REVIEW ARTICLE

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The feasibility of needleless jet injection versus conventional needle local anesthesia during dental procedures: a systematic review

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Abstract (J Korean Assoc Oral Maxillofac Surg 2022;48:331-341)

This systematic review evaluates current evidence regarding the feasibility of using needleless jet injection instead of a conventional local anesthetic needle. EBSCO, ProQuest, PubMed, and Scopus databases were used to identify relevant literature published in English from 2005 to 2020. Ten studies were selected. Five of them were randomized clinical trials, 3 case-control studies, and 2 equivalence trials. Using the Critical Appraisal Skills Program checklist, 6 studies scored between 67% and 100%, and 4 studies scored between 34% and 66%. According to Jadad's scale, 2 studies were considered strong, and 8 studies were considered moderate in quality. The results of the 10 studies showed differences in patient preference for needleless jet injection. Needleless injection technique has been found to be particularly useful in uncooperative patients with anxiety and needle phobia. Needleless jet injection is not technique sensitive. However, with needleless jet anesthesia, most treatments require additional anesthesia. Conventional needle anesthesia is less costly, has a longer duration of action, and has better pain control during dental extraction. Needleless jet anesthesia has been shown to be moderately accepted by patients with a fear of needles, has a faster onset of action, and is an efficient alternative to conventional infiltration anesthesia technique.

Key words: Needles, Phobic disorders, Anesthesia, Dentist, Pain

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I. Introduction

One of the most effective ways to control pain during invasive dental procedures is the use of local anesthesia. Anesthesia has been a mainstay in dentistry throughout its history and continues to be important with the increase in advanced techniques and devices[1]. Fear of painful dental injections can lead patients to avoid dental treatments. The idea of receiving an injection is fear-inducing for many individuals, both children and adults. Although such fears are outside the control of dentists, some treatment aspects can be modified to increase patient comfort[2].

Several techniques have been developed to administer painless anesthesia and address this problem, such as topical anesthetic gel or injection site pre-cooling, using vibration or pressure at the injection site, using slower injections with computer-controlled anesthesia delivery systems, and needleless jet injections[2]. Jet injections can be used in dental clinics as a less invasive approach to deliver dental anesthesia with significantly reduced pain for the patient. Jet injection systems deliver an anesthetic solution using high pressure and velocity to achieve mechanical penetration through the oral mucosa[1].

In this study, we consider whether needleless jet injectors have an advantage over the traditional needle in terms of onset of action, duration, mode of secretion, and patient fear. We used a systematic review of the literature to assess the latest evidence on the efficacy of jet injectors versus conventional local anesthesia.

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II. Method

1. Focused question (PICO; Patient, Intervention, Comparison, and Outcome)

The questions of focus here was as follows: In dental procedures, what is the feasibility of using pressure-delivered local anesthesia instead of needled local anesthesia?

2. Search strategy

Online search terms were used to browse literature published between 2005 and 2020 and that was available in the EBSCO, ProQuest, PubMed, and Scopus electronic databases. We used manual searches for our inclusion criteria.

The following combination of keywords was used in each database: ("Pressure anesthesia" AND "dentistry"), ("Needle free anesthesia" AND "dentistry"), ("INJEX" AND "dentistry"), ("Jet Injection" AND "dentistry"), ("Needleless anesthesia" AND "dentistry"), ("Needle anesthesia" AND "dentistry"), ("Local anesthesia" AND "Jet Injection" AND "dentistry"), ("Dental phobia" AND "Needleless anesthesia"), ("Dental phobia" AND "Jet Injection"), ("Needle phobia" AND "Needleless anesthesia"), ("Needle phobia" AND "Jet Injection"), ("Feasibility" AND "Needleless anesthesia" AND "dentistry"), ("Feasibility" AND "Jet Injection" AND "dentistry"), ("Efficacy" AND "Needleless anesthesia" AND "dentistry"), ("Efficacy" AND "Jet Injection" AND "dentistry").

3. Eligibility criteria

In this study, we used the PICO strategy and adopted the following inclusion criteria for studies related to human research: peer-reviewed articles published in the English language and focused on jet injection of local anesthetics. Only randomized clinical trials, clinical trials, and cohort and case-control studies were eligible. Articles focused on general anesthesia, editorials, reviews, magazines, letters, and foreign language articles were excluded.

4. Data extraction

We divided the articles and independently reviewed them manually. This process included three steps: in the first step, we eliminated all duplicate articles. In the second step, we read the titles and abstracts of the articles and removed those unrelated to the topic based on the inclusion criteria. In the third step, we conducted a thorough search by reading the full text of each remaining article. If we all agreed on an article, it was included in the analyses. If we disagreed, we consulted our supervisor.

5. Quality assessment of the studies

To assess the quality of the studies, we used the Critical Appraisal Skills Program (CASP) checklist, which contains 30 questions and was approved by our supervisor. The studies were graded as weak, moderate, or strong based on the total number of 'yes' answers to the questions. Studies that scored 0-33 were considered to provide weak evidence, studies that scored 34-66 were considered to offer moderate evidence, and those that scored 67-100 were considered to provide strong evidence.

6. Data synthesis and analysis

An evidence table was used to summarize the data. The table contained the study design (most articles were randomized clinical trials, and some were case-control studies), author(s) and year of publication, sample size, strength of the paper (CASP score), statistics from the articles, quality of the study, magnitude of benefit, main findings, and limitations.

III. Results

1. Study selection

Our searches returned 374 articles; PubMed (n=42), ProQuest (n=137), EBSCO (n=53), Scopus (n=142). First, duplicate citations were excluded (n=256). Then, we applied our inclusion and exclusion criteria, which yielded 54 remaining articles. The reasons for excluding studies in this step are depicted in our PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram.(Fig. 1) Among the remaining articles, only full text articles were considered. Moreover, other forms of local anesthesia and records from other medical fields were excluded manually. In the end, we selected 10 records as the most relevant articles. The detailed characteristics of each study are depicted in Table 1[3-12] and Table 2[3-12].

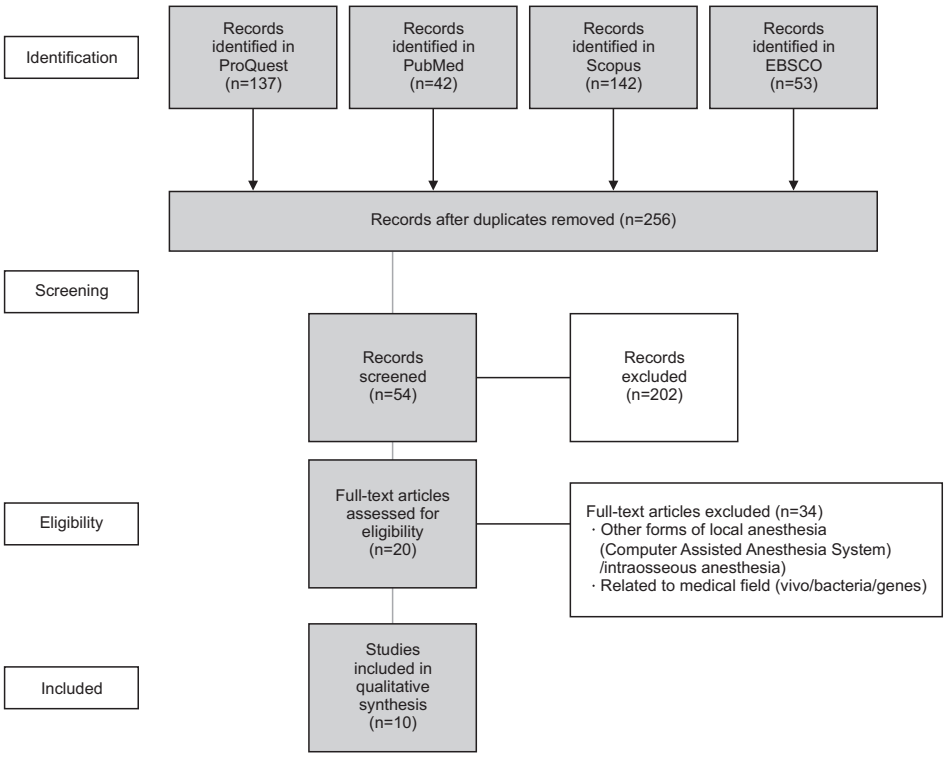

Fig. 1. Summary of the systematic review workflow using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) chart.
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2. Study characteristics

The magnitude of evidence in the 10 studies we selected was moderate in 8 articles and strong in 2 articles. The articles we chose were published between 2005 and 2020. The study quality according to the Jadad et al.'s scale[13] ranged from 2 to 4.

Five of the selected studies were randomized controlled trials, two were equivalence trials, and three were case-control studies. Six of the studies scored high in strength (67%-100% in CASP), and four scored moderate (34%-66% in CASP). All studies reported statistically significant results and contained statistical analyses. Only one study calculated the absolute risk reduction, and it reported visual analog scale (VAS) of 12.2 (range, 0-55.4) for the needleless jet method and of 12.1 (range, 0-53.8) for traditional infiltration anesthesia.

3. Study outcomes

1) Techniques

The use of pressure to safely push 0.1 mL of anesthetic solution into oral tissues at a depth of 2.0 to 2.5 mm[3], which is well-accepted by patients, is the most intriguing aspect of needleless products. With an onset of action of approximately 1 ms, the anesthetic solution infiltrates the tissue in the form of tiny droplets that are instantly taken up by the myelin sheath of the nerve.

The anesthetic system used most often was INJEX, which positions the needle at a 90° angle to the main body, contrary to the Madajet system. Compared with other pressure anesthesia devices, the delivery section forms a 45° angle with the gingiva, resulting in better and easier positioning with full contact with the gingiva, less pressure during administration, and less leakage and bad taste[4].

One study mentioned that the anesthetic solution with the INJEX method should include a vasoconstrictor[5]. Another study mentioned that ice can be used as a pre-cooling technique before using the INJEX[6]. One study used the Madajet XL needleless jet injection[3], whereas the others[5-10] used INJEX.

2) Duration

Compared with needleless jet injection, conventional infiltration anesthesia has a longer anesthetic duration[7] and a slower onset of action[4].

3) Pain assessment method

Three studies used a VAS as the pain assessment method[3,6,7]. One study used an additional verbal rating scale (VRS) for scaling and root planing[3]. Another study conducted an electric pulp test on the tooth before beginning the anesthetic procedure and documented the response[4]. Children's pain

Table 1. Evaluation of the studies included in the final analysis

Study	Condition	Study design	Sample size (n)	Strength of the paper (CASP)	Statistically significant	Quality of study score (Jadad et al.[13])	Quality of study (Jadad et al.[13])	Absolute risk reduction
de Souza Amorim et al.[12] (2020)	Needle-free anesthesia and extractions	Randomized clinical trial	40	90% Strong	Yes	4	Strong	N/A
Arapostathis et al.[8] (2010)	Jet injection INJEX and local infiltration anesthesia	Case-control study	87	66.6% Moderate	Yes	2	Medium	N/A
Bose et al.[6] (2019)	Infiltration and block anesthesia	Randomized clinical trial	100	76.6% Strong	Yes	3	Medium	N/A
Dabarakis et al.[5] (2007)	Jet anesthesia INJEX with two different anesthetic solutions	Randomized clinical trial	32	66.6% Moderate	Yes	3	Medium	N/A
Gupta et al.[3] (2018)	EMLA and needleless jet anesthesia	Equivalence trial	30	83% Strong	Yes	2	Strong	N/A
Makade et al.[4] (2014)	Pressure anesthesia and classical needle infiltration anesthesia	Case-control study	20	70% Strong	Yes	2	Medium	N/A
Ocak et al.[10] (2020)	Local anesthesia procedure, needleless injection, INJEX system, tooth extraction	Case-control study	28	70% Strong	Yes	0	Medium	N/A
de Oliveira et al.[7] (2019)	Local anesthesia was administered with needleless jet injection system and 30-guage short needle	Equivalence trial	41	80% Strong	Yes	3	Medium	The VAS was 12.2 (0-55.4) for the needleless jet method and 12.1 (0-53.8) for the traditional infiltration anesthesia
Kumar[9] (2015)	Clinical uses of various newer delivery systems for local anesthesia in the dental field	Randomized clinical trial	20	66.6% Moderate	Yes	2	Medium	N/A
Szmuk et al.[11] (2005)	Needle phobia, needle pain, and currently available alternatives (such as topical analgesic) used to reduce the intensity of injection pain	Randomized clinical trial	75	66.6% Moderate	Yes	2	Medium	N/A

(CASP: Critical Appraisal Skills Program, N/A: not applicable, VAS: visual analog scale)

Table 2. Outcomes and limitations of the studies included for the final analysis

Study	Main findings (outcomes)	Limitations
de Souza Amorim et al.[12] (2020)	"The liposomal formulation was able to induce adequate anesthesia in palatal mucosa during dental extraction, avoiding the local anesthetic infiltration. For the first time, a topical formulation allowed upper molars surgical removal without injection of any local anesthetic agent into palatal mucosa in adults."	• The study used a minimum sample size of 40 people. • The females made up 80% of the sample and there was minimal pharmacokinetics of drugs explanation.
Arapostathis et al.[8] (2010)	"Our study found that children aged 6 to 11 years preferred the traditional needle injection over the INJEX method. While we did not find gender or age differences, it is possible that these might be found in children of other ages."	• Relatively small sample size • The age and gender were not related to the acceptance or preference of either anesthesia method. • The sample was restricted to children who had never received anesthesia before, and who was also previously rated as non-fearful. • Additional studies should be conducted.
Bose et al.[6] (2019)	Cooling the soft tissue site significantly decreased the perception of pain (both infiltration and block anesthesia) in children during routine dental procedures. It proved to be an easy, reliable, and cost-effective method of local anesthetic administration.	• Relatively small sample size • The reliability of the results could have been further improved by videotaping the injection procedure and allowing a third investigator to evaluate it. • Could have Increased the patient compliance and improved the quality of care. • All the clinicians should be made familiar with this strategy.
Dabarakis et al.[5] (2007)	The INJEX technique exhibits all the advantages of jet anesthesia mentioned in this study. Although it is not a panacea, it is a useful adjunct to local anesthesia. The jet injection technique may be particularly beneficial in pediatric dentistry, where its use would reduce fear of needle view and contribute to limited dose administration, which is an important issue in the local anesthesia in young children.	• Relatively small sample size • The results are not reliable because there are no supportive tables or figures for evidence.
Gupta et al.[3] (2018)	"..It can be concluded under the limits of study that needleless jet device (Madajet) and topical anesthetic gel (EMLA) was effective in controlling pain and was well accepted and preferred by the patient."	• Minimum sample size has been used. • No sample power calculation. • The study relied on pain perception which is subjective and cannot be measured without bias.
Makade et al.[4] (2014)	"This technique may be particularly beneficial in reducing fear from needle view and contribute to limited dose administration which is proved to be beneficial for patients suffering from systemic disorders."	• Relatively small sample size • Additional studies should be conducted. • There were no postoperative complications reports.
Ocak et al.[10] (2020)	"Accordingly, the pain or discomfort score of the INJEX method during tooth extraction was significantly higher. Jet injection with the INJEX was not found to be effective for local infiltrative anesthesia, especially teeth extractions. It may be more acceptable when used previous to classical local infiltration anesthesia by patients. The main problem with jet injection was the "pop" sound when the INJEX device was pressed, and also inadequate supplying the anesthesia."	• Relatively small sample size • Has no evident randomization in the methodology. • The study relied on pain perception which is subjective and cannot be measured without bias. • There needs to be more information regarding the use of INJEX for extractions, not only topical anesthesia prior to extraction, which veered away from the aim of the study.
de Oliveira et al.[7] (2019)	The two anesthetics methods did not differ concerning pain experienced during the anesthesia. The anesthetic latency was 2 minutes for all subjects, and the traditional infiltration anesthesia resulted in a longer anesthetic duration when compared with the needleless jet injection.	• Relatively small sample size • Additional studies should be conducted.
Kumar[9] (2015)	Although the traditional aspirating syringe is the most common method by which local anesthetics are administered, newer technologies have been developed that can assist the dentist in providing enhanced pain relief with reduced injection pain and fewer adverse effects.	• The results are not reliable because there are no supportive tables or figures for evidence. • Additional studies should be conducted.
Szmuk et al.[11] (2005)	The results of this study show that there are various methods used to alleviate pain during dental procedures and that they have to be clinically and cost-effective, needle-less, and ultra-rapidly acting without causing pain or producing frightening sounds when triggered.	• Relatively small sample size • No supportive tables or figures for evidence.

perception was assessed using the WB-FPRS (Wong–Baker Faces Pain Rating Scale) and SEM (sound, eye, motor) scales for soft tissue[6].

4) Pain assessment score results

The VAS pain results revealed no statistical difference between the two approaches in the maxillary first molar[7]. However, VAS and VRS results from scaling and root planing showed that the INJEX provided less pain relief than the traditional method[3].

Two studies concluded that the INJEX method caused significantly more pain and discomfort during tooth extraction than traditional needle anesthesia[4,10]. Nevertheless, needleless injection is recommended as an alternative technique for surface anesthesia before infiltrative anesthesia for tooth extraction in patients with fear of needles[10].

5) Anxiety and fear

According to one of the studies, many needleless methods, including jet injectors, Eutetic Mixture of Local Anesthetics (EMLA), ethyl chloride spray, and Ametop gel, can be used to reduce the pain and anxiety associated with the conventional method[11].

Gupta et al.[3] found that 17 of 30 patients preferred EMLA (56.7%), and 10 patients preferred the Madajet injector (33.3%). The patients of Makade et al.[4] experienced less pain and fear during the procedure with needleless anesthesia. The jet injection technique might be particularly beneficial in pediatric dentistry, where its use could reduce fear and contribute to limited dose administration[4,5], which is an important issue in young children[5].

Needleless jet anesthesia was beneficial for patients suffering from systemic disorders, offered faster drug absorption at the injection site, and involves autoclavable devices[4]. Three studies mentioned patient anxiety related to a popping sound in the teeth when jet injection was triggered[4,10,11]. One study reported that 57.14% of the included patients were bothered by the sound[10], and another reported that 32.3% of patients feared the explosive released of anesthetic solution from the jet injector[9]. Furthermore, 17.6% of the patients experienced pain during jet injection[9]. It was also mentioned that patients showed apprehension about the jet injector due to its bulky appearance[3].

6) Uses and sites

The INJEX device can be used on all primary teeth for restorations and extractions. It can also be used for minor periodontal clinical procedures, Class I and II dental restorations, and vital pulp therapies if the procedure is completed in 20-25 minutes. For pulpectomy procedures, the device can be used for intrapulpal injections[4,7]. Mandibular infiltration is less effective than a mandibular block for lower primary molars in children[8]. Therefore, that study explored upper primary molars and upper and lower incisors and canines, where infiltration anesthesia is effective[8].

For permanent teeth, the INJEX was not effective for tooth extraction[10]. The INJEX jet injector cannot be used for nerve blocks; only infiltration and surface anesthesia are possible[9]. However, Makade et al.[4] found that jet anesthesia was successful for curettage and scaling; mental and nasopalatine blocks; cementing crowns, jackets, bands, and clamps; copper tube impressions; gingivectomies; direct pulp injections; biopsies; and pointing abscesses for incision and drainage procedures.

Local anesthetics applied to the skin will have a minimal effect because the stratum corneum acts as a barrier to drug delivery[9]. Although the anesthesia will wear off faster than that dispensed with a conventional needle, that can be an advantage to cardiac patients because the amount of local anesthesia infiltrate taken up by the nerves is too low to produce a systemic blood level[4].

7) Preference

The various studies differed in their reports of patient preference for pressure anesthesia. Two of the studies were conducted on pediatric patients, and 3 studies did not specify their patient group. Three studies reported that patients preferred the conventional method, and 2 studies reported that patients preferred pressure anesthesia. One study stated, "75% of pediatric patients preferred pressure anesthesia over the conventional method," but another study[4] said, "73.6% of the children preferred [the] conventional method, 5% experienced pain with [the] needleless [system], and 1% experienced pain with [the] traditional injection." The reason for the differing preferences is unclear. Based on our analysis of the limitations of jet anesthesia, the main reason could be the bulky appearance of the needleless anesthesia apparatus, which can cause fear in pediatric patients[8].

One study that did not specify a group stated that "70% of patients preferred pressure anesthesia over 20% of patients who prefer conventional needle anesthesia"[3]. The other two studies showed that 52.8% of patients preferred the conventional injection technique, and only 17.6% of patients preferred pressure anesthesia, with 29.6% expressing no prefer-

ence[4,5].

The bad taste that accompanies administration of anesthesia with the INJEX method had a statistically higher score than that associated with the conventional needle. Moreover, patients experienced significantly more discomfort during injections for pressure anesthesia than during classical infiltration[4]. That could be one reason why a higher percentage of patients preferred conventional over needleless anesthesia[14-18]. The study by Ocak et al.[10] concluded that during tooth extractions, patients were more highly disturbed by the flow of the local anesthetic solution injected using the conventional needle method than by the INJEX system.

8) Disadvantages

Inconveniences of INJEX are that it is more expensive than the conventional needle, involves pressure sensations during anesthetic delivery and has an invasive appearance[10]. Two studies stated that pressure anesthesia has the risk of causing residual hematomas and mucosal bleeding at the injection site[4,10]. Furthermore, patients registered higher bad taste scores for needleless jet anesthesia than for the conventional needle method. There was no postoperative swelling at the injection site in any of the patients[10].

9) Effectiveness

Jet injection technology uses a mechanical energy source to generate enough pressure to force a liquid drug through a very narrow orifice and into the subcutaneous tissues without the use of a needle[9,14,17].

Two studies emphasized management of pain in dentistry by achieving adequate local anesthesia without injecting a local anesthetic at all, instead using only topical anesthesia for dental procedures[11,12]. When comparing the efficacy of pain relief between needleless anesthesia and traditional anesthesia, only one study indicated that needleless devices successfully control pain[8]. The advantages of needleless jet anesthesia are painless injection and less tissue damage, faster injection, and a faster rate of drug absorption into the tissues than with conventional needle delivery[9].

One study found that patients experienced significantly less pain during the anesthetic procedure with pressure anesthesia[4]. However, needleless injectors are rarely suitable for intensive procedures. One study mentioned that administration of mepivacaine 3% using INJEX did not achieve pulp anesthesia in any of 10 patients, although soft tissue anesthesia was successful. In addition, administration of lidocaine with epinephrine using INJEX resulted in pulp anesthesia in only 14 patients, though soft tissue anesthesia was observed in all patients in that group[5].

One study claimed that the INJEX device could be used on all primary teeth for procedures such as restorations and extractions. However, mandibular infiltration using INJEX has been found to be less effective than the mandibular block using the conventional method for several dental procedures on the lower primary molars in children[8,19]. For more invasive procedures, conventional anesthesia is more effective[4]. In adults, onset of needleless jet anesthesia using INJEX seemed to be faster, but the difference was not significant[8].

One study included in this review reported that the Madajet XL needleless injector relieved pain better than EMLA during routine scaling and root planing procedures. In the conventional anesthesia group, 100% of the patients reported moderate pain when no anesthetic was administered, whereas in the Madajet XL (needleless anesthesia) group, 46.7% of the patients reported no pain, and 53.3% reported mild pain[3].

In some studies, patients required additional anesthesia, indicating low effectiveness of the anesthesia. For example, in one study, 28.57% of the patients using the needleless INJEX method required additional anesthesia, compared with 7.14% of patients who received anesthesia with the conventional method[10].

Another study showed that, among the 87 treatment procedures attempted following the use of needleless INJEX, 80.5% of patients required additional anesthesia, compared with 2.3% of those who received conventional infiltration[8]. Thus, conventional infiltration was more effective, acceptable, and preferred compared with the needleless INJEX[8].

IV. Discussion

This systematic review presents data from published studies conducted to determine the feasibility of using needleless anesthesia instead of conventional needle local anesthesia during dental procedures. Based on our review, we can infer that needless jet anesthesia is marginally better preferred in specific type of patients when compared to conventional local anesthesia. Local anesthesia in dentistry provides comfort for patients, but it also provides comfort for clinicians by allowing planned procedures to be carried out under the best possible conditions. Both clinical experience and the literature make it clear that local dental anesthesia is not always as successful as anticipated.

Needleless jet anesthesia is compared with conventional needle anesthesia in Table 3[3-8,10,11,20]. Jet injection technology

Table 3. Comparison between needle-free jet anesthesia and conventional needle anesthesia

Characteristic	Needle-free (jet anesthesia)	Conventional needle	Reference
Mode of action	High pressure forces the anesthetic solution to penetrate the mucosa; the drug infiltrates the tissue in tiny droplets that are then taken up immediately by the myelin sheath of the nerve, with an onset of action of approximately 1 ms	A needle delivers local anesthetic solution directly into the site of action	Makade et al.[4] (2014) Bose et al.[6] (2019)
Technique sensitive	Low	High	Makade et al.[4] (2014)
Duration of action	Shorter anesthetic duration	Longer anesthetic duration	de Oliveira et al.[7] (2019)
Onset of action	Faster onset	Slower onset	Makade et al.[4] (2014)
Pain acceptance	Higher pain during tooth extraction	Lower pain during tooth extraction	Ocak et al.[10] (2020)
Dosage	Limited dose administration	Possibility of overdose	Makade et al.[4] (2014)
Fear	No needle	Fear from needle view	Makade et al.[4] (2014) Dabarakis et al.[5] (2007)
	Fear due popping sound of the teeth	No popping sounds	Szmuk et al.[11] (2005) Ocak et al.[10] (2020) Makade et al.[4] (2014)
	Fear of bulky appearance	N/A	Gupta et al.[3] (2018)
Cost	High	Low	Ocak et al.[10] (2020)
Additional anesthesia	Most procedures needed	Most did not need	Ocak et al.[10] (2020) Arapostathis et al.[8] (2010)
Spread of infection	No needle	Needle prick injury	Makade et al.[4] (2014)
	Improper sterilization		Szmuk et al.[11] (2005)
Administration techniques	Infiltration	Infiltration, nerve block, intraosseous, intraligamentary, intrapulpal	Gupta et al.[3] (2018) Reed et al.[20] (2012)
Acceptance	There is controversy about pediatric patient preferences.		Makade et al.[4] (2014)
	One study supported needleless anesthesia, while another supported conventional needle anesthesia		Dabarakis et al.[5] (2007)
	One study supported that needleless is preferred and accepted	Two studies supported that needles are preferred and accepted	
	Less discomfort	More discomfort	
	Higher bad taste scores	Lower bad taste scores	Ocak et al.[10] (2020)
Effectiveness	Effective for dental procedures in all primary teeth, except for some procedures in permanent teeth	Effective for all dental procedures	Makade et al.[4] (2014)

(N/A: not applicable)

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uses mechanical energy to force a liquid drug into subcutaneous tissues without a needle, whereas the conventional method uses a needle and syringe to insert a local anesthetic solution with a vasoconstrictor into the site of action.(Fig. 2, 3) Conventional needle administration has higher technique sensitivity than needleless administration because needle use is dangerous and requires certain practices, such as handling the needle at a specific angle, to prevent harm and severe damage to the patient. With needleless administration, pressure is used instead of a needle, so it does not require as much caution.

Conventional needle anesthesia has a longer duration of action than jet injection, which is why it is preferred for complicated surgical procedures or extractions. Jet anesthesia has a faster onset of action (1 ms) than conventional needle anesthesia. Although jet anesthesia causes less discomfort and fear during administration, it causes more overall pain than conventional needle anesthesia during tooth extractions due to its short duration of action. The jet injection has lim-

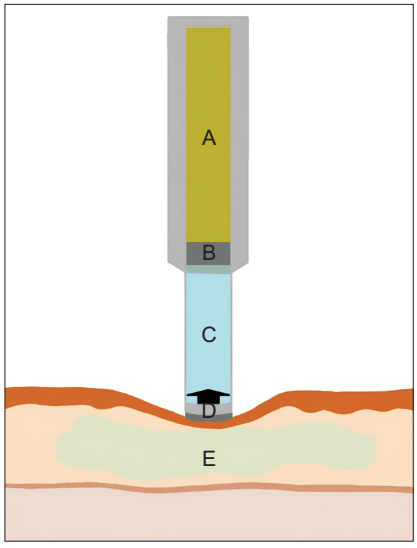

Fig. 2. Needleless injection technique. (A: source of energy, B: plunger, C: local anesthetic solution, D: device nozzle, E: local anesthesia deposited in the tissue)

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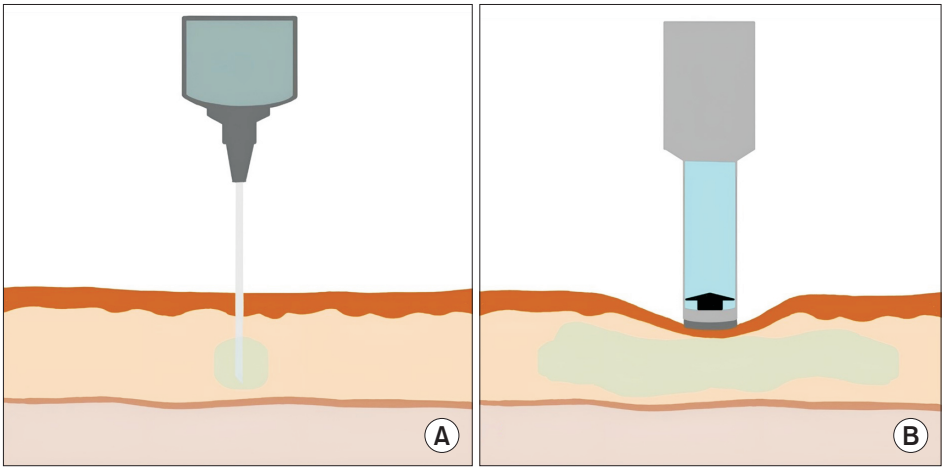

Fig. 3. A. Deposition on local anesthetic in using syringe and needle. B. Deposition of local anesthesia using needleless technique.
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ited dose administration, which proved beneficial for patients with systemic disorders because conventional needle delivery can cause overdoses. Conventional needle administration causes fear in patients with needle phobia and children, but jet injection can cause fear in some patients due to its bulky appearance and "pop" sound. Jet anesthesia is more expensive than conventional anesthesia.

Both types of injections are prone to spreading. The needleless jet anesthesia can spread disease through improper sterilization, and the conventional method carries the possibility of needle prick injuries. The jet anesthesia administration techniques are limited to infiltration, whereas conventional anesthesia can be used for infiltration, nerve block, intraosseous, intraligamentary, and intrapulpal anesthesia.

Previous studies have shown that the percentage of people who require additional anesthesia after a jet injection was much higher than after conventional anesthesia[8,10], but other studies reported that three times more patients accepted and preferred needleless jet anesthesia than the conventional needle[4,5]. On the other hand, conventional needle anesthesia did not require as much additional anesthesia as jet anesthesia[4].

These results offer healthcare providers a better understanding of the different drug delivery methods so they can choose the best method for their patients. For example, patients with needle phobia can benefit from jet anesthesia administered as infiltration anesthesia or as pre-conditioning pain relief before conventional needle anesthesia, which can reduce their fear and allow for a smooth treatment procedure. Although conventional anesthesia overdose is uncommon, jet administration can be used to remove the potential for an overdose by controlling the amount of anesthesia administered. On that point, it is important to note that jet anesthesia has a higher need for additional anesthesia; therefore, dentists must be sure not to cause an overdose. Jet anesthesia is less technique sensitive than conventional needle anesthesia, which might mean it could be used on uncooperative patients or by less experienced physicians.

In one study, patients showed apprehension to the Madajet XL because of its bulky appearance[3]. It is wise to understand that jet anesthesia can have various limitations, such as its appearance, the "pop" sound during administration (which can trigger anxiety in patients), and its short duration of action.

On the other hand, the literature results have limitations because they do not reveal important information, such as the exact duration of local anesthesia by route of administration and the type of drug used. Moreover, the articles fail to mention the use of jet anesthesia in different sites of the jaw or explain how the bulky appearance and technique affect which teeth are accessible to the jet anesthesia. The authors of several studies suggest that more patients from different age groups and with different conditions be tested to better understand the limitations of jet anesthesia. One study mentioned the possibility of residual hematomas from the use of jet anesthesia, but it did not mention the exact mechanism by which they could be caused or how to prevent them[10].

Although the studies reviewed here explored jet anesthesia, they made no clear statements about the indications and contraindications of jet anesthesia, such as whether it can be used on patients with systemic diseases, blood disorders with the possibility of hematomas, during pregnancy, or in patients with gingivitis or periodontal disease. More studies that explore the efficacy of jet anesthesia as infiltration local anesthesia are needed.

To improve the efficacy of jet anesthesia and make it more acceptable, we suggest making improvements to the design. Having a less bulky appearance and eliminating the "pop"

sound would reduce anxiety in some patients. In one study, 51.14% of the patients were bothered by the "pop" sound, and only a minority were not disturbed[10]. Another way to improve jet anesthesia is to lengthen the duration of action by improving its design and mode of action. Makade et al.[4] reported that the major disadvantage of pressure anesthesia was the initial cost of the equipment. To make the technology accessible to many dentists, the cost should be affordable, and how it works should be better explained.

Finally, more studies should explore the efficacy of jet anesthesia as a means to provide block anesthesia instead of just infiltration anesthesia, and more studies are needed to explore how the effects of jet anesthesia vary by sex and age differences.

V. Conclusion

Needle pain and needle phobia are serious concerns for many patients. Currently, the methods for administering local anesthesia other than conventional needles include jet injections, such as INJEX and Madajet, that can cause numbness to an area for a short time. Needleless jet anesthesia has been shown to be moderately accepted by patients who fear needles, and it has a faster onset of action than the conventional technique and offers effective infiltration anesthesia. On the other hand, needleless jet anesthesia is more expensive, has a bulky appearance, and requires additional anesthesia. Although jet anesthesia is an alternative to conventional needle anesthesia, many studies have concluded that patients prefer conventional needle anesthesia due to its long duration of action, efficiency, and familiarity.

VI. Clinical Recommendations

Various points about jet anesthesia require further research and clarification, such as the need for clear statements about the indications and contraindications of jet anesthesia. It is important to understand the limitations of jet anesthesia and perform research in a variety of conditions. Also, the efficacy of jet anesthesia in providing block anesthesia and infiltration should be emphasized in further research, along with tests for sex and age effects on jet anesthesia.

Making a less bulky jet anesthesia device and eliminating the "pop" sound could reduce anxiety in patients. Furthermore, prolonging the duration of action and making jet anesthesia more affordable are recommended.

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Authors' Contributions

All authors have participated and contributed to the study. The concept, study design, and data collection were done by A.A.A., A.M., A.A., H.A.A., M.M.A., and M.H.A. The study was revised critically by S.R.S., S.A.K, N.H.A.R., and M.M.M. All authors read and approved the final manuscript.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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