Review Article

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Computer-controlled local anesthetic delivery for painless anesthesia: a literature review

Eun-Jung Kwak, Nan-Sim Pang, Jin-Hyung Cho, Bock-Young Jung, Kee-Deog Kim, Wonse Park

Department of Advanced General Dentistry, College of Dentistry, Yonsei University, Seoul, Korea

Local anesthesia is administered to reduce pain during dental treatments, but may itself cause pain and contribute to increased dental fear. Computer-controlled local anesthetic delivery (CCLAD) is one the method to reduce patient pain during local anesthesia; it is a device that slowly administers anesthetics by using a computerized device to control the injection speed. This literature review aims to provide an objective assessment of the usefulness of CCLAD for controlling pain by reviewing papers published to date that have used CCLAD.

Keywords: Anesthetic device, Computer-controlled anesthesia, Local anesthesia, Pain

INTRODUCTION

Dental fear is the most common reason for patients to avoid visiting the dentist. Dental fear can occur for a variety of reasons, including noise and vibration from tooth-cutting devices such as dental handpieces, smell of drugs or materials used in dentistry, pain during dental treatment, and irrational fear of local anesthesia [1]. Because dental treatments may be painful, appropriate local anesthesia is necessary to reduce pain during such treatments. However, paradoxically, patients often fear pain caused by anesthetic injections more than pain from dental treatment itself [2].

Despite careful anesthetic procedures, dental local anesthesia can cause pain for various reasons, including soft tissue damage during penetration of the oral mucosa, pressure from the spread of the anesthetic solution, temperature of anesthetic solution, low pH of anesthetic solution, and pain from the characteristics of the drug. In order to reduce pain during local anesthesia, swabbing anesthesia is often performed on the injection point; similarly, local anesthetic techniques that can anatomically reduce pain, such as infiltration anesthesia, should be used rather than subperiosteal or intraosseous injections that can cause pain. In addition, the anesthetic ampoule must be used administered at a temperature similar to body temperature; sterile local anesthesia should be used; and effort should be made to slow the injection speed [3]. Although reducing the injection speed is the most effective method of reducing pain, controlling and maintaining the amount or speed of injection in actual clinical settings is difficult.

Many devices have been introduced that can inject local anesthetic into the tissues at a set speed. Collectively, these "painless anesthetic devices", are termed "computer-controlled local anesthetic delivery" (CCLAD) devices. CCLAD also collectively refers to devices that

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Corresponding Author: Wonse Park, Department of Advanced General Dentistry, Yonsei University College of Dentistry, 50 Yonsei-ro, Seodaemun-gu, Seoul 03722, Korea
Tel: +82-2-2228-8982 Fax: +82-2-2227-8906 E-mail: WONSE@yuhs.ac

not only slow and maintain the injection speed, but also maintain a constant speed while taking into account the anatomical characteristics of the tissues being injected [4,5]. The most widely known devices of this type include the Wand® (Milestone Scientific, Livingstone, NJ), Comfort Control Syringe (CCS; Dentsply, USA), QuickSleeper (Dental HiTec, France), and iCT (Dentium, Seoul, Korea).

The purpose of this review was to review published clinical trial papers on CCLAD in adults and children in order to share the latest knowledge and current state of CCLAD. Two authors (Kwak and Park) conducted a literature search of the National Center for Biotechnology Information (NCBI) Pubmed database for papers published between January 2001 and May 2016. The papers were limited to those published in the English language only using the CCLAD-related keywords "computer local anesthesia," "Wand," "Comfort Control Syringe," and "Quicksleeper." After the initial search, the original papers were assessed to identify those related to clinical trials, those that included dental local anesthesia and human subjects, and those that included comparison results. A total of 27 papers met these search criteria. These papers were then divided into those on adults and children.

BASIC CONCEPT AND DEVICES OF CCLAD

CCLAD can reduce pain by controlling anesthetic injection speed, which permits continuous administration of a small amount of anesthetic at a slow speed, which can reduce pain not only from resistance felt in the tissues, but also from anesthesia taking effect simultaneously with injection, which in turn allows the anesthetic to be injected into tissue that has already been anesthetized. Thus, owing to this series of processes, the patient feels less pain.

The design points to consider when evaluating CCLAD devices include whether the anesthetic cartridge is included in the main unit, speed and mode of drug injection, possibility of aspiration, weight, and ease of infection management. Milestone Scientific (Piscataway, NJ, USA) first introduced the Wand® in 1997; since then, several companies have also developed the computer-based, speed-controlled local anesthetic devices used today, including the Quicksleeper® and Comfort Control Syringe (CCS®) in use overseas; and the Comfort-in®, Deninjection®, iCT injection®, No Pain III®, Meg-inject®, and Smartject® devices used in South Korea. Because these devices have varying characteristics, such as design, injection speed, shape, weight, and possibility of aspiration, it is important to choose the appropriate product based on operator preference.

The Wand®, has been on the market for the longest period of time, and is known for its ease in operation due to its light weight and a circumference that is about half that of traditional anesthetic syringes. In contrast, the Quicksleeper® and CCS® have are about three times size and weight of traditional anesthetic syringes, which can present difficulties in handling for operators with small hands. This difference is because the syringe is contained within the main unit of the Wand®, whereas the Quicksleeper® and CCS® have the syringes and motors in the hand piece. The Korean products include a gun-type, such as the DenInjection®, as well as ergonomically designed products for better grip, such as the iCT injection® and Smartject®. Recently, various devices have been developed to enhance operator convenience. The Comfort-in® is an anesthetic device that utilizes a jet injection method and applies pressure with a needle, and thus has the advantage of being able to inject the anesthetic solution within a short period of time. However, it is difficult to consider it a speed-controlling CCLAD, and because this does not have a syringe needle, it is difficult to use this on posterior teeth; thus, this device is considered most suitable for use in treatment of children's anterior teeth or as a preliminary anesthesia method.

Different devices utilize different methods of changing the cartridge. The Wand® has the cartridge installed in the main unit, which allows the assistant to change the cartridge during anesthesia. However, 0.3-0.4 mL of

anesthetic solution inside the tube is lost with this change; in addition, there are many types of components, and a standard syringe needle cannot be used in this device. Having the cartridge on the outside of the main unit, as in the iCT injection device, allows the local anesthesia cartridge to be changed in a similar manner as conventional local anesthesia syringes, but because the cartridge needs to be sterilized during this process for infection management, it is recommended to choose a device designed with these aspects in mind. Ultimately, design aspects such as the position of the main unit and cartridge are related to the product's weight. CCLAD devices must be held stationary for long periods of time in order to ensure safe administration of anesthesia. If the device is too heavy, operation is difficult, and may lead to chance movement while the needle is inside the tissue, which may cause the needle to break. Therefore, it is important to select the right product with appropriate weight. Recently introduced products offer lightweight designs, and further technical advances are expected to lead to development of much lighter CCLAD devices.

With respect to anesthetic solution injection speed, the Wand®, Quicksleeper®, and CCS® have injection speed controls of three, four, and five stages, respectively, meaning that the CCS® offers the most diverse injection speed control, and all three products offer periodontal ligament anesthesia to block anesthesia. The iCT® device also allows three-stage injection, with speed controlled to allow a full cartridge to be injected within 250, 120, and 50 sec. Devices such as the No Pain III® control injection speed using Foot Software.

A point to consider in CCLAD is the potential for aspiration, as aspiration can also be used for block anesthesia. Aspiration is possible in devices such as the Wand®, CCS®, and Smartject®, and although 5 sec of aspiration time in the newly developed Wand PLUS® is an improvement over the 14 sec required for the original Wand® device, it is still relatively long. However, because infiltration anesthesia more often leads to pain in the maxillary palatal side than block anesthesia, aspiration is not a mandatory criterion for selecting a CCLAD device.

STUDIES ON CHILDREN

The findings from studies on children for comparison of CCLAD and local anesthesia using conventional syringes are shown in Table 1 [6-18]. Among 13 studies that assessed pain, six reported similar measured values, while seven determined CCLAD to be more effective in that it caused less pain and allowed behavioral control. The papers that reported CCLAD to be more effective were mostly those that were published relatively recently. The method most often used to assess the effects of anesthesia was visual analog scale (VAS), as well as indices that assess facial or bodily responses, such as sound, eye, motor scale (SEM), face legs activity cry consolability (FLACC), facial image scale (FIS), and faces pain rating scale (FRS). With respect to devices, the Wand® and CCS® were used; the Wand® assessed in 12 of 13 total studies, excluding 1 study. Among papers that reported CCLAD to be effective, three compared infiltration anesthesia on buccal and palatal sides, of which papers by Feda, et al. and Mittal, et al. reported that, in comparison to conventional anesthesia, there were no significant differences on buccal side; however, CCLAD on the palatal side resulted in less pain [6,8]. Compared to the buccal mucosa, with relatively fluid mucosa, dense palatal mucosa is put under significant pressure during administration of anesthetic solutions; thus, CCLAD offers advantages. Moreover, among three papers that compared the use of CCLAD for local anesthesia to the inferior alveolar nerve (IAN), two (by Baghlaf, et al. and Alamoudi, et al.) reported CCLAD to be more effective than conventional IAN block anesthesia [10,11].

Among studies that compared anxiety during local anesthesia, Tahmassebi, et al. and Versloot et al. reported no differences between using CCLAD and conventional local anesthesia with a syringe [13,14]. However, Versloot, et al. noted a positive correlation between patients who were more anxious and their perceived pain [14]. Therefore, pain during local anesthesia may be

Table 1. Literature on the effectiveness of CCLAD in children

Author	Publication year	Number of patients	Device	Anesthesia method	Anesthesia area	Operation type	Evaluation	Evaluation method	Results
Ram	2003	102	Wand®	IA, BA	All	Operative	Pain	Children's Reaction	Similar
Palm	2004	33	Wand®	BA	IAN	Operative	Pain	VAS	Similar
Klein	2005	21	Wand®	IA, PDL	Mx anterior	All	Disruptive behavior	Anxious and Disruptive Behavior Code (ADBC)	Less disruptive behavior
Al Amoudi	2008	80	Wand®	IA	Mx posterior	Operative, extraction	Pain reactions	SEM	Similar
Versloot	2008	147	Wand®	IA, BA, PDL	All	NA	Distress, pain, anxiety	Venham Distress scale, Visual Rating Scale, Children's Fear Survery Schedule, Dental subscale (CFSS-DS)	Similar
Tahmassebi	2009	38	Wand®	IA	Mx. posterior (buccal, palatal)	NA	Pain, anxiety	VAS, Venham Distress Scale	Similar
Feda	2010	40	Wand®	IA	Mx. posterior (buccal, palatal)	NA	Pain reactions and perceptions	SEM Eland color scale	Lower initial injection pain (palatal)
Kandiah P	2012	30	Wand®	IA	Mx. posterior (buccal)	Operative	Pain, Anesthetic onset	VAS Electric pulp tester	Similar
Langthasa	2012	50	CCS®	IA	All	all	Pain	VAS, FRS	Less pain
Mittal	2015	100	Wand®	IA	Mx. posterior (buccal, palatal)	Extraction	Pain	VAS, SEM	Similar (buccal) Lower (palatal)
Thoppe-Dhamodhara	2015	120	Wand®	NA	All	NA	Pain, Disruptive behaviour	FLACC, FIS	Lower pain ratings Less disruptive behavior
Baghlaf	2015	91	Wand®	BA, PDL	Mn. posterior	Pulpotomy	Pain-related behavior Pain perception level	Behavior code FRS	Less pain
Alamoudi	2016	91	Wand®	BA, PDL	Mn. posterior	Pulpotomy	Pain	SEM	Effective (no statistically significant differences)

IA: infiltration anesthesia, BA: block anesthesia, PDL: periodontal ligament anesthesia, IO: intraosseous, IAN: inferior alveolar nerve, NA: not available, Mx: maxillary, Mn: mandibular, VAS: visual analog scale, SEM: sound, eye, motor scale, FLACC: fFace legs activity cry consolability, FIS: facial image scale, FRS: faces pain rating scale

affected by intrinsic factors based the characteristics of children with fears of needles, rather than extrinsic factors associated with differences between using CCLAD versus conventional method using a syringe. In the studies described above, there were no differences in results based on the age of the children and it could not be concluded that there were significant differences based on anesthesia method, anesthesia site, or dental procedure used. However, most of the assessment tools used on children were subjective assessments of patient response and behavior. While the assessments were repeated by the operator, patient, third party, or other expert group to promote objectivity, these methods were still subjective. Moreover, children are more afraid than adults are of receiving an injection, regardless of using CCLAD or conventional local anesthesia-use syringe device. Therefore, there are limitations in the objective assessment of the potential correlations between local anesthesia effects and pain in children.

Klein, et al. reported that CCLAD caused less pain when the local anesthesia needle was inserted, but CCLAD was used for infiltration anesthesia, whereas local anesthesia using conventional syringe is typically used for periodontal ligament anesthesia. Because the difference in pain based on anesthesia injection site cannot be disregarded, accurate comparison is difficult

[16]. Moreover, Ram, et al.; Versloot, et al.; Langthasa, et al.; and Thoppe-Dhamodhara, et al. also compared all of cases, without distinguishing maxillary versus mandibular sites. In addition, the reliability of their results was also low [7,9,14,18]. Finally, pain based on dental treatment procedure must also be considered; however, Klein, et al.; Al Amoudi, et al.; Versloot, et al.; Tahmassebi, et al.; Feda, et al.; Langthasa, et al.; and Thoppe-Dhamodhara, et al. did not specify dental treatment procedures or did not include all dental treatments, which makes equivalent line of comparison difficult [6,7,9,13-16].

STUDY ON ADULTS

The findings from studies on adults for comparison of CCLAD and local anesthesia using conventional syringes are shown in Table 2 [4,19-31]. A total of 14 papers assessed pain, concluding that CCLAD resulted in less

Table 2. Literature on the effectiveness of CCLAD in adult

Author	Publication Year	Number of patients	Device	Anesthesia method	Anesthesia area	Operation type	Evaluation	Evaluation method	Results
Saloum	2000	40	Wand®	IA, BA	Mx. Premolar, IAN	NA	Pain	VAS	Less pain
Rosenberg	2002	150	Wand®	PDL, IA, BA	Random	Periodontal	Patient satisfaction, Acceptance	VAS	Superior
Lee	2004	40	Wand®	IA	AMSA	NA	Anesthetic success Onset Duration	EPT	Superior Similar Similar
Loomer	2004	20	Wand®	IA	Mx.	Periodontal	Pain, Anesthetic success	VAS, VRS	Less pain (GP, NP)
Nusstein	2004	40	Wand®	IA	AMSA	Endodontic	Pain	VAS	Needle insertion: similar Anesthetic soultion deposition: less pain
Sumer	2006	52	Wand®	BA	IAN	Extraction	Pain Anxiety	PRS, VAS DAS	Less pain More anxiety
Yesilyurt	2008	40	Wand®	BA	IAN	Operative	Pain	PRS, VAS	Less Pain
Yenisey	2009	16	Wand®	IA	AMSA	Prosthetic	Pain	VRS	Needle insertion: less pain Delivery of local anesthetic: less pain Tooth preparation: same pain level
Ozer	2012	40	QuickSleeper®	IA, BA	Mn.	Extraction	Pain Anesthetic Success	VAS	Less pain Superior
Shah	2012	10	Wand®	IA	AMSA	Periodontal	Pain	VAS	Less pain
Beneito -Brotons	2012	30	Quicksleeper®	IO	Mn.	Operative Simple Extraction	Latency Duration Patient preference	Time Preference	Shorter latency Sufficient duration More preferred
Singh	2013	100	Anaeject (Septodont)	IA	Mx. Canine	Operative	Pain	VAS	Less pain
Kammerer PW	2014	41	STA-System	PDL, IANB	Mn. Posterior	Operative	Pain anaesthetic efficacy	NRS	Less pain (than IANB), More pain (than PDL) Similar anesthetic efficacy Pain injection: no difference
Chang H	2016	31	iCT	IA	Mx . Posterior	Periodontal	Pain Anxiety Stress	VAS DAS PSS	Less pain Similar Similar

IA: infiltration anesthesia, BA: Block anesthesia, PDL: periodontal ligament anesthesia, IS: interseptal anesthesia, IO: intraosseous anesthesia, Mx.: maxillary, Mn.: mandibular, IAN: inferior alveolar nerve, AMSA: anterior middle superior alveolar, NA: nNot available, GP: greater palatine, NP: nasopalatine; EPT: Electric pulp tester, VAS: Visual analog scale, VRS: verbal rating score, PRS: pain rating scale, DAS: dental anxiety scale, PSS: perceived stress scale

pain or higher anesthesia success rates. The method most often used to assess these factors was the VAS, just as in children; the other methods used included electric pulp tester (EPT), verbal rating score (VRS), pain rating scale (PRS), dental anxiety scale (DAS), and perceived stress scale (PSS). Studies by Nusstein, et al.; Shah, et al.; Yenisey, et al.; Singh, et al.; and Chang, et al., conducted palatal anesthesia for anterior middle superior alveolar (AMSA) block, reporting less pain from CCLAD [21]; similarly, studies by Sumer, et al.; Yesilyurt, et al.; Ozer, et al.; and Kammerer, et al., also reported less pain in mandibular block anesthesia [19,26,28,29]. Based on these findings, CCLAD appears to be superior to conventional methods for maxillary and mandibular infiltration and block anesthesia.

Sumer, et al. and Yenisey, et al. reported that CCLAD showed superior results for both syringe needle insertion and injection [27,29]. In contrast, Nusstein, et al. and Kammerer, et al. reported that pain was similar when syringe needle was inserted, but less pain for CCLAD with spreading anesthesia [19,30]. These results support the hypothesis that CCLAD can reduce pressure generated when anesthetic solution spreads owing to the ability to control injection speed. Moreover, Loomer, et al. showed more significant differences during anesthesia of the greater palatine and nasopalatine nerves, as compared to other maxillary nerves. Thus CCLAD, which can better control speed and pressure during anesthesia, was more advantageous for anesthesia for palatal regions with thick mucosa [24].

Except for studies by Saloum, et al.; Lee, et al.; and Beneito-Brotons, et al., the remaining 11 studies on adults described the range of dental treatments applied; as such, they offered a fairer comparison than that of the studies in children [19-21,24-31]. All papers except for those by Saloum, et al. and Rossengerg, et al. defined the anesthesia site, which allowed assessment of CCLAD efficacy [19-30].

Two papers that assessed anxiety in CCLAD (Sumer, et al. and Chang, et al.) reported similar or increased levels of anxiety [21,29]. Due the size of the devices, CCLAD may have acted as anxiety and stress factor that induced fear in the patients in these studies.

Lee et al. assessed CCLAD for local anesthesia on anterior and middle superior alveolar nerves, revealing showed no significant differences in onset and duration times between CCLAD and conventional local anesthesia; however, CCLAD mostly showed higher efficacy with respect to anesthesia success rates [23]. In studies by Loomer, et al, Shah, et al., and Chang, et al., infiltration anesthesia for periodontal treatment did not show significant differences in either surgical and non-surgical treatments [21,24,25]. Both Sumer, et al. and Ozer, et al. reported less pain with CCLAD compared to conventional local anesthesia [26,29], which also proved the efficacy of CCLAD for extraction procedures, which are considered relatively invasive dental treatments.

Ozer, et al., compared IAN block anesthesia (the conventional anesthesia method) to intraosseous anesthesia by CCLAD in mandibular molar extraction cases, revealing that CCLAD showed superior pain control compare to conventional methods [26]. However, intraosseous anesthesia requires longer injection time, the syringe needle may become blocked during anesthesia, and has shorter anesthesia time than IAN block anesthesia; therefore, it was considered unfit for procedures that require long periods of time to complete.

CONCLUSION

CCLAD devices control the speed of anesthetic injected into tissue and are used to reduce pain during local anesthesia for dental treatments. The results of this review indicate that using CCLAD resulted in less pain and more effective anesthesia in adults than in children. However, differences in shape, weight, and injection speed should be considered when selecting choosing a device. Recent advances in CCLAD have led to the introduction of products that are lighter and easier to use. Establishment of assessment indices and methods for pain and anxiety, as well as additional clinical studies can

further evidence are necessary for more effective use of CCLAD in dental treatments.

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