and attention to specific risks are still required.

Microneedle-assisted dental anesthesia delivers local anesthetics to the oral mucosa or gingiva through arrays of micrometer-scale needles, making the procedure minimally invasive. It is meant to replace or supplement conventional local anesthetic injections. By improving mucosal penetration of topical anesthetics, microneedles may lessen the pain of later injections or superficial local procedures. The available evidence, however, comes mostly from studies with small sample sizes and from specific applications involving the palatal mucosa, so how far this approach can replace conventional injection anesthesia in clinical practice is still unclear.

4. Comparison of clinical evidence across anesthetic techniques

This section compares conventional injection anesthesia with three needle-free or minimally invasive alternatives, drawing on recent randomized controlled trials, meta-analyses, and systematic reviews. The comparison covers four domains: anesthetic efficacy; patient pain, anxiety, and preferences; clinical safety; and patient suitability. Sample sizes across the included studies are taken into account when weighing confidence in the evidence, so as to limit the influence of bias from individual studies and give an objective picture of clinical efficacy.

About anesthetic efficacy, needle-free jet injection produces a noticeably faster onset than conventional injection for superficial mucosal infiltration. For superficial procedures — among them restorative work on maxillary primary molars and excision of small mucosal masses — reported anesthetic success rates show no statistically significant difference. A randomized controlled trial published in 2026 recorded lower heart rates during anesthetic administration in children treated with the Comfort-In™ needle-free jet injector, which points to reduced anxiety. These children also received more favorable Wong – Baker FACES pain scores and behavioral ratings than children given conventional needle injections. When analgesia must reach deeper tissues, however — root canal treatment, extractions extending into deeper structures, and periodontal flap surgery — the limited penetration of needle-free jet injection leads to significantly higher rates of anesthetic failure and intraoperative pain compared with conventional injection. In a pilot randomized controlled trial published in 2022, the needle-free device worked in six of eight

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maxillary extraction cases, a success rate of 75%. This suggests that needle-free anesthesia alone may not suffice for extraction in every patient [7]. Microneedle-assisted anesthesia performs at an intermediate level, between needle-free jet injection and conventional injection: its success rates approach those of conventional injection for superficial tissues and tissues of intermediate depth. One study randomly assigned 90 children aged 7 – 11 years who needed tooth extraction to three groups: conventional palatal injection, EMLA cream alone, or EMLA cream plus a microneedle patch. EMLA, whether or not paired with microneedles, provided enough palatal tissue anesthesia, so both approaches qualify as effective alternatives to conventional palatal injection in children [8]. The duration of analgesia remains limited, though, and reliability drops during prolonged procedures. Taken together, conventional injection still offers the best overall combination of reliability, depth, and duration; needle-free jet injection fits only superficial procedures, microneedle-assisted anesthesia suits procedures of moderate complexity, and topical anesthesia cannot stand alone as an anesthetic technique.

When it comes to patient pain, anxiety, and preferences, several stratified controlled studies have found markedly lower intraoperative pain scores on the numerical rating scale (NRS) and lower dental anxiety scores with needle-free jet injection and topical anesthesia than with conventional injection or microneedle-assisted anesthesia. In a pediatric study, the median Face, Legs, Activity, Cry, Consolability (FLACC) pain score was 2 in the needle-free jet injection group versus 7 in the conventional injection group, a difference that reached statistical significance. Cooperation during treatment reportedly improved by more than 40% [9]. Microneedle-assisted anesthesia produces only mild insertion pain, and patients prefer it over conventional injection. Even so, the minor tissue trauma that microneedles cause comes with higher anxiety scores than those seen with entirely needle-free techniques. With conventional injection, needle-insertion pain is a major source of dental fear. Long-term clinical follow-up, however, has shown greater acceptance of conventional anesthesia among adults, who care more about anesthetic reliability and achieving successful anesthesia without repeat administration and who tolerate mild insertion pain better. Patient responses to these techniques differ more sharply in children and people with needle phobia, and less so in the general adult population.

When it comes to clinical safety, multicenter comparative studies have found no statistically significant differences in how often serious adverse reactions occur across the four techniques. These studies reported no major adverse events, such as anaphylactic shock or severe nerve injury. With conventional injection anesthesia, the main risks are needle-related hematoma, mucosal injury, and transient numbness. Needle-free jet injection removes needle-puncture injuries, though the high-pressure delivery can lead to localized mucosal congestion and transient swelling. Microneedle-assisted anesthesia carries similar risks to conventional injection, albeit milder. For topical anesthesia, adverse reactions consist mainly of localized mucosal numbness and mild allergic reactions, giving this approach the most favorable systemic safety profile of the four.

When it comes to patient suitability, needle-free jet injection and topical anesthesia work best for children, adolescents, patients with needle phobia or marked anxiety, and those having superficial, minimally invasive procedures. Microneedle-assisted anesthesia fits patients who are sensitive to pain, refuse injections with conventional larger-diameter needles, and need anesthesia of tissues at intermediate depths. Conventional injection anesthesia covers the widest range of ages and levels of procedural complexity, particularly for complex surgery, procedures involving deeper tissues, and pain control in severe pulpitis. For older adults and patients with coagulation disorders, needle-free and minimally invasive approaches can avoid puncture-related bleeding and are safer. In highly

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cooperative adults, conventional injection anesthesia is more cost-effective and more reliable as an anesthetic method.

5. Discussion of clinical roles

Judged by how well they work and what clinical evidence exists, needle-free and minimally invasive dental anesthetic techniques fit into three clinical situations: as possible alternatives for certain superficial procedures, as adjuncts to routine care, and as approaches that cannot yet take the place of conventional injection anesthesia when procedures are complex. Framed this way, their complementary roles become clearer, as does how far they might substitute for the conventional injection.

Where substitution is possible at all, it is mostly confined to brief, superficial dental procedures with little tissue trauma [10]. Examples include removing superficial carious tissue from primary teeth in children, superficial mucosal debridement, scaling at localized sensitive sites, and superficial mucosal biopsy — in other words, situations where the deeper tissues do not need to be anesthetized. In selected cases, needle-free jet injection can serve as an alternative to conventional injection, providing enough anesthesia while markedly reducing pain and anxiety and making the experience better for the patient. Several clinical studies back up its feasibility for these settings. For patients with a severe fear of needles, measures to improve comfort — topical anesthesia, behavioral interventions, needle-free anesthetic pretreatment, or others — may be prioritized so that injection-related discomfort is reduced [11]. When deeper tissues or a nerve block must be anesthetized, conventional local anesthesia should remain the foundation of pain control.

For most routine dental work, these methods play a supporting role alongside conventional injection anesthesia. In moderately complex procedures — root canal treatment in primary teeth, simple restorations in permanent teeth, or minor periodontal scaling — a topical anesthetic can be applied beforehand to lessen the pain and discomfort caused by mucosal needle insertion during the conventional injection [11]. Needle-free jet injection may add further local analgesia during treatment when superficial analgesia proves insufficient. On their own, however, needle-free and minimally invasive techniques cannot achieve enough anesthesia in these situations. What they offer is limited to making the anesthesia experience more comfortable for the patient, while conventional injection still provides the main analgesic effect.

These needle-free approaches are not now suited to complex, deep, or prolonged oral surgical procedures as stand-alone alternatives to conventional injection anesthesia. Complex tooth extraction, root canal treatment in permanent teeth, periodontal flap surgery, alveolar bone recontouring, and dental implant surgery all call for reliable, sustained analgesia of deeper tissues. Jet injection offers limited penetration and duration, topical anesthesia cannot reach deep tissues, and microneedle-assisted anesthesia has not shown enough reliability [12]. For interventions that involve deeper tissues, such as root canal treatment, the evidence is inconsistent. A few recent studies have described effective anesthesia using specific needle-free articaine protocols. Even so, independent replication, multicenter studies, and long-term safety data are still lacking, so the available evidence does not justify routine use of these methods in place of conventional injection. In short, needle-free jet injection, topical anesthesia, and microneedle-assisted anesthesia are not yet capable of replacing conventional injection as the main anesthetic technique for complex procedures involving deep tissues. That said, topical anesthesia and other minimally invasive options may still be applied before injection to improve patient comfort [10].

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6. Conclusion

Needle-free and minimally invasive local anesthetic techniques, together with conventional injectable anesthesia, each have their own strengths and drawbacks. They cannot simply replace one another across the board; rather, they can complement each other or serve as substitutes in particular clinical settings. Injectable anesthesia continues to be the standard of care for long or complicated procedures and for those involving deeper tissue planes. For certain superficial infiltration procedures, needle-free jet injection is a workable alternative, especially in children and in patients afraid of needles. Topical and microneedle-assisted anesthesia are, at present, used mainly as adjuncts, and the evidence base supporting microneedle-assisted methods is still developing. Larger randomized controlled trials with sound designs are needed, stratified by patient age, tooth location, procedure type, and depth of anesthesia required, along with standardized outcome measures covering pain, anesthetic success rates, and the need for supplemental anesthesia. Additional work on oral mucosal microneedle array patches, nanocarrier delivery systems, and liposomal or hydrogel-based formulations for sustained anesthetic release could help move the field toward atraumatic, painless dental anesthesia.

References

[1] Zhang, Z. H., & Liang, X. H. (2026). Research progress in delivery methods for local anesthetics in dentistry. *Beijing Journal of Stomatology, 34*(2), 142–147. doi:10.20049/j.bjkqyx.1006-673X.2026.02.014.

[2] Remi, R. V., Anantharaj, A., Praveen, P., Prathibha, R. S., & Sudhir, R. (2023). Advances in pediatric dentistry: New approaches to pain control and anxiety reduction in children - a narrative review. *J Dent Anesth Pain Med, 23*(6), 303–315. doi:10.17245/jdapm.2023.23.6.303. Epub 2023 Nov 27. PMID: 38076502, PMCID: PMC10703556.

[3] Wang, X., & Liu, M. (2023). Ya ke wu zhen zhu she ma zui yu chuan tong zhu she ma zui de teng tong ji jiao lv dui bi yan jiu [Comparison of pain and anxiety between needle-free injection anesthesia and traditional injection anesthesia in dentistry]. *Lin Chuang Kou Qiang Yi Xue Za Zhi, 39*(2), 112–115.

[4] Chen, L., & Zhang, W. (2022). A review of the association between dental anxiety and local anesthetic techniques [J]. *Chinese Journal of Practical Stomatology, 15*(3), 345–349.

[5] Kadam, U., Kalaskar, R., Kalaskar, A. R., Sharma, N., & Jagtap, S. (2026). Comparative evaluation of pain perception between needleless jet infiltration anaesthesia and conventional needle anaesthesia for maxillary primary molars in children: A systematic review and meta-analysis. *Cureus, 18*(1).

[6] Qian, S., Meng, Z., Zhang, H., Li, K., Zhang, F., Zhang, S., Liu, J., & Zhou, Z. (2025). Articaine needle - free anesthesia vs conventional anesthesia in root canal treatment of irreversible pulpitis in permanent teeth: A prospective study on anesthetic efficacy and effects on pain. *J Pain Res, 18*, 2115–2125.

[7] Belevcikli, Altan, Demir. Effect of the new needle-free injection system on pain perception and dental anxiety during anesthesia: randomized controlled split-mouth study. *Journal of Dental Anesthesia and Pain Medicine, 23*(1), 1–8.

[8] Brunton, P. A., McLean, M., Vedagiri, S., McKeage, J., Ruddy, B., Weatherly, K., White, D., Taberner, A., & Loch, C. (2022). Jet injection needle-free dental anaesthesia: Initial findings. *J Dent, 122*, 104165. doi:10.1016/j.jdent.2022.104165. Epub 2022 May 14. PMID: 35580835.

[9] Maganur, P. C. (2025). Pain and anxiety levels during dental restorations in primary molars: INJEX needleless system vs traditional syringe. *Med Sci Monit, 31*.

[10] Kim, S. K., et al. (2021). Needle-free injection systems for local anesthesia in dentistry: A systematic review. *J Dent Anesth Pain Med, 21*(5), 383–397. doi:10.17245/jdapm.2021.21.5.383.

[11] Orenius, T., Säilä, H., Mikola, K., & Ristolainen, L. (2018). Fear of injections and needle phobia among children and adolescents: An overview of psychological, behavioral, and contextual factors. *SAGE Open Nurs, 4*, 2377960818759442. doi:10.1177/2377960818759442.

[12] Malamed, S. F. (2020). *Handbook of local anesthesia* (7th ed.). Elsevier.