

ADVANCES IN DENTAL LOCAL ANAESTHETIC DELIVERY DEVICES - A REVIEW

M.Pooja Umaiyal, M.Dhanraj

1st author/corresponding author:

M.Pooja Umaiyal,
Graduate student,
Saveetha Dental College and Hospital,
Saveetha University,
162, Poonamalle high road,
Velappanchavadi,
Chennai- 600077.
India.

2nd author:

M.Dhanraj Ganapathy,
Professor and Head,
Department of Prosthodontics,
Saveetha Dental College and Hospital,
Saveetha University,
162, Poonamalle high road,
Velappanchavadi,
Chennai- 600077.

Corresponding author:

M.Pooja Umaiyal,
Graduate student,
Saveetha Dental College and Hospital,
Saveetha University,
162, Poonamalle high road,
Velappanchavadi,
Chennai- 600077.
India.

Abstract: Effective local anesthesia is arguably the single most important pillar upon which modern dentistry stands. One drawback associated with intraoral local anesthesia is patients' fear of injections and the perception that these are painful. Although the traditional aspirating syringe is the most common method by which local anesthetics are administered, newer technologies and recent advances have resulted in the use of computer-controlled local anesthetic delivery vehicles to regulate the delivery and rate of flow of local anesthetics at the injection site, enhancing the pain relief and potential discomfort associated with injections. New injection techniques that provide reliable anesthesia have also been introduced, and depending on the technique used and area of anesthesia necessary, they do not result in undesired extraoral soft tissue anesthesia. These new injection techniques have been aided by the use of computer- controlled local anesthetic delivery systems.

Keywords: local anesthesia, delivery system, CCLAD, intra-osseous anesthesia, STA, wand

INTRODUCTION

In every patient's mind, dental treatment has been associated with pain. Indeed, the phobia of pain is the most significant factors that restricts even the adult population from receiving non-emergency dental care, even more than the expense of treatment. And the greatest source of patient fear is the usage of needle as a part of the armamentarium for the delivery of local anesthetics.

Local anesthetics has been in use in dental practice for more than 100 years. It has been the backbone of pain control techniques in dentistry. A new era of patient comfort while permitting more extensive and invasive dental procedure has been evolved by the advent of local anaesthetics with the development of nerve blockade injection techniques heralded Dentists are able to select an anaesthetic that acquires certain definite properties such as time of onset and duration, hemostatic control, and degree of cardiac side effects that are suitable for each specific dental procedure and for every individual patient due to advance and availability of variety of local anesthetic agents.^[1]

The ability to administer a safe, adequate pain control with minimal discomfort and effective local anesthesia is the most important skill required in every dental practitioners and this has also been a significant concern of dental practitioners. The proficiency of the contents used in local anesthesia, the involved neuroanatomy and the best techniques and devises available are the most important concern of administering a local anesthesia. In the current world, an effective management of the pain associated with

dental procedures can be provided by the practitioners through the usage of various means, like the selection of anesthetic delivery system and equipments.

There were many futile attempts made over the years to provide a clinically adequate pain controlled method of local anesthetic injection, and only recently many innovations have been added to the traditional method of injection invented by Cook a hundred years ago. These include computer controlled local anesthetic delivery systems, jet injectors, intra-osseous systems, vibrotactile devices, safety dental syringes and dentipatch. This article focuses on these systems and their applications in dentistry.

Computer controlled local anesthetic delivery system

It is essential to deliver local anesthetic solution at a constant rate and slower speed to avoid causing discomfort to the patient. Precise control of flow rate is not exactly achieved in Conventional syringes, and adequate pressure is needed to inject into dense tissues like palate which is difficult with conventional syringes. As a result of research in 1997, a new delivery system using computer technology to control the rate and flow of anesthetic solutions evolved, and are called as computer controlled local anesthetic delivery systems.

The design points of CCLAD devices include whether the anesthetic cartridge is a part 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.^[2]

Wand/CompuDent system

This system enabled operator to accurately manipulate needle placement with fingertip accuracy and deliver the LA with a foot-activated control. The lightweight handpiece is held in a pen-like grasp that provides the user with greater tactile sensation and control compared to a traditional syringe. The available flow rates of LA delivery remains consistent from one injection to the next because they are controlled by a computer. The greater control over the syringe and the fixed flow rates of the LA drug are responsible for a significantly improved injection experience, as demonstrated in many clinical studies conducted with CCLAD devices in dentistry.^[3] A growing number of clinical trials in medicine also demonstrate measurable benefits of CCLAD technology^[4]. Among which includes clinical trials performed by Nicholson et al. conducted a randomized clinical study in which two operators administered four different types of dental injections, comparing CCLAD to a standard syringe^[5]. Mean injection discomfort ratings were found to be consistently lower with CCLAD when compared to the manual syringe. Two-thirds of the patients wanted future dental injections to be performed with a CCLAD system. The investigators in the study increasingly preferred to perform all injections with the CCLAD technology. Dr. Mark Hochman and coworkers were the first to demonstrate a marked reduction in pain perception for injections using a CCLAD system^[6]. Fifty blindfolded dentists participated in a controlled clinical study (they received the injection) comparing the standard manual syringe to a CCLAD system (the Wand) for palatal injections. Forty-eight (96%) preferred the CCLAD injections. Overall, pain perception was reduced two- to threefold when compared to the standard manual syringe. Fukayama et al. conducted a controlled clinical study evaluating pain perception of a CCLAD device. Seventeen of the 20 subjects reported a slight or no-pain rating on a visual analogue scale (VAS) for palatal injections administered with CCLAD. They concluded that “the new system provides comfortable anesthesia for patients and can be a good alternative for conventional manual syringe injection.”^[7]

Comfort control syringe

The Comfort Control Syringe differs from the Milestone products in that there is no foot pedal. It has two main components: A base unit and a syringe. Several functions of the unit- most importantly injection and aspiration- can be controlled directly from the syringe, possibly making its use easier to master for practitioners accustomed to the traditional manual syringe. The Comfort Control Syringe has five pre-programmed speeds for different injection techniques and can be used for all injection techniques. These are regulated accordingly in specific applications, block, infiltration, PDL, IO and Palatal regions^[8]. Two stages of delivery rates are used in the unit for every injection. It initially expresses the LA solution at an extremely low rate and after 10 seconds the rate slowly increases to the pre-programmed value for the selected injection technique. The bulkiness of the syringe and its cumbersome to use when compared to the wand hand piece is its main disadvantage. Several CCLAD systems are available including the Wand/CompuDent™ system, Quicksleeper™, SleeperOne, Ora Star and Anaject™. The speed of injection, starting slowly and accelerating the speed of injection to minimize pain are controlled by both the Comfort Control Syringe and the Anaject^[9]. Five pre-programmed speeds for different injection techniques are programmed in the comfort control syringe and can be used for all injection techniques. Three pre-programmed speeds are present in Anaject. CCLAD allows local anesthetics to be administered comfortably to the patient in virtually all areas of the oral cavity. This is of greatest importance in the palate, where the level of patient discomfort can be quite significant. The stress and pain reaction experienced following the buccal infiltration without computerized delivery and that of palatal infiltrations with computerized delivery of local anesthesia were compared and the result has been shown to be with low levels of stress and a low pain reaction present in the delivery of local anesthetic via computerized system. The nasopalatine nerve block may be administered atraumatically in most patients^[10]. Although, use of the Comfort Control Syringe may be more perceptive than that of the CompuDent system in the sense that the injection is controlled by hand, the syringe is bulky and more cumbersome to use than the Wand handpiece.^[11] A comparison between the traditional dental syringe and the

Comfort Control Syringe revealed no meaningful differences in ease of administration, injection pain and efficacy, and acceptance by patients.^[12]

Jet Injectors

Jet-injection technology is based on the principle of using a mechanical energy source to create a release of pressure sufficient to push a dose of liquid medication through a very small orifice, creating a thin column of fluid with enough force that it can penetrate soft tissue into the subcutaneous tissue without a needle. Jet injectors deliver the medicine without the physiological traumas associated with needles. The injection site remains virtually free of swelling, allowing the physician or dentist to suture the surgical incision or wound without further distortion of the tissue, leading to a shorter recovery time. The anesthetic is delivered in micro-droplets and are taken up more quickly by the myelin sheaths on the nerves involved^[13].

In dental procedures such as mandibular blocks which require deep needle penetration for anesthetic delivery due to the volume of medication involved, a jet injection numbs the area and allows insertion of the needle and delivery of the fluid in a relatively painless manner.

The needle-free technology offers a psychological boost to the patient as well. Since the injections are virtually painless and take effect quickly, anxiety over injections is reduced or even eliminated, leading to less stressful procedures.

With their reusable tips, jet injectors also reduce medical waste pollution. They may be sterilized by autoclaving, soaking in a disinfectant solution, or other processes that do not involve dry heat. Jet injectors are believed to offer advantages over traditional needle injectors by being fast and easy to use, with little or no pain, less tissue damage, and faster drug absorption at the injection site.^[14] Drawbacks are: it cannot be used for nerve blocks, only infiltration and surface anesthesia are possible. Controlled studies evaluating efficacy are lacking, and reports are primarily anecdotal. To date, the effectiveness of the technique in dentistry has been reported to be limited.^[15]

Syrijet

The Syrijet Mark II (Keystone Industries [aka Mizzy], Cherry Hill, NJ, USA) has been on the market for nearly 40 years and has had some minor improvements over the years. Some good features of the device is that it accepts the standard 1.8 mL cartridges of LA solution (thereby ensuring sterility of the solution), permits the administration of a variable volume of solution from 0 to 0.2 mL, and is completely autoclavable.^[16]

MED-JET H III

MED-JET (Medical International Technologies, Montreal, QC, Canada) has been launched in 2011 with the manufacturer's claim that medication being injected with the device is directed through a small orifice which is 7 times smaller in size than the smallest available needle in the world. This extremely small stream of liquid under pressure pierces and then the remainder of the dose will be dispersed into the desired layer of tissue. The system's uniqueness is its ability to utilize low pressure delivery methods without compromising accuracy, convenience and ease of use - while ensuring patient comfort, environmental safety and user affordability.^[17]

Vibrotactile Devices

Some of the newer local anesthetic delivery systems aimed at easing the fear of the needle take advantage of the gate control theory of pain management, which suggests that pain can be reduced by simultaneous activation of nerve fibers through the use of vibration. Inui and colleagues have shown, however, that pain reduction due to non-noxious touch or vibration can result from tactile-induced pain inhibition within the cerebral cortex itself and that the inhibition occurs without any contribution at the spinal level, including descending inhibitory actions on spinal neurons.^[18]

VibraJect

It is a small battery-operated attachment that snaps on to the standard dental syringe. It delivers a high-frequency vibration to the needle that is strong enough for the patient to feel. VibraJect® produces a mild vibrating sensation that helps over-ride the pain signals from the needle. The nerve endings associated with sensing temperature and pain are small, uninsulated and have a relatively low signal intensity. The nerves which counter vibration and pressure are larger, have a relatively high signal intensity and they are insulated.

When vibration and pain signals are combined, as in the case with an injection using VibraJect, it is believed that the "pain" message carried by the smaller uninsulated nerves are predominated by the "vibration" message carried by the insulated nerves. The "tactile" pathway appears to have an inhibitory action on the "pain" pathway at the dorsal horn of the spinal cord. The patient only experiences vibration as proven by the Gate Theory of Perception. VibraJect® is a cost effective device that snaps right on to your existing syringe. VibraJect uses very simple and cost effective, proven technology to improve your injections whether giving intraligamentals, palatals or blocks. There are no new procedures to learn and no disposable aspects.^[19]

Researches evaluating the effectiveness of VibraJect, have shown mixed results. Nanitsos *et al.*,^[20] have recommended the use of VibraJect for painless injection. In contrast, Yoshikawa *et al.*,^[21] found no significant pain reduction when VibraJect was applied with a conventional dental syringe. Saijo *et al.*,^[22] evaluated the effectiveness of VibraJect in combination with an electrical injection device. They also found no statistically significant decrease in pain scores at needle insertion or anesthetic injection.

DentalVibe

Another system that uses vibration diversion based on the pain gate theory is recently introduced DentalVibe (BING Innovations LLC, Crystal Lake, IL, USA). It is a cordless, rechargeable, hand held device that delivers soothing, pulsed, percussive micro-oscillations to the site where an injection is being administered. Its U-shaped vibrating tip attached to a microprocessor-controlled Vibra-Pulse motor gently stimulates the sensory receptors at the injection site, effectively closing the neural pain gate, blocking the painful sensation of injections. It also lights the injection area and has an attachment to retract the lip or cheek.^[23] DentalVibe can be used with any anesthetic syringe to deliver comfortable injections in all areas of the mouth.

Accupal

The Accupal (Hot Springs, AR, USA) is a cordless device that uses both vibration and pressure to precondition the oral mucosa. Accupal provides pressure and vibrates the injection site 360° proximal to the needle penetration, which shuts the “pain gate,” according to the manufacturer. After placing the device at the injection site and applying moderate pressure, the unit light up the area and begins to vibrate. The needle is placed through a hole in the head of the disposable tip, which is attached to the motor. It uses one AAA standard battery.^[24]

ACCUPAL incorporates four known and proven pain-reducing theories into one economical, user-friendly device:

- ACCUPAL incorporates the "Pain Gate" theory to energize the dental tissue in and around the site to be punctured by the needle.
- ACCUPAL's ultrasonic tissue stimulation disrupts the tissue injection site to allow standard topical gel to pre-condition the injection site, thus further reducing the needle's pain-producing effects.
- ACCUPAL vibrates the needle at the injection site. The pain-reducing effects of direct needle vibration are well documented as having a positive effect on injection comfort.
- ACCUPAL ensures that the clinician inserts the needle bevel at its narrowest point, which provides the most minimally invasive path possible and reduced tissue damage to deliver a comfortable palatal injection every time.

Safety dental syringes

In recent years there has been a move toward the development and introduction of ‘safety’ syringes in both medicine and dentistry. Use of a safety syringe minimizes the risk of accidental needle-stick injury occurring to a dental health provider with a contaminated needle after the administration of LA. These syringes possess a sheath that ‘locks’ over the needle when it is removed from the patient's tissues preventing accidental needle stick.^[25] Both OSHA and the CDC have recommended that health care personnel should adopt safer work practices and consider using medical devices with safety features. Subsequent to this several syringes appeared in market. Surveys reported wide user dissatisfaction with many of the safety devices, however. Results of a review and bench tests indicate that the devices tested were no safer than traditional anesthetic needles.^[26] Most have disappeared from the market. There is still a need for safety syringes that will protect providers from needle-stick injury, and some are available on the market.

Ultra Safety Plus XL syringe

The Ultra Safety Plus XL syringe has a sterile disposable protective shield that is fitted with a dental needle into which anesthetic carpules are placed. The plunger assembly is reusable and autoclavable. The Ultra Safety Plus XL syringe provides protection from the needle because the needle is covered both before and after injection, and the needle does not have to be disassembled prior to disposal, which further protects the worker who is cleaning the dental tray. Providers who used this type of syringe reported that there was more time required for changing anesthetic carpules.^[27]

UltraSafe Syringe

The UltraSafe syringe is a disposable syringe and needle with a transparent, plastic syringe barrel, which has a retractable needle sheath. Providers can view the carpule contents through the clear plastic syringe barrel; this is further helpful in aspiration and in viewing anesthetic content, and also protects the provider from injury because the needle is covered before and after injection. The difference between this type of syringe and the Ultra Safety Plus XL syringe is that in the UltraSafe syringe the entire assembly is disposable and is not autoclavable.^[28]

HypoSafety Syringe

The HypoSafety syringe is a translucent disposable plastic syringe and needle combination. The needle can be retracted into the barrel of the syringe after the injection. Therefore, the needle is covered before and after injection, which will minimize the chance of needle-stick injury for providers. The obstacle with this type of syringe is that the dentist is not able to re-expose the safety shield in order to administer a second injection if the needle has been bent; this can therefore delay the procedure and will require use of a second syringe in the case of a bent needle technique having been used.^[29]

SafetyWand™

In response to the Needlestick Safety and Prevention Act, the SafetyWand has been developed for use with the CompuDent system. The safety system has a pen-like grasp that allows maximum tactile control and an auto-retracting design that shields the needle. When not in use. It is lighter than a traditional syringe, and the shield is operated with one hand, apparently making it safer to use.

RevVac™ safety syringe

The RevVac safety syringe operates the same as a standard conventional syringe. No additional training, skills, or procedures are necessary. It works on a simple concept; where retracting and pressing the plunger creates a robust vacuum at the time of use. When the plunger reaches the bottom, after all medicine is administered, a further push on the plunger breaks the seal, and the needle retracts into the plunger. The syringe cannot be reused

Devises for intra-osseous anaesthesia

Several systems have been developed to achieve Intra-osseous anesthesia. Although, significant differences exist among them, they all aim to inject local anesthetic solution into the cancellous bone adjacent to the apex of the tooth. These systems are Stabident, X-tip and IntraFlow.

Stabident

Numerous studies have shown the Stabident system to be safe and effective when used as directed. The advantages of the product are that it is relatively inexpensive and can be used with equipment already existing in a dental office: A standard dental anesthetic syringe for the needle and a slow-speed hand piece with a latch contrangle for the perforator. The main disadvantage of the device is that the perforation needs to be made in a reasonably accessible and visible location in the attached gingiva distal to the tooth to be anesthetized. It can be extremely difficult to locate the perforation site with the anesthetic needle if the penetration zone is located in alveolar mucosa that moves once the perforator is withdrawn. ^[30]

X-Tip

In view of above difficulty of Stabident system to locate the perforation hole, the X-Tip solves this problem by making the pilot drill itself a hollow tube through which a 27-gauge needle can pass. The anesthetic is placed without hunting for the hole that was just created with the help of the initial drill that stays in place. More post-operative pain in males were reported by the use of X-Tip, 1 to 3 days after the procedure, which may be contributed to by increased heat formation during perforation because of the X-Tip's wider diameter of the drill and guide sleeve. The manufacturer has discontinued making the X-Tip now.

IntraFlow

The IntraFlow device is essentially a dental handpiece equipped with an injection system built into the body. The entry into the penetration zone, injection, and withdrawal in one continuous step, without the need to relocate the perforation site is the biggest disadvantage of IntraFlow anesthesia system. This single-step method can be helpful in penetration zones that are difficult to visualize or access, such as the second and sometimes the first molar areas, or where there is horizontal bone loss or a limited band of attached gingiva in the desired penetration zone. IntraFlow to provide reliable anesthesia of posterior mandibular teeth in 13 of 15 subjects, compared to 9 of 15 with an inferior alveolar nerve block was found in a recent study. Start-up and maintenance costs, and that the device can occasionally leak anesthetic, especially if not assembled properly are the major disadvantages of the IntraFlow. ^[31]

CONCLUSION

Research shows CCLAD systems to control the speed of anesthetic injected into tissue and are used to reduce pain during local anesthesia for dental treatments. However, differences in shape, weight, and injection speed should be considered when selecting choosing a device. Vibrotactile devices also are useful in achieving patient satisfaction during injection. Jet injectors are not very useful when compared to other devices. Intra-osseous systems are very useful tools to achieve profound anesthesia, as an alternative to conventional injections. Accidental needle stick injuries and its associated transmission of diseases are prevented by safety syringes, and it is advisable to use them in future. Many newer delivery systems for local anesthesia have evolved due to the advancement of technology and the dental practitioners must be well aware of their usage and applications. The required armamentarium may be chosen according to the patient's needs. Dentists must be well aware of these newer delivery systems, their usage and must have an up-to-date knowledge, so as to provide the benefits of latest technology to their patients. The patient compliance with dental treatment can be aided by the ability to deliver painless injections and a desirable level and duration of anesthesia results in reduced patient fear, reduced patient stress and therefore reduced stress for the clinician.

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