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Novel dental anesthetic and associated devices: a scoping review

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The efficient management of pain and discomfort is essential for successful dental treatment and patient compliance. Dental professionals are commonly evaluated for their ability to perform treatment with minimal patient discomfort. Despite advancements in traditional local dental anesthesia techniques, the pain and discomfort associated with injections remain a concern. This scoping review aims to provide a comprehensive overview of the literature on novel dental anesthetics and associated devices designed to alleviate pain and discomfort during dental procedures. The Joanna Briggs Institute and the Preferred Reporting Items for Systematic reviews and Meta-Analyses Extension for Scoping Reviews guidelines were used to prepare the review. Six databases and two sources of gray literature were searched. This review analyzed 107 sources from 1994 to 2023. Local anesthesia devices were grouped into computer-controlled local anesthetic delivery (CCLAD) systems, intraosseous anesthesia (IOA), vibratory stimulation devices, and electronic dental anesthesia (EDA). CCLAD systems, particularly the Wand and Single-Tooth Anesthesia, have been the most researched, with mixed results regarding their effectiveness in reducing pain during needle insertion compared to traditional syringes. However, CCLAD systems often demonstrated efficacy in reducing pain during anesthetic deposition, especially during palatal injections. Limited studies on IOA devices have reported effective pain alleviation. Vibrating devices have shown inconsistent results in terms of pain reduction, with some studies suggesting their primary benefit is during needle insertion rather than during the administration phase. EDA devices are effective in reducing discomfort but have found limited applicability. These findings suggest that the CCLAD systems reduce injection pain and discomfort. However, the evidence for other devices is limited and inconsistent. The development and research of innovative technologies for reducing dental pain and anxiety provides opportunities for interdisciplinary collaboration and improved patient care in dental practice.

Keywords: Computer-Controlled Anesthesia; Counter-Stimulation; Dental Anesthetic Delivery Device; Dental Anxiety; Electronic Dental Anesthesia; Local Anesthesia.

INTRODUCTION

Efficient management of pain and discomfort within contemporary oral healthcare is essential, as it significantly influences the successful delivery of dental services and patient compliance. Inadequate pain management can not only create detrimental patient experiences but also cause fear and negative attitudes towards future dental treatments [1]. The psychological impact of dental pain and anxiety can have adverse consequences on overall oral health, potentially resulting in the prolonged avoidance of necessary dental care and further exacerbating dental problems, leading to further pain and anxiety [2]. Local anesthesia is the cornerstone of pain management in dentistry, with the traditional method using a syringe,

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cartridge, and needle, with the administration of approximately 1,600 cartridges per dentist per year [3]. Paradoxically, pain from injections remains a major concern [4]. This basic design in the local anesthetic armamentarium remains largely unchanged, where needle insertion during dental procedures may worsen existing fears related to dental care, perpetuating a cycle of negative dental associations in many patients.

The dental industry has responded to this issue with the emergence of innovative technologies seeking to alleviate the discomfort associated with anesthesia administration. Strategies, such as adjusting injection rates, warming anesthetic solutions to body temperature, and employing fine needles, demonstrate a commitment to enhancing patient comfort, supporting regular dental visits, and ultimately improving oral health outcomes. However, achieving a completely painless injection, a hallmark of quality patient care in dentistry, remains an ongoing challenge, with a notable gap in current pain management approaches [4]. This persistent challenge emphasizes the need for continued development and advancement of dental pain alleviation innovations.

It has long been recognized that with the advancement of dental technology, computer-assisted syringes should become more common [5]. Although some progress has been made with the introduction of computer-controlled local anesthetic delivery devices showing superior performance to conventional methods, thorough research into alternative approaches is still needed. The broader field of pain research recommends new collaborations and methodologies that reflect the multifaceted nature of pain and the importance of integrating various technologies and approaches [6]. Additionally, the existing literature often focuses narrowly on computer-controlled systems, warranting investigations into other emerging technologies. This lack of research affects the advancement of newly developed equipment and aids designed to reduce anesthesia administration discomfort in dental settings.

This scoping review aimed to bridge the evidence gap by conducting a comprehensive systematic review and synthesis of the literature on novel dental anesthetics and associated devices. The findings of this study have the potential to inform clinical oral healthcare practice and identify current research gaps in this field, with the aim of providing recommendations for future investigations.

METHODS

Research protocol: A scoping review was undertaken and presented based on the Preferred Reporting Items for Systematic reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) and Joanna Briggs Institute (JBI) guidance for scoping reviews [7]. The protocol for this scoping review is available in the public domain [8].

Eligibility criteria: The selection of relevant literature was based on the Population, Concept, and Context (PCC) framework outlined by Aromataris and Munn (2020) [7]. The study population included human participants spanning all age groups exposed to local anesthesia. The concept was any alternative (non-traditional) local anesthetic delivery system or associated device that aided in reducing pain or discomfort prior to and during the administration of local anesthesia. The context of the review was not limited to geographical location, setting, ethnicity, culture, age, or sex.

Types of evidence sources: The review included sources of information in English from primary and secondary research studies, reviews, guidelines, websites, reports, and gray literature published until April 2023.

Exclusion criteria: Study protocols, letters, blogs, book reviews, book chapters, editorials, commentaries, and brochures were excluded. Languages other than English were excluded from this study to ensure a consistent and thorough understanding of the content, as the researchers' expertise was limited to English-language texts. Primary and secondary studies, guidelines, webpages, and sources on needleless jet-injector systems were excluded.

Information sources and search strategies: The methodology employed in this scoping review followed the rigorous three-step search procedure recommended by

Table 1. Search Strategy for EBSCO Health

Search	Strategy
#1	anesthesia delivery system device OR anaesthesia delivery system OR computer-delivery anesthesia OR computer-delivery anaesthesia OR computerized local anesthesia OR computerized local anaesthesia OR computerized local anesthesia delivery systems OR computerized local anaesthesia delivery systems OR computerized local anesthetic delivery systems OR computerized local aesthetic delivery systems OR computer-controlled local anesthetic device OR computer-controlled local anaesthetic device OR cclad OR wand injection system OR wand OR quicksleeper OR calaject OR smartject OR morpheus OR computer OR comfort control syringe OR anaeject OR electronic anesthesia OR electronic anaesthesia OR single tooth anesthesia OR single tooth anaesthesia OR single tooth anesthesia system OR single tooth anaesthesia system OR sta OR sta system OR Vibraject OR DentalVibe OR counter-stimulation dental anaesthesia OR counter-stimulation local anaesthesia
#2	(pain* or discomfort) N3 (reduc* or control* or eliminat* or perception or perceive* or lower* or injection)
#3	#1 AND #2

Table 2. The following information is presented in appendix 1 and 2.

Author, Year	Study design	General study population	Name of devices	Pain and discomfort prior to (insertion) administration of LA	Pain and discomfort during and after administration of LA	Key findings

Author, year	Reported strengths and limitations	Suggestions for future research by authors

LA, local anesthetic.

the Joanna Briggs Institute. A preliminary search was conducted using the EBSCO health database to assess the thematic breadth of interest. Examining the articles obtained at this stage enabled a thorough comprehension of the relevant vocabulary used in the titles, abstracts, and index keywords, thereby enhancing the keyword strategy applied in the systematic search. To formulate a comprehensive search strategy, consultations were sought from an experienced librarian specializing in the health sciences before initiating the subsequent search. The second phase of the search strategy involved searches across the following databases: CINAHL, MEDLINE, Dentistry and Oral Sciences Source, and Scopus. This process aimed to capture as many relevant sources as possible. Table 1 presents a comprehensive record of the search terms, keywords, and variants used in each database search. The three-step search method concluded by conducting a final search that involved searching for references from the list of all papers and sources reviewed. To expand the scope of the investigation, Google and Google Scholar were searched, and the initial 100 outcomes from each search engine were thoroughly examined and screened for sources that satisfied the inclusion criteria.

Selection of sources: After compiling all sources obtained via the systematic search into EndNote X9, they were imported into Covidence, a specialized online platform for conducting systematic reviews that supports collaborative research [9,10]. The preliminary stage utilized EndNote and Covidence features to remove duplicate sources. Two independent reviewers simultaneously examined the titles and abstracts and assessed their suitability according to the inclusion and exclusion criteria. After conducting this evaluation, full-text articles and citation information from potentially relevant sources were retrieved for a more thorough analysis. Finally, both reviewers performed a detailed analysis of the full-text articles to determine the eligibility of the sources for inclusion in this review. When disagreements arose among the reviewers while extracting or selecting data, they engaged in an iterative dialog to resolve issues and reached a consensus on the suitability of the content being evaluated.

Data extraction: The data collection process commenced with a pilot evaluation of the data extraction tables for a subset of 10 articles. Following this initial evaluation, the initial data extraction table was revised with the consensus of both examiners to capture all the

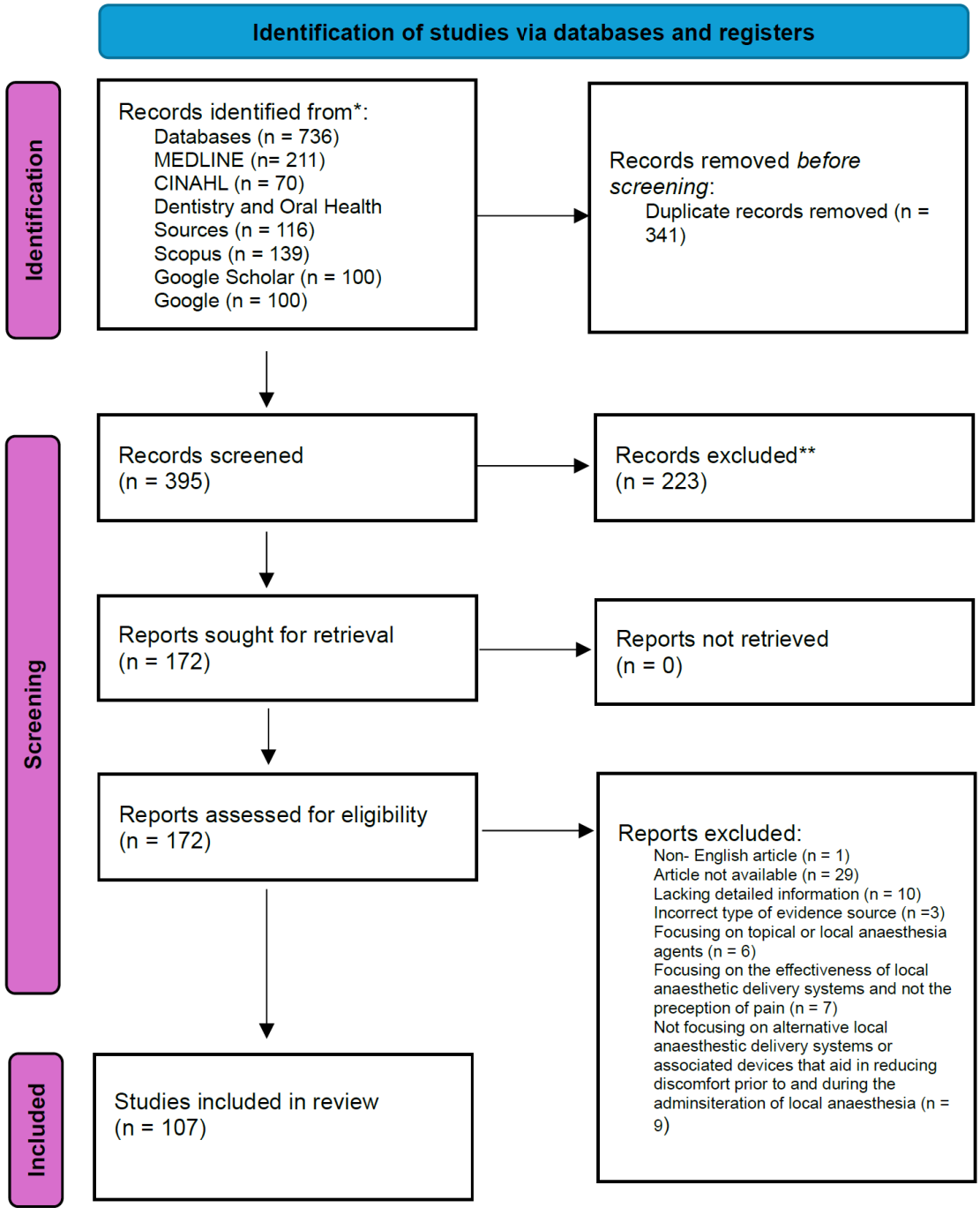

Fig. 1. The preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 flow diagram of the study selection process. n, number.

necessary information (Table 2) using an Excel spreadsheet.

The principal examiner was primarily responsible for data extraction, while the secondary examiner validated the accuracy and completeness of the compiled data by cross-verifying the extracted data to ensure that the data prepared for subsequent analyses were robust and reliable.

Synthesis of results: The results of the included studies were summarized in tabular form and further illustrated using charts, accompanied by a narrative explanation and discussion of the results.

Table 3. Local anesthesia and associated device types: Number of sources investigating each device

Device type	Device name	Number of sources mentioning device
Computer-controlled Local Anesthesia (CCLAD)	Wand	56
	Single Tooth Anaesthesia (STA)	22
	Comfort Control Syringe	7
	Calaject	5
	Anaject or Anaject II	5
	Carti-Ace Pro	1
	Smartject	1
	Varioject	1
Intraosseous anesthesia (IOA)	QuickSleeper or SleeperOne	12
	Intraflow	2
	Stabident	2
Vibrating devices	Vibraject	12
	DentalVibe	7
	Accupal	1
	Other vibratory device	1
Electrical dental anesthesia (EDA)	Transcutaneous Electirical Nerve Stimulation (TENS)	9
	DentaPen	3
	Other (unnamed)	1
Total		148

RESULTS

A total of 736 articles were identified during the search of four different databases, including gray literature. Following this preliminary search, 395 articles remained after the elimination of duplicate articles. After screening the abstracts, titles, and full texts, 107 articles met the inclusion and exclusion criteria. An overview of the study selection process is presented in the PRISMA-ScR flowchart (Fig. 1).

Characteristics of the included studies: This scoping review presents the findings obtained by examining 107 articles published between 1997 and 2023 (Appendix 1). Among the 107 articles, 148 devices were mentioned, which were characterized based on four distinct categories of device methodologies used to administer local anesthesia (Table 3): computer-controlled local anesthesia (CCLAD) (n = 98), intraosseous anesthesia (IOA) (n = 15), vibrating devices (n = 21), and electrical dental anesthesia (EDA) (n = 13). Devices, such as Stabident, Intraflow, and Accupal, are mentioned in some articles; however, these sources did not provide information regarding the efficacy of these devices in reducing pain and discomfort during their use.

Key findings of the included studies:

1. CCLAD

Numerous innovative devices emerged in the CCLAD category, including Wand, Anaject/Anaject II, Comfort Control Syringe, Carti-Ace Pro, Single Tooth Anesthesia (STA), Calaject, Smartject, and Varioject devices. Of the 107 studies, 96 (89.7%) focused on CCLAD devices, as presented in Appendix 1. Among these categories of devices, 56 out of 96 (58.3%) CCLAD devices were on the Wand system, followed by 22 (22.9%) studies on STA, 7 (7.3%) studies on the Comfort Control Syringe, 5 (5.2%) studies on Anaject/Anaject II and Calaject, and 1 (1%) study mentioning the Carti-Ace Pro, Smartject, and Varioject.

Regarding the Wand system, Figure 2 shows that 37 of 56 (66%) sources of the Wand system highlighted patient reports of minimal pain or discomfort during its use. Conversely, 14 of 56 (25%) studies reported minor differences in pain before the insertion of local anesthesia. Notably, 40 of 56 (71%) studies demonstrated the

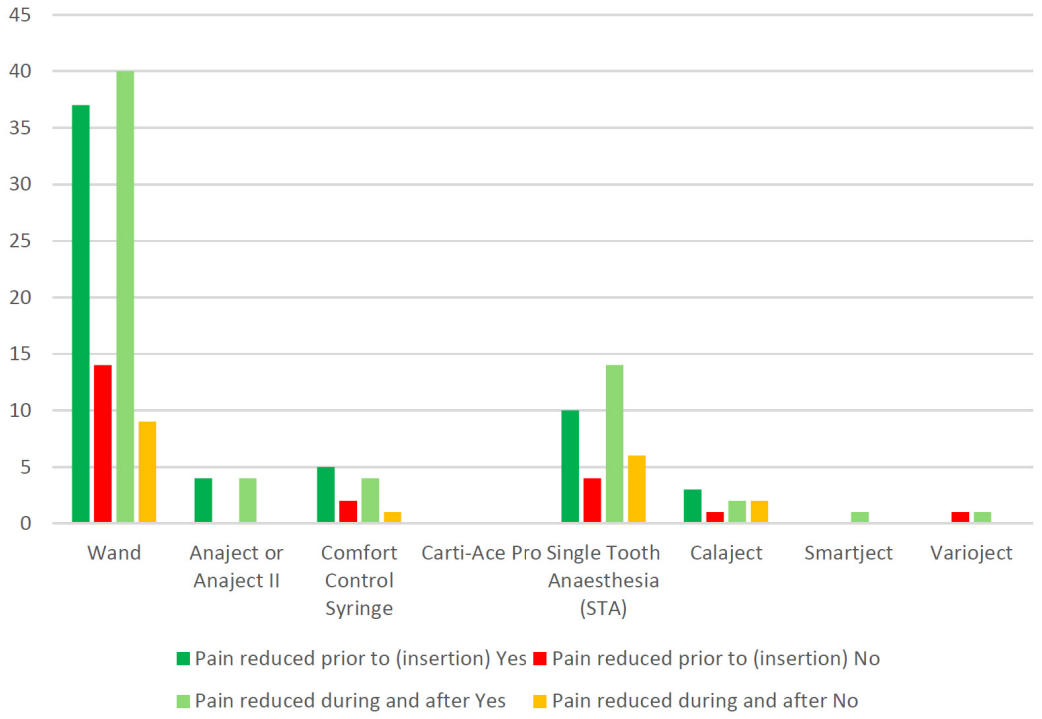

Fig. 2. Computer-controlled local anesthesia: Number of sources reporting reduced pain prior to insertion (Yes/No), and during and after anesthesia administration (Yes/No)

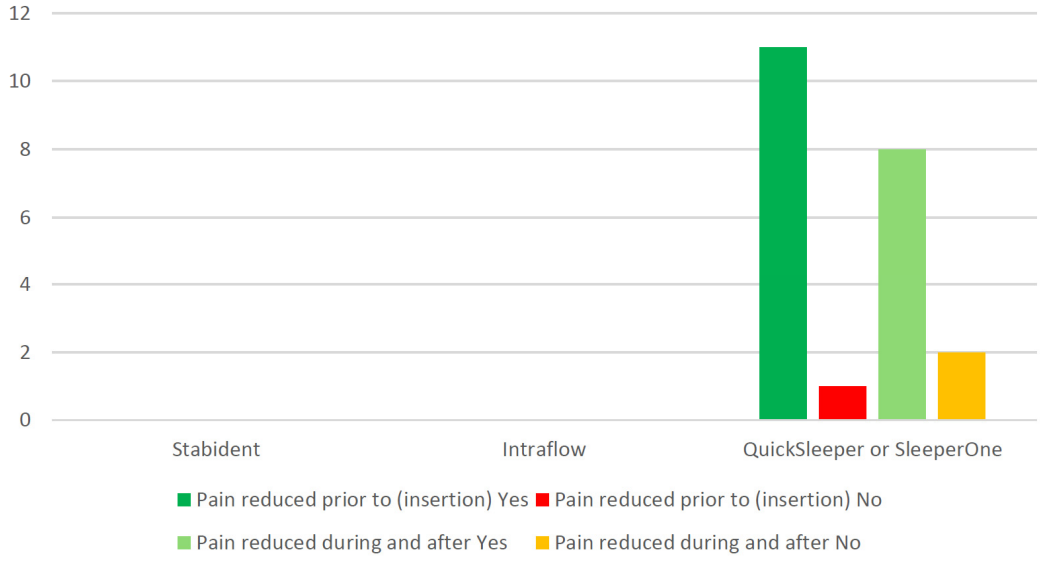

Fig. 3. Intraosseous anesthesia: Number of sources reporting reduced pain prior to insertion (Yes/No), and during and after anesthesia administration (Yes/No)

effectiveness of the Wand system in reducing pain and discomfort during anesthetic administration, compared to 9 (16%) studies that found no significant difference compared to traditional methods. While these results emphasize the Wand system's prominence in current research, it is important to acknowledge that other CCLAD devices, which have received less research attention than the Wand system, have shown promise in mitigating pain and discomfort during local anesthesia's insertion and administration phases. One specific system,

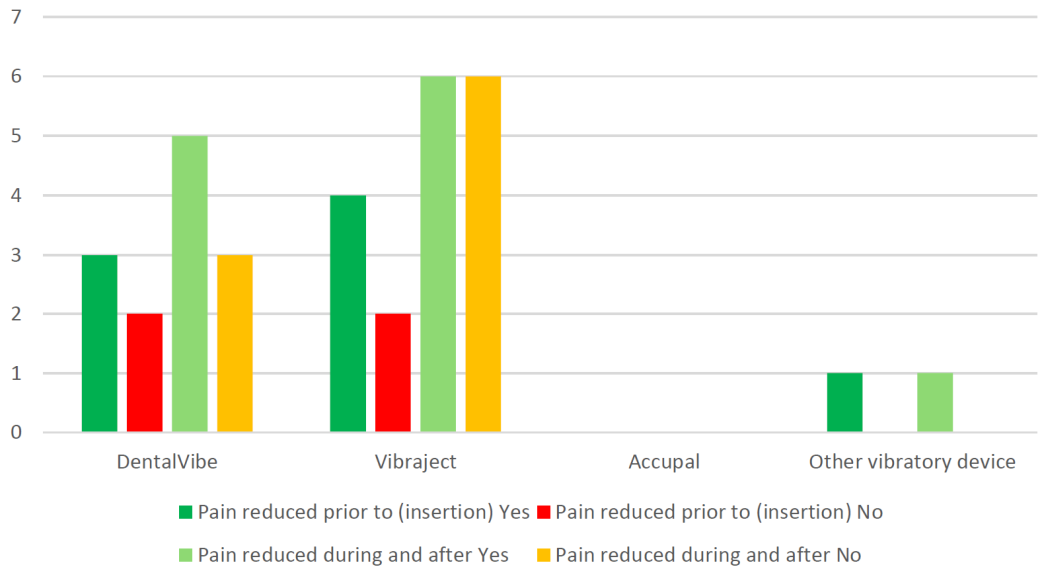

Fig. 4. Vibrating devices: Number of sources reporting reduced pain prior to insertion (Yes/No), and during and after anesthesia administration (Yes/No)

Carti-Ace Pro, is notable for the limited direct research on its efficacy in reducing pain. However, Chong et al. (2014) mentioned that its function and features are similar to those of Anaject/Anaject II, suggesting its efficacy in reducing pain and discomfort during local anesthetic administration [11].

2. IOA

A relatively limited portion of the literature has investigated IOA systems, with only 15 studies referenced, as listed in Table 3. Among the devices utilizing IOA techniques, the QuickSleeper/SleeperOne stands out as being prominent, mentioned in approximately 12 articles, all highlighting its capacity to alleviate pain and discomfort during insertion and local anesthesia delivery. Of the 12 studies focusing on pain during insertion shown in Figure 3, 11 (91.2%) demonstrated that the QuickSleeper/SleeperOne resulted in minimal pain and discomfort compared to traditional local anesthesia. Only one study (8.3%) found no statistically significant differences in patient discomfort levels [11]. Vitale et al. (2023) also noted that patients preferred SleeperOne to conventional local anesthesia [10]. Stabident and Intraflow are two other devices utilizing the IOA method of local anesthesia; however, their efficacy in delivering pain-free anesthesia to patients has not been mentioned in the literature [12-14].

3. Vibrating devices

DentalVibe and Vibraject, in particular, featured the most prominently in studies, as shown in Figure 4. Vibraject was discussed in 12 studies (57.1%), while DentalVibe was mentioned in seven (33.3%). These studies evaluated the efficacy of vibrating devices in alleviating the pain and discomfort associated with needle insertion and subsequent local anesthesia administration. Several studies have reported that vibrating devices contribute to reduced pain and discomfort, both before needle insertion and during the administration of local anesthesia. However, these findings were not consistent across all the investigations. For instance, six studies (50%) reported a reduction in pain during local anesthesia administration with vibrating devices, while an equal number of studies disagreed with this claim. Chong et al. (2014) noted a significant lack of data demonstrating the effectiveness of Vibraject in reducing pain compared to the standard local anesthesia administration method [11,15,16]. Their findings indicated that needle insertion pain with the Vibraject was similar to that with the standard local anesthetic method. However, supporting

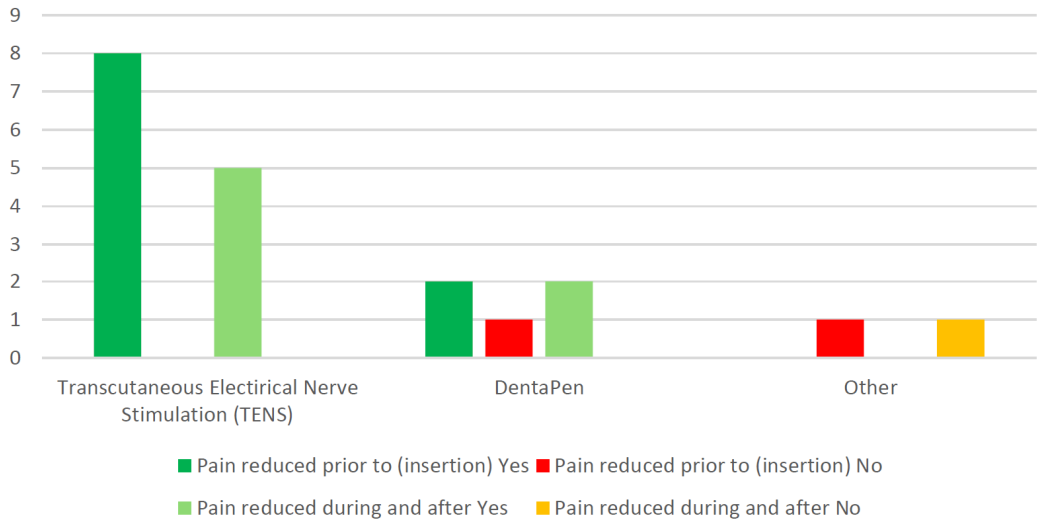

Fig. 5. Electronic dental anesthesia: Number of sources reporting reduced pain prior to insertion (Yes/No), and during and after anesthesia administration (Yes/No)

evidence suggests that vibrating devices assist primarily during needle insertion for local anesthesia rather than during the actual administration phase, possibly because of the confounding factor of pressure build-up during administration [15].

4. EDA

Although Dentapen has been the focus of only three studies, it has shown promise in reducing pain during needle insertion and anesthesia delivery, as shown in Figure 5. This initial evidence suggests that electrical stimulation devices may play a role in managing discomfort during dental procedures, which warrants further investigation.

Suggestions for future research and the strengths and limitations of this study are presented in Appendix 2.

DISCUSSION

The primary objective of this scoping review was to provide a systematic overview of the literature on alternative local anesthetics and associated devices specifically designed to alleviate pain and discomfort during dental procedures.

CCLAD devices constituted a significant portion of the research, a trend likely attributable to the introduction of computerized local anesthesia technologies in 1997 [13]. Within this category, particular attention is given to the 'Wand' system, a pioneering method for local anesthetic administration known for its ability to minimize patient discomfort. Additionally, the Single Tooth Anesthesia (STA) device, an innovative refinement of the Wand system introduced in 2006, has garnered considerable attention, emerging as the second most researched device, following the Wand system, with less research on other devices [16].

Overall, the evidence regarding needle insertion pain with CCLAD devices compared with traditional syringes is mixed. Multiple studies have found that needle insertion pain is significantly higher than pain experienced during anesthetic solution deposition, regardless of the technique used. This suggests that needle insertion is the most painful aspect of the injection process [17]. Vibration during needle insertion reduces pain scores compared to no vibration; however, only few studies have reached solid conclusions. Limited research suggests that operator experience can also play a role in influence pain perception.

Evidence suggests that CCLAD systems are more

effective in reducing pain during anesthetic deposition than traditional syringes, particularly for palatal injections. Vibration devices show promise, particularly for children, but have yielded mixed results. Needle insertion pain was often similar between the techniques. However, controlled injection flow is a more important factor than needle insertion in reducing overall pain, highlighting the importance of injection flow [18,19]. Novel devices also tend to reduce disruptive behavior in children compared with traditional syringes and are often preferred by patients. However, operator technique is an important factor [17]. This was attributed to the devices' lower pain scores and less-threatening appearance.

Several studies have assessed dental anxiety but found no correlation among anxiety scores, pain, and type of device. Children with anxiety tended to report more pain regardless of the technique used. Some studies have reported lower anxiety scores with CCLAD devices, possibly because of their less threatening appearance. However, other studies have found no difference in anxiety between techniques [17,19-22]. In studies that assessed patient preferences between techniques, more tended to prefer CCLAD or vibration devices to traditional syringes for future appointments.

EDA uses transcutaneous electrical nerve stimulation to alleviate pain during the administration of local anesthesia. Despite its longstanding availability, the adoption of EDA in dentistry has been limited because of its inability to entirely replace traditional local anesthesia [16,23]. While the current research highlights EDA's effectiveness in reducing pain and discomfort during local anesthesia insertion and application, its use is not recommended for specific patient populations. Individuals with anxiety, cardiac pacemakers, cerebrovascular issues, epilepsy, or pregnant women are advised not to use EDA [16].

Despite these constraints, studies have confirmed the efficacy of this modality in reducing the discomfort associated with local anesthesia delivery. Ram and Peretz (2002) described EDA as encompassing devices, such as Dentapen and other unspecified EDA devices [20].

A limitation of this study was the exclusion of non-English language sources, which may have led to the omission of potentially relevant studies. While scoping reviews provide a broad and comprehensive review of the existing literature, they do not formally assess the quality of sources or the risk of bias. This may have affected the reliability and generalizability of the findings. Future studies should conduct systematic reviews, including such assessments to provide definitive evidence and recommendations.

Future research could provide a more comprehensive understanding of the benefits, limitations, and optimal use of novel dental local anesthetic devices and associated devices. Future studies should focus on high-quality, well-controlled studies that directly compare innovative methods with traditional approaches. Investigators should explore strategies to reduce needle insertion and local anesthetic delivery pain, assess long-term outcomes, and evaluate the impact of patient characteristics and operator techniques on effectiveness, pain, and anxiety perception. In addition, systematic reviews and meta-analyses of the range of novel devices are required. Researchers should also investigate the cost-effectiveness and feasibility of implementing these devices in various dental practice settings and the potential of combining novel delivery methods with other pain and anxiety management strategies to provide improved holistic care.

The rationale for this investigation was the crucial role that dental anesthesia plays in providing comfortable and efficient modern dental services. This facilitates patient compliance and reduces stress on the dental team, whereas inadequate pain management can lead to pain, anxiety, and avoidance of necessary dental care [1].

Conclusions

These findings suggest that the CCLAD systems reduce injection pain and discomfort. However, the evidence for other devices is limited and inconsistent. Therefore, there is an urgent need to develop and research innovative technologies to reduce dental pain and anxiety. This provides opportunities for interdisciplinary collaboration,

ultimately leading to improved patient care and comfort in dental practice.

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AUTHOR CONTRIBUTIONS

Kyung Hyuk Min: Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Validation, Visualization, Writing - original draft, Writing - review & editing
Zac Morse: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing

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