Review Article
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Efficacy of computer-controlled local anesthesia delivery system on pain in dental anesthesia: a systematic review of randomized clinical trials

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Computer-controlled local anesthesia delivery (CCLAD) is an innovative electronic injection device that represents a cutting-edge approach to dental anesthesia. This system is promising for painless anesthesia using controlled anesthetic injections. This review aimed to compare the discomfort experienced by patients during local anesthesia using a traditional syringe and the CCLAD system and evaluate the potential of the CCLAD system as a painless dental anesthesia solution. The inclusion criteria for this study were based on the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines. The study population, including children and adults, underwent dental anesthesia using the CCLAD system, ensuring a comprehensive and representative sample that instills confidence in the validity of the results. Fourteen clinical trials were included in the analysis after they fulfilled the eligibility criteria. We found that using computer-assisted anesthetic equipment not only led to a significantly lower pain perception score, but also had a profound positive impact on patient behavior. Patients using the CCLAD device exhibited more cooperative and helpful conduct, indicating the system's effectiveness in improving patient comfort and experience and reassuring the audience about its positive impact. In conclusion, using a computer-assisted anesthetic device such as the CCLAD system significantly reduced pain perception scores and improved patient behavior, making them more cooperative and helpful. These findings offer hope for pediatric dentistry and apprehensive adult patients, suggesting a more comfortable and less daunting dental experience with the CCLAD system.

Keywords: Computer-Assisted; Delivery System; Local Anesthesia; Needles; Pain Perception.

INTRODUCTION

Dental fear is the most frequent cause of fear among patients and can preclude dental visits. Several factors contribute to dental anxiety, such as the sound and vibration of tooth-cutting devices, smell of medications or dental supplies, discomfort during dental procedures, and unfounded dread of local anesthetics [1]. Regional anesthesia is a fundamental component of dentistry and is mandatory before operative dental procedures [2]. Appropriate local anesthetics are required to minimize pain during dental treatment because they can cause discomfort [1]. However, it may cause pain during needle pricking and delivery of anesthetic solution [2]. Paradoxically, patients frequently fear discomfort from anesthetic injections more than the actual pain from dental treatment [1].

Local dental anesthesia can be painful even with meticulous anesthetic procedures because of several factors such as drug properties, soft tissue damage from the anesthetic's penetration of the oral mucosa, pressure

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from the anesthetic's spread, temperature, and low pH. Swabbing anesthesia is frequently used at the injection site to reduce pain during local anesthesia. Subperiosteal or intraosseous injections, which can cause pain, should be avoided in favor of regional anesthetic techniques that can anatomically reduce pain, such as infiltration anesthesia. Furthermore, sterile local anesthesia must be used, the anesthetic ampoule must be supplied at a temperature comparable to body temperature, and an attempt must be made to slow the injection pace [3]. Although slowing the pace or volume of injection is the most effective way to reduce discomfort, controlling and maintaining these parameters in clinical settings can be challenging [4].

The development of local anesthetic delivery devices that use computer technology to regulate anesthetic solution flow through a needle began in the mid of the 1990s. Computer-controlled local anesthetic delivery (CCLAD) is a new concept. The WandTM (Milestone Scientific, Inc., Livingston, NJ) was the first CCLAD device released in 1997. The same manufacturer's later iterations were Wand Plus and CompuDent, the brand names used today. Comfort Control Syringe (Dentsply International, York, PA, USA) was introduced in 2001 as a replacement for Wand Plus. Similar products include Anaeject (Nippon Shika Yakuhin, Shimonoseki, Japan) and Ora Star (Showa Uyakuhin Kako, Tokyo, Japan) syringes as well as QuickSleeper and SleeperOne devices (Dental Hi-Tec, Cholet, France) [5]. These are electronic injection devices with multiple speeds that can be adjusted to provide painless anesthesia via controlled anesthetic injections [2]. In 2018, a systematic review and meta-analysis showed that CCLAD had significantly less pain perception than that with conventional injections [6]. Hence, this study aimed to assess and compare the discomfort experienced by patients undergoing local anesthesia using a traditional syringe and the CCLAD system.

METHODS

1. Reporting format

This study was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines [7]. The study protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO) with the registration number CRD42024526849. Owing to the high heterogeneity of the studies, a meta-analysis was not performed.

2. Focused question

Is the CCLAD system less painful compared to the conventional dental anesthesia injection?

3. Patients, interventions, control, and outcome (PICO)

The PICO format was based on the following: (P) patients receiving a dental injection, (I) CCLAD system, (C) conventional dental anesthesia injection, and (O) pain during dental anesthesia injection.

4. Eligibility criteria

The eligibility criteria were as follows: (a) children or adults undergoing dental injection, (b) experimental group: use of CCLAD, (c) control group: use of conventional dental anesthesia injection, (d) studies that compared experimental and control groups, and (e) randomized controlled trials. Only studies published in English were included to avoid bias. In vitro and in vivo studies, case reports and series, commentaries, letters addressed to the editor, and retrospective and non-randomized studies were excluded.

5. Search strategy and data extraction

The indexed databases (PubMed/Medline, EMBASE, OVID, Scopus, and Cochrane) were independently searched by two authors. Relevant studies published between 2019 and April 2024 were included in the study and were searched using a combination of the following

Table 1. Search strategy for electronic databases

Database search	Keywords	Results
PubMed	Patients AND Computer-Controlled Local Anesthesia AND Conventional dental anesthesia injection AND Pain OR Patients AND Computer-Controlled Local Anesthesia Delivery AND Conventional dental anesthesia injection AND Pain during dental anesthesia injection OR Patients AND Computer-Controlled Local Anesthesia AND Conventional dental anesthesia injection AND Pain during dental anesthesia injection OR Computer-Controlled Local Anesthesia Delivery AND Conventional dental anesthesia injection AND Pain during dental anesthesia injection OR Computer-Controlled Local Anesthesia AND Conventional dental anesthesia injection AND Pain during dental anesthesia injection	147
Embase	('patients'/exp OR patients) AND ('computer-controlled local anesthesia delivery system' OR ('computer controlled' AND local AND ('anesthesia'/exp OR anesthesia) AND ('delivery'/exp OR delivery) AND system)) AND ('conventional dental anesthesia injection' OR (conventional AND ('dental'/exp OR dental) AND ('anesthesia'/exp OR anesthesia) AND ('injection'/exp OR injection))) AND ('pain during dental anesthesia injection' OR (('pain'/exp OR pain) AND during AND ('dental'/exp OR dental) AND ('anesthesia'/exp OR anesthesia) AND ('injection'/exp OR injection))) ('patient'/exp OR patient) AND ('computer-controlled local anesthesia' OR ('computer controlled' AND local AND ('anesthesia'/exp OR anesthesia))) AND ('conventional dental anesthesia injection' OR (conventional AND ('dental'/exp OR dental) AND ('anesthesia'/exp OR anesthesia) AND ('injection'/exp OR injection))) AND ('pain during dental anesthesia injection' OR (('pain'/exp OR pain) AND during AND ('dental'/exp OR dental) AND ('anesthesia'/exp OR anesthesia) AND ('injection'/exp OR injection))) ('patient'/exp OR patient) AND ('computer-controlled local anesthesia' OR ('computer controlled' AND local AND ('anesthesia'/exp OR anesthesia))) AND ('conventional dental anesthesia' OR (conventional AND ('dental'/exp OR dental) AND ('anesthesia'/exp OR anesthesia))) AND ('pain'/exp OR pain) ('computer-controlled local anesthesia' OR ('computer controlled' AND local AND ('anesthesia'/exp OR anesthesia))) AND ('conventional dental anesthesia' OR (conventional AND ('dental'/exp OR dental) AND ('anesthesia'/exp OR anesthesia))) AND ('pain'/exp OR pain)	64
Scopus	patients AND computer-controlled AND local AND anesthesia AND conventional AND dental AND anesthesia AND injection AND pain OR patients AND computer-controlled AND local AND anesthesia AND delivery AND conventional AND dental AND anesthesia AND injection AND pain AND during AND dental AND anesthesia AND injection OR patients AND computer-controlled AND local AND anesthesia AND conventional AND dental AND anesthesia AND injection AND pain AND during AND dental AND anesthesia AND injection OR computer-controlled AND local AND anesthesia AND conventional AND dental AND anesthesia AND injection AND pain AND during AND dental AND anesthesia AND injection.	80
Web of science	Patients AND Computer-Controlled Local Anesthesia AND Conventional dental anesthesia injection AND Pain (All Fields) Patients AND Computer-Controlled Local Anesthesia Delivery AND Conventional dental anesthesia injection AND Pain during dental anesthesia injection (All Fields) Patients AND Computer-Controlled Local Anesthesia AND Conventional dental anesthesia injection AND Pain during dental anesthesia injection (All Fields)	54
Cochrane library	Patients AND Computer-Controlled Local Anesthesia AND Conventional dental anesthesia injection AND Pain OR Patients AND Computer-Controlled Local Anesthesia Delivery AND Conventional dental anesthesia injection AND Pain during dental anesthesia injection OR Patients AND Computer-Controlled Local Anesthesia AND Conventional dental anesthesia injection AND Pain during dental anesthesia injection	78
Ovid	(Patients and Computer-Controlled Local and Conventional Dental Anesthesia and Pain).mp. [mp=title, book title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms, population supplementary concept word, anatomy supplementary concept word]	1

Table 2. List of excluded studies

Reference	Reasons for the exclusion
Hrishikesh Saoji, et al. 2019 PMID: 32190214	The focus question needs to be addressed.
Meenu Mittal, et al. 2019 PMID: 31184941	The focus question needs to be addressed.
J C Abou Chedid, et al. 2023 PMID: 36933183	The focus question needs to be addressed.
Jeanette, et al. 2016 PMID: 27446999	The focus question needs to be addressed.
Erick Rafael, et al. 2021 PMID: 34946280	The focus question needs to be addressed.
Anna Riba-Roca, et al. 2020 PMID: 33282134	The focus question needs to be addressed.
L Giannetti, et al. 2018 PMID: 29569452	The focus question needs to be addressed.
R Patini, et al. 2018 PMID: 30143396	The focus question needs to be addressed.
C Perugia, et al. 2017 PMID: 29254346	The focus question needs to be addressed.
Garret-Bernardin, et al. 2017 PMID: 28293129	The focus question needs to be addressed.
May Feda, et al. 2010 PMID: 20578658	The focus question needs to be addressed.
Kunal Gajendragadkar, et al. 2019 PMID: 31338419	The focus question needs to be addressed.
Sara Fowler, et al. 2018 PMID: 30715932	The focus question needs to be addressed.

keywords based on Medical Subject Headings: (1) computer-controlled local anesthetic delivery, (2) conventional local anesthesia injection, (3) dental treatments, (4) pain, (5) adults, (6) children, (7) pain

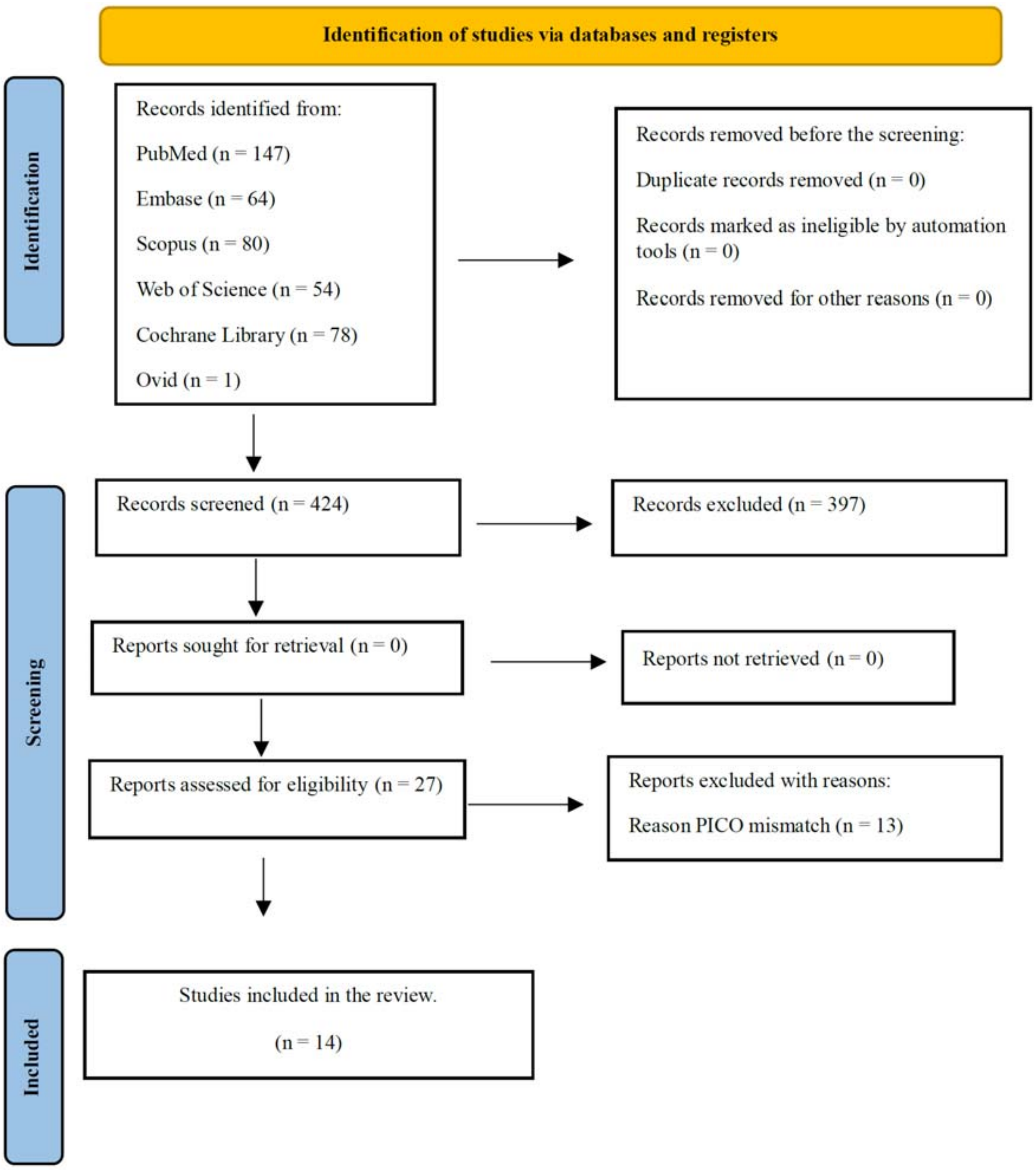

Fig. 1. PRISMA Flow Chart based on PRISMA guidelines. PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analyses.

measurement, and (8) pain perception. Specific vital languages were merged using Boolean operators (OR and AND) to broaden the results. Subsequently, two authors assessed the titles and abstracts of the studies identified using the tools mentioned above, and the texts of pertinent studies were evaluated independently. Additionally, reference lists of relevant original studies and review articles were manually searched to identify potentially overlooked studies in the initial phase. Any discrepancies were addressed through discussion with a third researcher.

RESULTS

1. Study selection

The initial search yielded a total of 834 studies. A PubMed search revealed 147 studies; Embase, 64; Scopus, 80; Web of Science, 54; Cochrane Library, 78;

Table 3. General characteristics of the included studies

Author	Country	Study design	Sample (n)	Study group	Control group	Mean age / age range	M/F	Duration of study	Funding
Smolarek, et al. [16]	Brazil	RCT, Single-blinded	105	CCLAD Morpheus device	1. Conventional anst inj 2. Vibrational anst with device DentalVibe™	10.91 ± 0.8 (9-12 yrs)	42/63	1 yr	No
Ludovichetti, et al. [12]	Italy	RCT	100	Computerized QuickSleeper anesthesia	Conventional anst inj	8.62 (3-15 yrs)	NR	NR	No
Shetty, et al. [15]	India	RCT	30	LA injection using the No Pain III™ CCLAD system	Conventional anst inj	9 ± 1.8003 (6-12 yrs)	14/16	NR	No
Helmy, et al. [11]	Egypt	RCT, Single-blinded	50	CCILA	Conventional anst inj	6.10 ± 0.76 (5-7 yrs)	Study G:11/14 Control G:10/15	24 hrs	No
Castelo, et al. [14]	Spain	RCT, Split-mouth	100	1. CDS-ILA using Wand STA device 2. CDS-IOA using QuickSleeper system	Conventional anst inj Aspijet syringe	7.6 ± 2.0 (6-12 yrs)	Study G:45/55 Control G: NR	NR	No
Anil, et al. [8]	Turkey	RCT, Single-blinded	60	CCLAD	Conventional anst inj	Study G: 8.73 ± 1.41 Control G:8.73 ± 1.38 (7-11 yrs)	Study G:15/15 Control G:13/17	NR	Scientific Research Projects Unit of Gaziantep University
Flisfisch, et al. [10]	Switzerland	RCT split mouth	20	CCLAD using Wand/STA system	Conventional anst inj	64 (42-76 yrs)	10/10	NR	No
Attia, et al. [9]	Germany	RCT, single-blinded	60	Computer-controlled device Calajet	Conventional anst inj	NR	19/41	NR	Masaryk University Grants
O'Neal, et al. [13]	USA	RCT, single-blind	130	Dentapen	Conventional anst inj	18-65 yrs	55/75	21 months	Resident Research Grant from the American Association of Endodontists Foundation.
Chengappa, et al. [17]	India	RCT, Split-mouth	80	CCLAD system	Conventional anst inj	6-13 yrs	40/40	12 months	The office of the Directorate General Armed Forces Medical Services and Defence Research Development Organization, Government of India.
Berrendero, et al. [18]	Spain	RCT, Split-mouth	40	Computerized controlled anesthesia with Calajec	Conventional anst inj A three-ring syringe	45.65 ± 14.90 (18-79 yrs)	16/24	NR	NR
Vitale, et al. [19]	Italy	RCT, Split-mouth	30	SleeperOne® computerized device	Conventional anst inj	8.57 ± 2.44 (5-15 yrs)	16/14	NR	NR
Beegum, et al. [20]	KSA	RCT, Split-mouth	25	Computer-controlled I-Ject device	Conventional anst inj	8.55 ± 2.34 (6–12 yrs)	8/17	8 months	The Nil
Muller-Bolla, et al. [21]	France	RCT, split-mouth, crossover, multicentre	111 (107 complete the study)	Computerized controlled anesthesia, SleeperOne5®	Conventional anst inj	5.6 ± 1.2 (4-8 yrs)	58/53	20 months	CHU Nice

anst, anesthetic; CCILA, computer-controlled intraligamentary anesthesia; CCLAD, computer-controlled local analgesic delivery; CDS-ILA, computer-controlled local anesthetic delivery system-intraligamentary anesthesia; CDS-IOA, computer-controlled local anesthetic delivery system-intraosseous anesthesia; F, female; G, group; hrs, hours; inj, injection; KSA, Kingdom of Saudi Arabia; LA, local anesthesia; M, male; n, number; NR, not reported; RCT, randomized clinical trial; STA, single tooth anesthesia; TM, trademark; USA, United States of America; yr, year; yrs, years.

and Ovid, 1 studies. After duplicates were removed and titles and abstracts were reviewed, 27 studies were thoroughly evaluated, excluding 13 studies (Tables 1 and 2). Fourteen RCTs met the inclusion criteria for a final qualitative analysis (Fig. 1).

2. Characteristics of the included studies

All the included studies were conducted in different countries [8-21] and had a parallel-group design consisting of an intervention group utilizing CCLAD and

Table 4a. General characteristics of computer-guided injections

Author	Tooth	Dental condition	Dental procedure	Provider	Type of device
Children					
Smolarek, et al. [16]	Max post teeth	NR	Restoration	Dentist	Computerized Morpheus equipment
Ludovichetti, et al. [12]	Mand or Max (any tooth)	NR	A child with two dental treatments, type of treatment NR	Pediatric Dentist	Quick Sleeper system
Shetty, et al. [15]	Mand teeth	NR	Various dental procedures, type of procedure NR	Single trained operator	No Pain III™ CCLAD system
Helmy, et al. [11]	Mand primary molars	Non-restorable teeth Crown fractures Periapical disease Failed pulpotomies	Extraction	NR	Wand-STA system
Castelo, et al. [14]	Primary Mand molars	Dental caries	Pulpotomies of vital teeth Extraction	Pediatric Dentist	CDS-ILA: Wand STA® device CDS-IOA: QuickSleeper® system
Anil, et al. [8]	Max primary molar & first permanent molar	Dental caries	NR	Pediatric Dentist	Sleeper One®
Beegum, et al. [20]	NR	NR	NR	Dentist	I-Ject device
Chengappa, et al. [17]	Mandibular nd maxillary arch	Dental caries	Extraction Pulp therapy Minor surgical work Restorations.	Dentist	CCLAD system
Vitale, et al. [19]	Seventeen were lower primary first molars, 15 were lower primary second molars, 14 were upper primary first molars, and 14 were upper primary second molars.	Dental caries	Restoration	Operator	SleeperOne®
Muller-Bolla, et al. [21]	Maxillary and mandibular primary molars	Dental caries	Restoration	Trained operator	SleeperOne5®
Adults					
Flisfisch, et al. [10]	NR	Tooth neck defects	NR	Trained & experienced clinician	Wand STA system
Attia, et al. [9]	First premolar (R and L)	NR	NR	Dental student & Oral Surgeon	Computer-controlled injection using Calaject system®
O' Neal, et al. [13]	Max lat incisor	NR	NR	NR	Dentapen
Berrendero, et al. [18]	Lower molars, upper incisors, and upper molars	Dental caries, Periodontal diseases	Restorative treatment in lower molars (RT1) Restorative treatment in upper incisors (RT2) Extraction of upper molars (EXT) Scaling and root planning in lower molars (SRP)	Restorative dentistry specialist	Computerized controlled anesthesia using the Calaject system

CCLAD, computer-controlled local anesthesia delivery; CDS-ILA, computer-controlled local anesthetic delivery system-intraligamentary anesthesia; CDS-IOA, computer-controlled local anesthetic delivery system-intraosseous anesthesia; L, left; mand, mandibular; max, maxillary; NR, not reported; post, posterior; R, right; STA, single tooth system; TM, trademark.

a control group receiving conventional dental anesthesia injection. The number of participants in the included RCTs ranged from 20-130, with ages ranging from 3 to 79 years [8,10-21]. Notably, in one study, the age range was not reported [9]. Twelve studies included patients of both sexes [8-11,13-21]. However, in a study by Castelo et al. [14], sex of the control group was not reported. In a study by Ludovichetti et al., sex was not reported in either the study or the control groups [12]. Additionally, various CCLAD systems were used in the included studies. Simultaneously, the control group received conventional anesthesia injection [8-21]. Moreover, the duration of the three studies ranged from 24 to 20 months [11,13,16,17,20,21]. Eight studies reported the study duration [8-10,12,14,15,18,19]. In six studies, funding was reported by different organizations, such as the Scientific Research Projects Unit of Gaziantep University, Masaryk University Grants, a Resident Research Grant from the American Association of Endodontists Foundation, the office of the Directorate General Armed Forces Medical Services and Defence Research Development Organization, Government of

Table 4b. General characteristics of computer-guided injections

Author	Topical anst	Anst	Inj site	Needle gauge	Needle length	Type of inj	Number of inj	Anst cart	Anst vol	Rate of inj	CCLAD inj characteristics
Children											
Smolarek, et al. [16]	Benzotop™ (20% benzocaine gel—DFL Indústria e Comércio S.A., Rio de Janeiro, Brazil)	Lidocaine with epinephrine	Alv mucosa	NR	20	Infiltration	One per site.	NR	NR	1.0 mL /min, 108 sec	1. The Morpheus device had a base with a pedal that released inj solution. 2. The puncture was performed by activating the introduction pedal, followed by activating the aspiration button.
Ludovichetti, et al. [12]	Topical EMLA 2.5 mg/g + 2.5% mg/g cream (Lidocaine + Prilocaine)	Lidocaine with or without vasoconstrictor	Mand or Max	NR (DHT needle)	16 mm (DHT needle)	Infiltration	One each in Max & Mand	NR	NR	NR	1. Quick sleeper anesthesia with 2. A DHT needle was used
Shetty, et al. [15]	Procaine gel	Lignospan Special consisting of 2% lidocaine with 1:80,000 epinephrine	Mand arch (bilateral)	27-gauge needle (0.27 mm × 35 mm, Septoject™	NR	Infiltration	Two (both sides of mand arch)	NR	NR	Slow speed	1. Pain III™ CCLAD system 2. Composed of a disposable component, a handpiece, a handpiece component, & a computer-controlled unit. 3. The handpiece was an ultra-light pen-like handle 4. The handpiece was linked to an anesthetic cartridge with plastic microtubing
Helmy, et al. [11]	20% Benzocaine topical anst gel	1.8 ml LA cartridge of 4% Articaine hydrochloride with adrenaline 1:100,000	PDL of each root of a tooth	30	NR	1. The needle was bent 45° into the gingival sulcus of the DL & ML line angle at approx 30° to the long axis of the tooth. 2. The bevel faced the alv bone.	NR	NR	0.4 mL per tooth	5 sec	1. The needle was bent 45° for proper placement. 2. The operator waited 5 sec before the needle was advanced into the PDL.
Castelo, et al. [14]	20% Benzocaine topical anst gel	2% lidocaine with epinephrine 1:100,000	1. CDS-ILA: radicular portion of tooth (mesial & distal) 2. CDS-IOA: inter radicular space distal to the tooth	30	25	IANB	NR	NR	1. CDS-ILA: 0.9 ml in each radicular portion (M and D) 2. CDS-IOA: 0.9 ml inj into the inter radicular space	NR	NR
Anil, et al. [8]	10% lidocaine spray	Ultracaine (Articaine HCl & Epinephrine)	NR	30	16	Infiltration	NR	NR	NR	Every 2 sec	1. The Sleeper One system was programmed to run continuously in slow mode. 2. A server provided The device with over 1.8 mL every 2 sec.
Beegum, et al. [20]	NR	1.8-ml anesthetic cartridge (2% lidocaine with 1/80.000 adrenaline)	NR	27	NR	Infiltration	NR	NR	NR	NR	1. The I-Ject device consisted of a stainless-steel ampule cap that held a cartridge and a handpiece component with a computer control unit. 2. The handpiece is a very light pen-like handle connected to an anesthesia cartridge. 3. The local anesthesia was delivered at a slow speed
Chengappa, et al. [17]	NR	NR	Buccal and lingual anesthesia infiltration in the mandibular arch and buccal and palatal infiltration in the maxillary arch.	NR	NR	Infiltration	NR	NR	NR	NR	CCLAD system disposable lightweight injection handpiece

Table 4b. (continued)

Author	Topical anst	Anst	Inj site	Needle gauge	Needle length	Type of inj	Number of inj	Anst cart	Anst vol	Rate of inj	CCLAD inj characteristics
Vitale, et al. [19]	NR	articaine 4% + adrenaline 1/100,000 vial	on the vestibular and lingual sides	30	9 mm (DHT needle)	Infiltration	NR	NR	NR	NR	A slow injection was performed both on the vestibular and lingual sides. The DHT needle was used with an insertion angle of 15 ○ between the needle and the mucosa. The speed was slow and steady, with a 2-second pause every 4 seconds.
Muller-Bolla, et al. [21]	Topical lidocaine, xylocaine or benzocaine	Articaine 4% 1:200 000; Septodont	NR	30	9 mm (DHT needle)	Infiltration	NR	NR	NR	NR	The IOA mode is indicated by a blue light among the three pre-programmed injection modes corresponding to different speeds.
Adults											
Flisfisch, et al. [10]	NR	4% articaine 1:200,000 adrenaline	1. Two tooth-neck defects were selected, each in different quadrants & buccal infiltration was given 2. A total of 46 tooth neck defects were treated.	27	40	Buccal infiltration	Two tooth-neck defects each. Three patients: 4 tooth-neck defects each	NR	1.5 mL (from 1.7 mL cartridge)	0.005 mL/sec, 4:50 min	1. The Wand STA system had a pre-sterilized single-use handpiece and a drive unit. 2. A needle was attached to the handpiece using a Luer-Lock mechanism. 3. Used in the regular modus (control flow). 4. No topical anesthesia was used. 5. Mucosal puncture was performed with a pre-puncture technique. 6. A beveled needle was inserted into the tissue with continuous positive pressure.
Attia, et al. [9]	NR	NR	G1: lower right IANB & infiltration anesthesia in the region of the first right premolar G2: first premolar left and right buccal side	NR	NR	Supraperiosteal infiltration & IANB	At four sites for each subject	NR	NR	one ampule per min	NR
O' Neal, et al. [13]	NR	2% lidocaine with 1:100,000 epinephrine	Max lateral incisor	30	1 inch	Infiltration	NR	1	NR	>162 sec	1. Injection was administered using the Dentapen, using a traditional grip. 2. The flow rate was set as 1.8 mL over 162 seconds on the Dentapen. 3. The ramp-up mode was also used, which gradually increased the flow rate over the first 5 seconds of the infiltration.
Berrendero, et al. [18]	NR	1.8 ml of Articaine with epinephrine (40 mg/ml + 0.01 mg/ml)	Both in the lower and the upper arch.	30	0.3 × 30-mm needle	Infiltration	NR	NR	NR	60 sec	1. This program started with 10 seconds of slow injection of the anesthetic solution. After that, the equipment automatically switched to the fastest pace until the cartridge was empty. 2. According to the manufacturer, the infiltration duration was around 60 seconds. The system provides the clinician with audible and visual feedback. 3. The audible signs indicated the injection speed and a scale of LEDs indicated the applied pressure.

Alv, alveolar; Anst, anesthesia; Cart, cartilage; CCLAD, computer-controlled local anesthesia delivery; CDS-ILA, computer-controlled local anesthetic delivery system-intraligamentary anesthesia; CDS-IOA, computer-controlled local anesthetic delivery system-intraosseous anesthesia; DHT, dental Hi-Tech; DL, distolingual; G, group; HCl, Hydrochloric acid; IANB, inferior alveolar nerve block; Inj, injection; IOA, intraosseous anesthesia; LA, local anesthesia; Mand, mandibular; Max, maxillary; min, minute; ML, mesial lingual; NR, not reported; PDL, periodontal ligament; sec, second; STA, single tooth anesthesia; TM, trademark.

Table 5a. General characteristics of conventional LA injections

Author	Tooth	Diagnosis	Dental procedure	Provider	Topical anesthesia	Type of local anesthesia	Injection site
Children							
Smolarek, et al. [16]	Max post teeth	NR	Restoration	Dentist	20% Benzocaine gel	Lidocaine with epinephrine	Alv mucosa
Ludovichetti, et al. [12]	Mand or Max (any tooth)	NR	Any dental procedure under LA	Dentist	EMLA 2.5 mg/g + 2.5% mg/g cream (Lidocaine + Prilocaine)	NR	Alv mucosa
Shetty, et al. [15]	Primary Mand teeth	NR	Various dental procedures	Dentist	Topical anesthetic gel Precaine® B	2% lidocaine with 1:80,000 epinephrine;	Alveolar mucosa
Helmy et al. [11]	Mand primary molars	Non-restorable teeth due to primary or secondarycaries,crownfractures,periapicaldisease, andfailedpulpotomies	Extraction	Dentist	20% benzocaine topical anesthetic gel	4% Articaine hydrochloride with adrenaline 1:100,000	CC-ILA-Gingival Sulcus IANB-Buccal-ILA Gingiva
Castelo, et al. [14]	Molar	Dental caries	Restoration	Dentist	20% benzocaine topical anesthetic gel	2% Lidocaine with epinephrine 1:100000	Radicular portion
Anil, et al. [8]	Upper primary molar and first permanent molar	Dental caries	Restoration	Dentist	10% Locanest TM Lidocaine spray	Conventional infiltrative anesthesia (Genject Brand Syringe (30G1, Genject Health Products, Turkey)+Ultracaine™D-Sforteampule	Alv Mucosa
Beegum, et al. [20]	NR	NR	NR	Dentist	NR	2% lidocaine with 1/80,000 adrenaline	NR
Chengappa, et al. [17]	Mandibular and maxillary arch	Dental caries	Extraction Pulp therapy Minor surgical work Restorations.	Dentist	NR	NR	Buccal and lingual anesthesia infiltration in the mandibular arch and buccal and palatal infiltration in the maxillary arch.
Vitale et al. [19]	Maxillary and mandibular first or second primary molar	Dental caries	Restoration	Operator	NR	Articaine 4% + adrenaline 1/100,000 vial	On the vestibular and lingual sides
Muller-Bolla, et al. [21]	Maxillary and mandibular primary molars	Dental caries	Restoration	Trained operator	Topical lidocaine, xylocaine or benzocaine	Articaine 4% 1:200 000; Septodont	Intra-mucosal buccal
Adults							
Flisfisch et al. [10]	Cervical area	Tooth neck Defect	Restoration	Dentist	NR	4% articaine as the anesthetic agent and 1:200,000 adrenaline as the vasoconstrictor.	NR
Attia, et al. [9]	NR	NR	NR	Dentist	NR	NR	Supra periosteal
O' Neal, et al. [13]	Max lateral incisor	NR	NR	Dentist	NR	2% lidocaine with 1:100,000 epinephrine	Alv mucosa
Berrendero, et al. [18]	Upper molar and anterior teeth. Lower arch	Dental caries, Periodontal diseases	Restoration Extraction	Restorative dentistry specialist	NR	articaine with epinephrine (40 mg/ml + 0.01 mg/ml)	For the extraction of the molars, the upper dental nerve and the posterior palatal nerve. For restorations of the anterior teeth, the needle was the height of the mucobuccal fold above the apex of the teeth. For the lower arch, The needle was inserted between the internal oblique edge and the pterygomandibular raphe about 1 cm above the occlusal surface in a direction coming from the opposite side until the needle contacts the bone.

Alv, alveolar; CC-ILA, computer-controlled intraligamentary anesthesia; IANB, inferior alveolar nerve block; ILA, intraligamentary anesthesia; LA, local anesthesia; Mand, mandibular; Max, maxillary; NR, not reported; post, posterior; TM, trademark.

Table 5b. General characteristics of conventional LA injections

Author	Needle gauge/ length (mm)	Inj number	Number of anst cartridges	Anst vol	Rate of inj	Type of injection	Control group anesthesia injection characteristics
Children							
Smolarek, et al. [16]	NR/20 mm	One per site.	NR	1.8 mL of 2% lidocaine	1.0 mL /min, 108 sec	Infiltration	The bevel of the needle turned to the alveolar mucosa and slightly penetrated the soft tissue.
Ludovichetti, et al. [12]	30 gauge/ 16 mm	NR	NR	NR	NR	Infiltration	NR
Shetty, et al. [15]	27 gauge/ 35 mm	NR	1	NR	NR	IANB	NR
Helmy, et al. [11]	27/NR	1 per site	1	1.8 ml La in CCILA 1.5 ml in IANB	NR	Infiltration	The needle was withdrawn 2 mm to aspirate. Then 1.0 mL of Articaine hydrochloride 4% with adrenaline 1:100,000 was injected, followed by 0.5 mL as a prolonged buccal infiltration distal to the second primary molar. Numbness was assessed by placing a dental probe on the gingiva every 30 s and checking for lower lip tingling.
Castelo, et al. [14]	30/NR	1 per site	1	1.8 mL	NR	IANB	NR
Anil, et al. [8]	30/NR	1 per site	1	1.5-2 mL	NR	Infiltration	Bone contact was taken by entering the stretched mucosa. The needle tip was withdrawn by 1 mm, and 1.5–2 mL solution was injected into the tissue after aspiration.
Beegum, et al. [20]	27	NR	NR	2% lidocaine with 1/80,000 adrenaline	NR	Infiltration	The child received both types of infiltrations in two consecutive visits, using a metallic syringe on the first visit and the I-Ject device on the other visit.
Chengappa, et al. [17]	NR	NR	NR	NR	NR	Infiltration	This was administered to the children needing the administration of local anesthesia for more than two consecutive treatment sessions.
Vitale, et al. [19]	30/9 mm	NR	NR	articaine 4% + adrenaline 1/100,000 vial	NR	Infiltration	A slow injection was performed both on the vestibular and lingual sides
Muller-Bolla, et al. [21]	30/9 mm	NR	NR	Articaine 4% 1:200 000; Septodont	NR	Infiltration	A distraction technique in the form of a cheek wiggle was used upon inserting the syringe.
Adult							
Flisfisch, et al. [10]	27/ N	1	1 per site	1.7 mL	2.25 min	Infiltration	NR
Attia, et al. [9]	7G -0.4x 23 mm	1	1 per site	One ampule	One ampule/min	Infiltration	NR
O' Neal, et al. [13]	30/NR	1	1	1.8 mL	1.8 mL/60 sec	Infiltration	NR
Berrendero, et al. [18]	30G 0.3 × 30-mm needles	NR	NR	articaine with epinephrine (40 mg/ml + 0.01 mg/ml	NR	Infiltration IANB Palatal nerve block	Two different techniques were used for conventional anesthesia. 1. An infiltrative anesthesia technique was used for the upper maxillary treatments. The upper dental and posterior palatal nerves were anesthetized to extract the molars. The anterior dental nerve was blocked at the interincisal level for restorations of the anterior teeth. 2. The inferior alveolar nerve block (IANB) was performed for the treatments in the lower arch.

Anst, anesthesia; IANB, inferior alveolar nerve block; CC-ILA, computer-controlled intraligamentary anesthesia; Inj, injection; min, minutes; mL, milliliter; mm, millimeter; NR, not reported.

Table 6. Study outcomes

Author	Post op med	Pain measurement time points	Pain evaluator	Parameter ass tool	Statistical sig	Outcome
Children						
Smolarek, et al. [16]	NR	NR	Dentist	WBF, NRS, FLACC, Corah, VPTm.	$P > 0.05$	None of the techniques influence the levels of anxiety and disruptive behavior. Pain perception was reduced with conventional anesthesia.
Ludovichetti, et al. [12]	NR	NR	Dentist	VAS for pain and Venham Test for Anxiety	$P < 0.05$	Traditional anesthesia: higher pain perception score, more hostile, uncooperative behavior. QuickSleeper computer-assisted anesthesia system resulted in a significantly lower pain perception score and helpful, cooperative behavior.
Shetty, et al. [15]	NR	At the baseline, during the deposition, and after the deposition of LA.	Dentist	WBF	Group B: Lower Pain Scores compared to Group A statistically significant ($P < 0.05$)	No Pain III™ CCLAD system resulted in reduced pain perception and better. acceptancewhencomparedtotheuseoftheconventionalsyringeforIANBinchildren
Helmy, et al. [11]	NR	An impartial observer recorded SEM pain scores by observing and classifying each child's behavior on videotapes. After a 7-day interval, these steps were repeated to ensure the results were accurate and reliable.	Dentist	Physiologically using HR, subjectively using FPS, and objectively using the SEM	Significantly lower scores in the heart rate in the CC-ILA group during injection ($P < 0.05$), but no significant difference was recorded between the two groups during extraction ($p>0.05$). During injection, the SEM and FPS showed significantly lower scores in the CC-ILA group ($P < 0.05$).	CC-ILA provides significantly less painful injections than conventional techniques and proved to be as effective as IANB during the extraction of mandibular primary molars. An essential advantage of this technique was the complete absence of lip/cheek-biting events.
Castelo, et al. [14]	NR	A follow-up phone call 24 hours after the dental procedure was completed to record the postoperative morbidity.	Dentist	VAS, WBS, and FLACC	Statistically significant differences in favor of CDS-ILA w.r.t "pain due to anesthesia injection" ($P < 0.05$), "physical reaction during the anesthesia injection" ($P < 0.05$), "postoperative morbidity" ($P < 0.05$), and "type of postoperative complication" ($P < 0.05$)	Pediatric patients' preference for CDS versus conventional technique
Anil, et al. [8]	NR	NR	Dentist	VAS, WBS, MCDAS, FLACC.	Pulse, VAS, WBS, MCDAS, FLACC, and salivary cortisol values were increased after the anesthesia in the control group ($P < 0.05$). WBS, MCDAS, FLACC, and salivary cortisol values were decreased after the anesthesia in the study group compared to the control ($P < 0.05$).	Computer-controlled anesthesia devices can be recommended for pediatric patients as they reduce pain and anxiety.
Beegum, et al. [20]	NR	Before anesthesia administration, all the children's anxiety scales were recorded. Pain was evaluated after LA was performed.	Dentist	MCDAS, FPS-R	The patient's pain was measured and showed significant differences (P-value < 0.01)	Patients reported more comfort in injection with the I-Ject computer-controlled device than with conventional anesthesia.
Chengappa, et al. [17]	NR	Fear and anxiety levels were evaluated both before and after administration using the traditional injection. The pain perception during the actual injection.	Children	CFSS-DS, WBS	The comparison of CCLAD and conventional groups' pretest and post-test CFSS-DS scores showed significantly lower values for the CCLAD group, indicating lower anxiety levels. The difference between CCLAD and conventional groups with Wong-Baker Pain scale scores is statistically significant.	The CCLAD system could be a helpful alternative in administering local anesthesia. The disadvantages of CCLAD systems are that they require a longer time during administration and cost.
Vitale, et al. [19]	NR	After the local anesthesia administration	Observer	VAS WBS	The technique has been shown to influence pain significantly ($P < 0.05$), with lower values for the SleeperOne device than the traditional syringe.	SleeperOne® device seems to be a valid support for the reduction of pain related to anesthetic injection, especially in children.
Muller-Bolla, et al. [21]	NR	During the injection of the local anesthetic (from needle penetration to complete injection)	Children	FPS-R Modified Venham scale (6-point scale ranging from 0 [relaxed child] to 5 [child out of control]	Reduced pain perception during LA in the CCLAD group compared with the CONV group (-0.72, 95% CI: -1.43, -0.006), but not during dental treatment. Stratified analyses showed that this effect was observed only in primary dentition ($P = .006$) and mandibular molars ($P = .005$). Behavioral issues were fewer in the CCLAD group than in the CONV group ($P = .05$) only during the injection.	Pain intensity during dental treatment appears to be lower in the CCLAD group than in the CONV group, in the mandible only. Children's behavior was significantly more relaxed during analgesic injection with CCLAD than with CONV. Most operators considered the SleeperOne5 device as the most suitable for young patients.

Table 6. (continued)

Author	Post op med	Pain measurement time points	Pain evaluator	Parameter ass tool	Statistical sig	Outcome
Adults						
Flisfisch, et al. [10]	NR	NR	Dentist	VAS	The level of anxiety-inducement and pain during administration was three times higher with the conventional syringe (35.95%–11.85%, $P < 0.005$ and 21.3%–7.7%, P ¼ 0.005, respectively); no difference in mean sensation of mucosal puncture, nor a statistically significant correlation between duration of administration and time until disappearance of numbness. Once anesthesia was administered, there was no pain during treatment.	Using CCLAD increased patients' comfort visually and in terms of administration; patients' preference for CCLAD increased with time.
Attia, et al. [9]	NR	NR	Dentist/ operator students	VAS scale, DAS	Pain perception on puncture between CCLA and conventional injections was not statistically significant ($P > 0.05$); pain perception during injection was significantly different ($P < 0.05$)	Professional experience influenced the perception of pain when applying local anesthesia.
O'Neal, et al. [13]	NR	NR	Dentist	Corah, Heft-Parker VAS	The pain of solution deposition was significantly less for the Dentapen injection than the traditional injection ($P < 0.05$)	The Dentapen, using the slow flow rate and ramp-up mode, significantly reduced the pain of solution deposition for maxillary lateral incisor infiltrations.
Berrendero, et al. [18]	NR	During the deposition of LA anesthesia.	Restorative dentistry specialist	VAS	$P < 0.05$	A computerized anesthesia system produces significantly less pain than a conventional syringe. Patients chose electronic anesthesia as the most satisfactory system.

CC-ILA, computer-controlled-intraligamentary anesthesia; CCLA, computer-controlled local analgesic; CCLAD, computer-controlled local analgesic delivery; CDS, computer-controlled local anesthetic delivery system; CDS-ILA, computer-controlled local anesthetic delivery system-intraligamentary anesthesia; CFSS-DS, Children's Fear Survey Schedule-Dental Subscale; CONV, conventional; Corah, Corah's Dental Anxiety; DAS, Dental Anxiety Scale; FLACC, Faces, Legs, Activity, Cry, Consolability; FPS-R, Face Pain Scale-Revised; HR, heart rate; IANB, inferior alveolar nerve block; LA, local anesthesia; MCDAS, modified Child Dental Anxiety Scale; NR, not reported; NRS, Numerical Rating Scale; SEM, Sound-Eye-Motor scale; TM, trademark; VAS, Visual Analog Scale; VPTm, modified Venham Picture Test; WBF, Wong-Baker FACES Pain Rating Scale.

India, The Nil, and CHU [8,9,13,17,20,21]. In eight studies, funding was not reported [10-12,14-16,18,19] (Table 3).

3. Characteristics of CCLAD

Different types of CCLAD systems were used in the included studies, such as the Morpheus device [16], Computerized QuickSleeper anesthesia [12], No Pain III™ Computer-controlled local analgesic delivery [15], CDS-IOA using the QuickSleeper system [14], CDS-ILA using Wand STA device [10,14], Dentapen [13], Computer-controlled device Calajet [9], Computer-controlled local analgesic delivery [8], Computerized controlled anesthesia with Calajec [18], SleeperOne® [19], Computer-controlled I Ject device [20], and SleeperOne5® [21].

Computer-controlled or -guided LA injections were used for different dental therapeutic procedures; for instance, a restoration procedure was performed in three studies [16,19,21]. In two studies, tooth extraction was performed [11,14]. In a study by Chengappa et al. [17], various dental procedures were performed, including extraction, pulp therapy, minor surgical work, and restorations. Berrendero et al. [18] performed different procedures, such as restorative treatment of the upper incisors, extraction of the upper molars, and scaling and root planning of the lower molars. Dental procedures were not reported in seven studies [8-10,12,13,15,20]. Moreover, in six studies, topical anesthesia was applied at the injection site before dental anesthesia was induced [8,11,12,14-16]. In contrast, topical anesthesia was not applied at the injection site in seven studies [9,10,13,17-20]. Both infiltration and block dental anesthesia techniques were reported in all the included studies. Infiltration dental anesthesia techniques were performed in 11 studies [8,10,12,13,15-21]. In a study by Castelo et al. [13], only inferior alveolar nerve block (IANB) was performed on the participants, while Attia et al. [9] reported both supraperiosteal infiltration and IANB. However, in a study by Helmy et al. [11], the needle was bent 45° into the gingival sulcus of the distolingual and mesioligual line angles at approximately 30° to the long axis of the tooth. Moreover, different dental anesthesia solutions were used in the presented studies, such as lidocaine and articaine dental local anesthesia with or without vasoconstrictors. In 6 studies, lidocaine was used with epinephrine [12-16,20].

In five studies, Artican dental anesthesia was used with epinephrine [8,10,11,18,19]. One study used lidocaine anesthesia with and without epinephrine, a vasoconstrictor [12]. The type of dental anesthesia was not reported in two studies [9,17]. A study by Muller-Bolla et al. [21] used articaine (4%, 1:200000) and Septodont. The injection sites differed in eight studies, such as the alveolar mucosa, intra-articular area, or buccal side of the tooth [9-16]. The injection site was not reported in three studies [8,20,21]. 27- [10,15,20] and 30-gauge needles [8, 11,13,14,19,21] were used at varied lengths of 1-inch [13], 16 mm [8,12], 20 mm [16], 25 mm [14], and 40 mm [10]. Four studies did not disclose the needle size [9,12,16,17], and five studies did not report the needle length [9,11,15,17,20]. The injection speeds with computer-guided devices differed in ten studies [8-11,13, 15,16,18-21]. In three studies, the speed of anesthesia injection was not reported [12,14,17] (Table 2). The number of injections per site varied between one and four among five studies [9,10,12,15,16]. In nine studies, the number of injections per site was not mentioned in the CCLAD group [8,11,13,14,17-21] (Tables 4a and 4b).

4. Characteristics of conventional dental anesthesia injections

The dental anesthesia injection technique used in the included studies varied between infiltration and IANB. Eleven studies used infiltration dental anesthesia techniques [8-14,16,17,19-21]. In two studies, IANB techniques were used [14,15]. In a study by Berrendero et al. [18], infiltration, IANB, and palatal nerve block were used.

The needle gauges used varied among 12 studies [8-15, 18-21]. 27- [10,11,15,20] and 30-gauge needles [8,12-14, 18,19,21] were used at lengths of 16 [12], 20 [16], and 35 mm [15]. In seven studies, the needle length was not reported [8,10,11,13,14,17,20]. Moreover, in seven studies, topical anesthesia was applied at conventional dental anesthesia injection sites before dental anesthesia was administered [8,11,12,14-16,21]. In contrast, in seven studies [9,10,13,17-20] topical anesthesia was not applied at the injection site. In two studies, the speed and duration of injection were not reported [12,14]. Moreover, the number of injections was 1 per site in seven studies [8-11, 13,14,16]. The number of injections was not reported in seven studies [12,15,17,18,20,21]. In all included studies, a dentist administered both types of injections: the CCLAD system, and conventional dental anesthesia (Table 5a, Table 5b).

5. Characteristics of outcome variables

In all 14 RCTs, various pain and anxiety assessment tools were used, such as the Wong-Baker FACES pain rating scale (WBS), visual analogue scale (VAS), modified child dental anxiety scale (MCDAS), pulse, face-pain scale (FPS), objectively sound eye-motor scale (SEM), systolic blood pressure, diastolic blood pressure, heart rate (HR), oxygen saturation (SpO_2), respiratory rate (RR), anxiety emotional state (VPTm), numerical rating scale (NRS), Corah's dental anxiety (Corah) scale, modified Venham picture test (VPTm), and Faces, Legs, Activity, Cry, and Consolability (FLACC) scale, and the dentist evaluated the pain following the dental anesthesia injection in both groups [8-21] (Tables 4a and 4b). In eight RCTs, VAS was used for pain assessment [8-10, 12-14,18,19]. In a study by Smolarek et al. [15], different tools, such as the WBF, NRS, FLACC, Corah, and VPTm, were used to evaluate anxiety and pain. However, none of these techniques influenced stress levels or disruptive behaviors. Conventional anesthesia reduced pain perception [16]. In the study by Ludovichetti et al., VAS and VPTm were used for pain evaluation and anxiety, respectively. This study showed that conventional anesthesia caused high pain perception. However, QuickSleeper, a computer-assisted anesthesia system, showed significantly lower pain perception scores, and

Table 7. Risk of bias (Rob) assessment across individual studies using the Cochrane RoB tool for interventions

Author	Randomization sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias	Overall
Smolarek, et al. [16]	Low	Low	High	Low	Low	Low	Low	Some concerns
Ludovichetti, et al. [12]	Low	High	High	High	Low	Low	Low	High
Shetty, et al. [15]	Low	Low	High	Low	Low	Low	Low	Some concerns
Helmy, et al. [11]	Low	Low	High	Low	Low	Low	Low	Some concerns
Castelo, et al. [14]	Low	High	High	Low	Low	Low	Low	Some concerns
Anil, et al. [8]	Low	Low	High	Low	Low	Low	Low	Some concerns
Flisfisch, et al. [10]	Low	High	High	High	Low	Low	Low	High
Attia, et al. [9]	Low	Low	Low	Low	Low	Low	Low	Low
O' Neal, et al. [13]	Low	Low	Low	Low	Low	Low	Low	Low
Chengappa, et al. [17]	Low	Low	Some concerns	Some concerns	Low	Low	Some concerns	Some concerns
Berrendero, et al. [18]	Low	Low	Low	Low	Low	Low	Low	Low
Vitale, et al. [19]	Low	Low	High	Low	Low	Low	Low	Some concerns
Beegum, et al. [20]	Low	Low	High	Low	Low	Low	Low	Some concerns
Muller-Bolla, et al. [21]	Low	Low	High	High	Some concerns	High	Some concerns	High

the participants displayed helpful and cooperative behavior [12]. Shetty et al. [15] used WBS for pain assessment. The No Pain III™ CCLAD system used in the study group resulted in reduced pain perception and better acceptance when compared to the conventional anesthesia injection in children. Additionally, in a study by Helmy et al. [11], different assessment tools were used to evaluate the pain with the CCLAD system and conventional anesthesia injections, such as the physiological HR, subjective FPS, and objective SEM. CC-ILA involves significantly less painful injections than conventional techniques and proved to be as effective as IANB during the extraction of mandibular primary molars. Castelo et al. [13] used different pain assessment tools, such as VAS, WBS, and FLACC. The study showed that pediatric patients preferred the CCLAD system over the conventional technique because it decreased pain and anxiety. Anil et al. [8] used various pain and anxiety tools, such as WBS, MCDAS, and FLACC, and reported that computer-controlled anesthesia devices can be recommended for pediatric patients as they reduce pain and anxiety. Flisfisch et al. [9] used only VAS for pain evaluation and reported that CCLAD increased patients' comfort visually and in terms of administration; patients' preference for CCLAD increased with time. However, in a study by Attia et al. [9], VAS and DAS were used to assess pain and anxiety, and the study showed that professional experience influenced the perception of pain when applying local anesthesia. In a survey by O'Neal et al. [12], Corah, Heft-Parker, and VAS were used to assess pain and anxiety. The study reported that Dentapen, using a slow flow rate and ramp-up mode, significantly reduced the pain of solution deposition for maxillary lateral incisor infiltrations. Beegum et al. [20], used MCDAS and pain scale-revised (FPS-R) and found that patients reported more comfort during injection with the I-Ject computer-controlled device than with conventional anesthesia. Chengappa et al. [17] used the Fear Survey Schedule-Dental Subscale and WBS and showed that The CCLAD system could be a useful alternative for administering local anesthesia. The disadvantages of CCLAD systems are that they require additional time and cost. Vitale et al. [19], used VAS and WBS and showed that the SleeperOne® device provided a valid support for reducing pain related to anesthetic injection, especially in children. Muller-Bolla

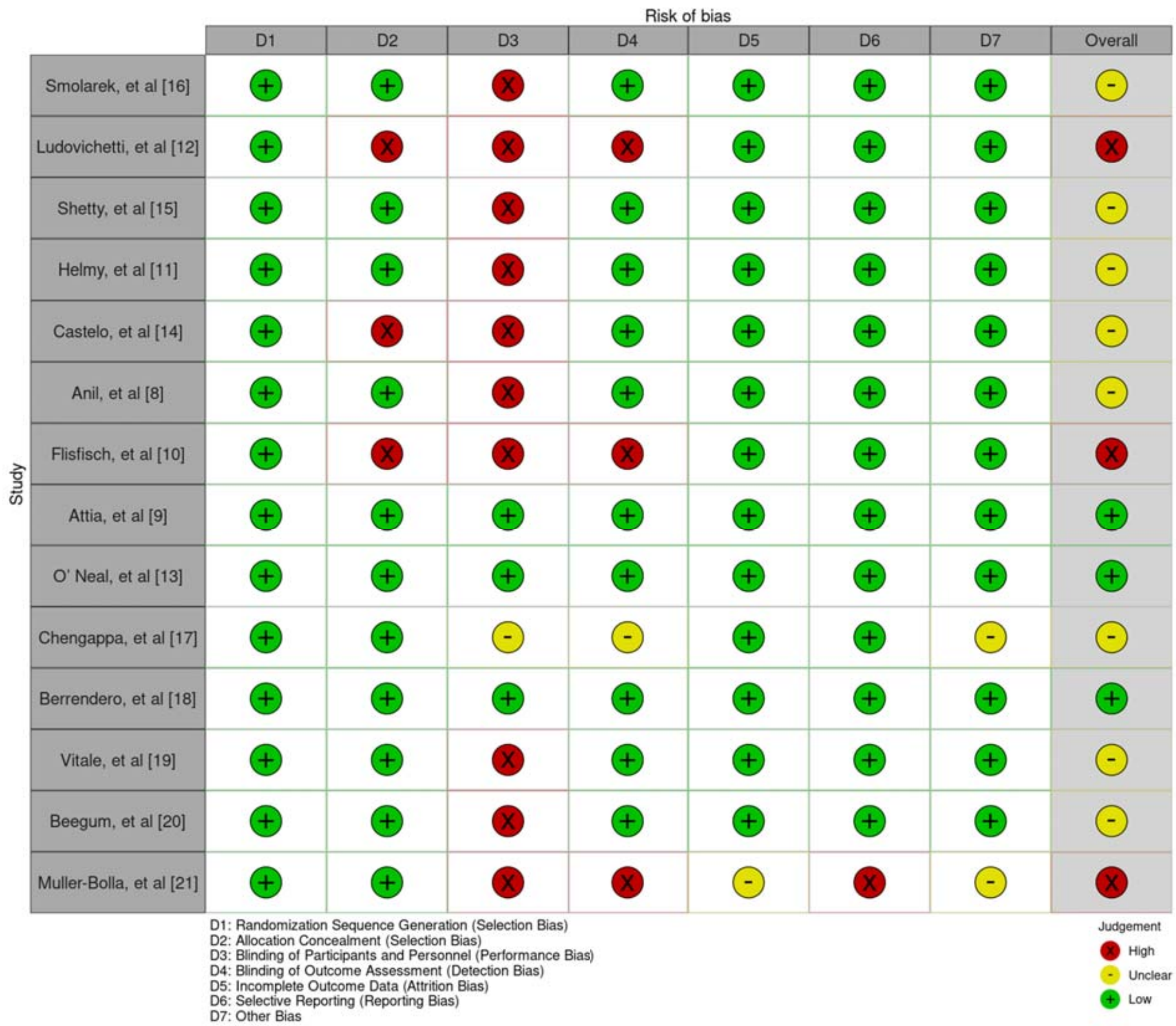

Fig. 2. Traffic light plot

et al. [21] used FPS-R and modified Venham scale (6-point scale ranging from 0 [relaxed child] to 5 [child out of control]) and showed that pain intensity during dental treatment was lower in the C-CLADS group than in the CONV group in the mandible only. Children's behavior was significantly more relaxed during analgesic injection with C-CLADS than with CONV. Most operators considered the SleeperOne5 device the most suitable for young patients. However, in a study by Berrendero et al. [18], only VAS was used, and a computerized anesthesia system produced significantly less pain than a conventional anesthesia syringe. Patients chose electronic anesthesia as the most satisfactory system (Table 6).

6. Risk of bias (RoB) in individual studies

RoB was assessed using the Cochrane RoB tool for interventions, RevMan 5.4 software. The Cochrane collaboration guidelines evaluated the likelihood of bias in the included randomized controlled trials in six dimensions: i) sequence generation, ii) allocation concealment, iii) blinding of participants and outcome assessors, iv) incomplete outcome data, v) selective outcome reporting, and vi) other sources of bias [22]. Two authors assessed the RoB of the individual studies. The overall RoB was classified as high, low, or concerning. Randomization Sequence Generation (selection bias) was low in all studies [8-21]. Allocation

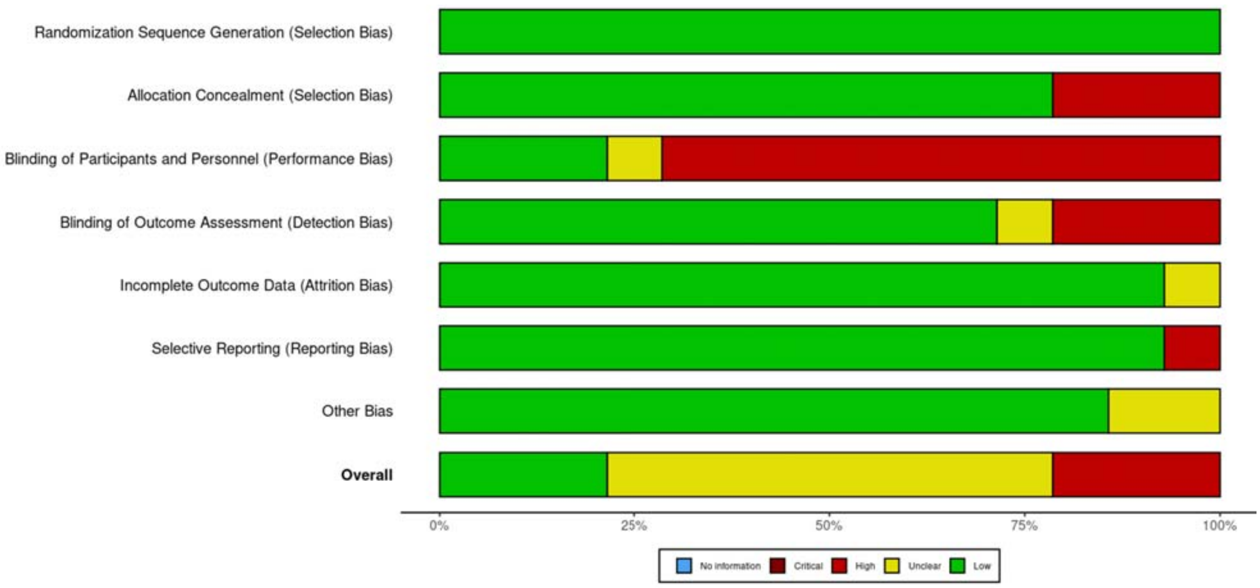

Fig. 3. Risk of Bias of included studies.

Concealment (Selection Bias) was low in 11 studies [8,9,11,13,15-21] and high in three studies [10,12,14]. Blinding of participants and personnel (performance bias) was low in three studies [9,13,18] and high in 10 studies [8,10-12,14-16,19-21]. There were some concerns regarding one study [17]. Blinding of outcome assessment (detection bias) was low in 10 studies [8,9,11,13-16,18-20], high in three studies [10,12,21], and some concerns in one study [17]; incomplete outcome data (attrition bias) and selective reporting (reporting bias) were low in 13 studies [8-20] and one study had some concerns about attrition bias and high reporting bias [21], and other biases were low in 12 studies [8-13,15,16,18-20] and some concerns in 2 studies [17,21] (Table 7, Fig. 2 and Fig. 3).

DISCUSSION

To manage pain and anxiety among pediatric and apprehensive adult patients, the development of innovative delivery devices and adjustments to injection procedures for local dental anesthesia offers practitioners a more straightforward treatment approach that results in less pain during injection. CCLAD is a unique technology [23,24]. This study found that using the computer-assisted anesthetic equipment QuickSleeper led to significantly lower pain perception scores and cooperative and helpful conduct. When administering IANB to children, the no pain ITM CCLAD device resulted in higher acceptability and lower pain perception than conventional syringes. CC-ILA injections were as successful as IANB in the extraction of mandibular primary molars. Moreover, they also caused less pain than traditional procedures. There were no instances of lip or cheek biting, which is a significant advantage of this technique.

Considering that computer-controlled local anesthetic distribution reduces pain and anxiety, pediatric patients may benefit from such devices. The use of a local anesthetic affected how painful it felt because of the expert experience. With the use of CCLAD, patients' comfort levels during administration and sight improved, and with time, their appreciation of the treatment increased. The ramp-up mode and modest flow rate of Dentapen significantly reduced the pain associated with solution deposition. The theory behind this system is that the anesthetic solution must be delivered at a specific flow rate and continuous pressure compatible with tissue acceptance. This results in reduced pain perception and consequently, decreases patient anxiety levels [25].

The effectiveness of a computerized system (QuickSleeper) compared with a standard syringe for injecting a local anesthetic was examined by Ludovichetti et al. [12], who emphasized the feeling of pain and anxiety in pediatric patients. The Venham test was used to gauge the patients' level of anxiety following each anesthetic infusion. In terms of the Venham pain scale, electronic anesthesia performed significantly better than traditional anesthesia at both mandibular and maxillary sites. The computer-assisted anesthesia system produced helpful and cooperative behavior and a marked reduction in the pain perception score. Therefore, it is a better option than conventional injection anesthesia and helps spare children of all ages from trauma or invasive procedures.

A study by Berrendero et al. [26], when comparing the Calaject CCLAD system and traditional anesthetic, reported that most children experienced less discomfort using the CCLAD system. Another similar study conducted by Shetty et al. [15] evaluated how children's IANB discomfort was perceived when using a no-discomfort ITM CCLAD system against a traditional syringe. Physiological measures, such as blood pressure, HR, and RR were measured at baseline, during, and after LA deposition. The WBS was used to subjectively assess pain perception. When IANB was administered to children, the no-pain ITM CCLAD device produced better acceptability and lower pain perception than the traditional syringe. In another study by Anil et al. [8], both approaches showed increased patient pulse levels following anesthesia. Nevertheless, there was no discernible variation in SpO_2 readings. This could be related to the potential of the pulse oximeter screen displaying recorded SpO_2 values later than the pulse values. Nonetheless, following anesthesia, the pulse and SPO_2 readings of the study group were lower than those of the control group. Thoppe-Dhamodhara et al. [27] reported changes in pulse values after infiltrative anesthesia or nerve-blocking procedures using epinephrine solutions. However, Akinmoladun et al. [28] and Meyer [29] postulated that elevated HR and changes in blood pressure during dental procedures are derived from endogenous catecholamine release brought on by emotional strain, rather than being side effects of medication. Tolas et al. [30] and Meechan et al. [31] found that anesthetics significantly influenced cardiovascular reactions to dental treatment under LA. Özer et al. [32] observed an increase in pulse rate when patients were administered infiltrative, intraosseous, and mandibular anesthetics. Goyal et al. [33] examined 15 juvenile patients with indications for extraction using the Wand and conventional anesthetic procedures. According to previous reports, there were similarities in SpO_2 and pulse readings between groups. When Smolarek et al. [34] evaluated three anesthetic procedures, they discovered no differences in the SpO_2, RR, or pulse readings among groups.

The device reduces discomfort, eliminates injection anxiety, and improves patient comfort. This device relieves dentists' strained muscles by repeatedly administering manual injections. Some of its benefits include autoaspiration to pinpoint the precise injection location and automated priming upon device initiation, eliminating the possibility of hematoma formation and trismus. CCLAD devices are designed to continuously monitor the pressure at the injection site to prevent overpressure, which is a painful side effect of manual injections. To provide smooth injection flow, the infusion flow is adjusted based on the best assessment of the anesthetic dose, which is processed using sophisticated control algorithms [2]. One of the main factors contributing to this preference is that CCLAD eliminates visual stimuli from dental syringes and reduces injection pain. However, the cost of purchasing replacement syringes and disposable attachments, injection duration, requirement to alter work schedules, and additional space required for the device continue to be obstacles to its widespread adoption in clinical practice [35]. A larger sample size would have been better to observe changes in pain perception. The duration of each LA deposition period should also be considered. Various CCLAD systems could be used to objectively assess pain perception in children, using physiological markers.

CONCLUSION

The computer-assisted anesthetic device resulted in a significantly reduced pain perception score and helpful cooperative behavior. CCLAD devices are particularly beneficial in pediatric dentistry and apprehensive adult patients. The various settings and speeds make the injection virtually undetectable and unthreatening, which eases the patient's anxiety, as most patients are afraid of the traditional injection needle. These devices minimize pain during local anesthesia for dental procedures by regulating the rate at which the anesthetic is delivered to tissues. The findings showed that adults who used CCLAD experienced less discomfort and more potent sedation than children. Compared with the traditional syringe, the CCLAD device improved acceptability and decreased pain perception in children receiving IAN.

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