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Journey of local anaesthesia from past to recent advances: A review literature

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Abstract
Without a question, the most important part of patient care in dentistry is local pain management. The advancements in local anaesthetic equipment, agents, and techniques are perhaps the most significant achievements in dentistry science, allowing the profession to make major therapeutic advances that would not have been feasible otherwise. The capacity to administer safe and effective local anaesthetic is essential in clinical oral surgery. Like any regional anesthetic technique, the use and effectiveness depends on patient considerations, the extent and duration of the procedure, choice of drug and technique, and the skill and experience of the practitioner. Every clinician should be aware of his or her skill limitations, and the limitations of the contemplated technique and agent. The administration of local anesthetics is often complicated by the existence of multifactorial psychological considerations associated with the delivery of dental care. It is imperative for health care professionals to understand and appreciate these issues to properly implement perioperative behavioral or pharmacologic management strategies to reduce fear and anxiety to acceptable levels.

Keywords: local anaesthesia, recent advances, literature

Introduction

Carl Koller, an Austrian ophthalmologist, demonstrated the effect of cocaine as a local anesthetic for eye surgery in 1884. He instilled drops of cocaine onto the surface of the eye, providing topical anesthesia. For the first time, a patient was able to undergo a surgical procedure awake and without pain. Later the same year, in Baltimore, Maryland, a surgeon, William Halstead, administered an injection of cocaine (with epinephrine) via inferior alveolar nerve block for the removal of a neuroma. Cocaine, considered a "wonder drug," allowed dental and medical patients to undergo painful surgical procedures painlessly while still conscious. In late November 1884, William S. Halsted and Richard J. Hall first achieved neuroregional anaesthesia in the mandible by injecting a solution of cocaine in the vicinity of the mandibular foramen. Since that revolutionary injection, dentists have possessed the remarkable ability to deliver invasive dental treatment in a pain-free manner and relieve suffering of the patients.

In today's practice an array of options are available for anesthetic agents and delivery equipments to manage pain. Developments in anaesthesia have come a long way since first discovered properties of cocaine to computer controlled anaesthesia with newer agents today. It is possible to perform a dental procedure completely imperceptible to pain if one understands the origin of pain and chooses appropriate agent and technique to alleviate pain. Local anesthesia forms the backbone of pain control techniques in dentistry, and local anesthetics are the safest and most effective drugs in medicine for the prevention and management of pain. Nonetheless, the administration of these drugs is the most frightening and uncomfortable part of the dental appointment for most patients. The needle is the most fear inducing part of the armamentarium for the delivery of LAs. Over the years, many futile attempts have been made to provide clinically adequate pain control without the need for injection of drugs.

Recent advances in equipments resulted in the use of computer-controlled anaesthesia, electronic dental anaesthesia, pressure syringes, vibrajet, accupal, jet injections. Advances in anesthetic techniques that provide alternatives to conventional methods include lingual infiltration, periodontal lligament injections, intraosseous anesthesia, computer-controlled injections, needleless injections, and electronic dental anesthesia. Additionally, new injection techni ues 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 i.e anterior middle superior alveolar block, palatal approach anterior superior alveolar nerve block and a new app

-roach to inferior alveolar nerve block. Newer anaesthetic agents are oraverse, articaine hydrochloride, sodium bicarbonate with local anaesthesia, lidocaine and prilocaine periodontal gel.

Advances in Anaesthetic Equipment

Computer Controlled Anesthesia

The dental syringe is a drug delivery device requiring that the operator simultaneously attempt to control the variables of drug infusion and the movement of a penetrating needle. The operator's inability to precisely control both of these activities during an injection can compromise an injection technique. In additional the traditional syringe is handled with a palm-thumb grasp, which is not designed for ideal ergonomics or needle control during the injection.

Milestone Scientific (Piscataway, NJ, USA) introduced the first C-CLAD system in the United States in 1997[4]. Originally known as the Wand, subsequent versions were sequentially renamed the Wand Plus and then Compudent, the current designationin 2001 is the Comfort Control Syringe.

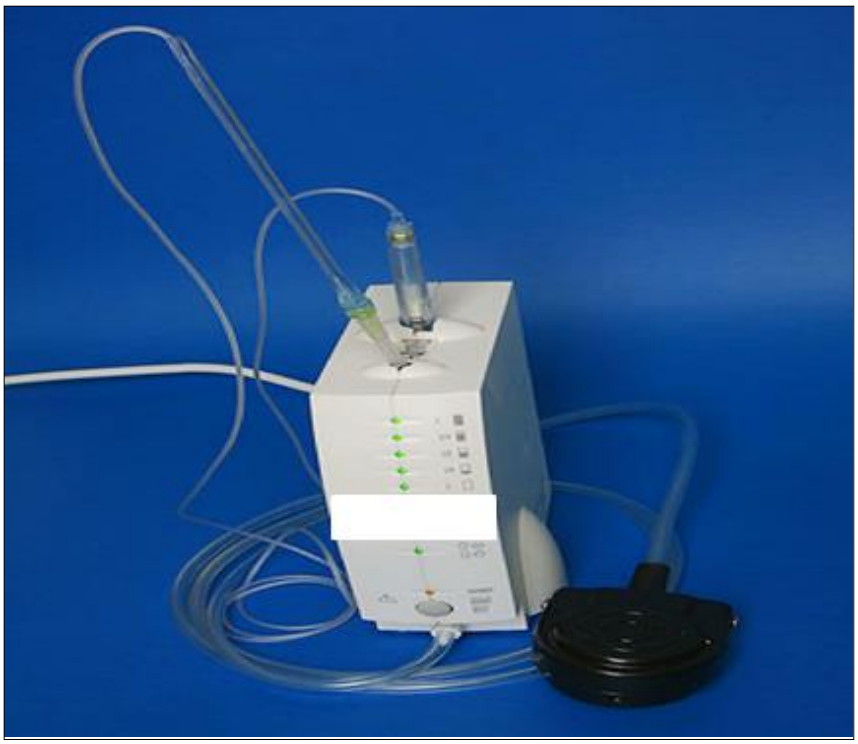

Fig 1

The wand (Milestone Scientific, New Jersey) was designed to improve on the ergonomics and precision of the dental syringe. The CCLAD technology had helped to redefine our perception and, even more important, the perception of our patients, as to how local anesthesia can and could be achieved [5]. The operator focuses attention on needle insertion and positioning, allowing the motor in the device to administer the drug at a pre - programmed rate of flow.

The C-CLAD devices provide clinicians with the ability to precisely control the rate of delivery of the local anesthtic solution [6]. In addition, it also introduced the concept of using a disposable handpiece weighing less than 10gm, allowing the clinician to hold it in a pen like fashion, greatly increasing tactile control and improving dexterity during injection [4].The wand system administers local anaesthesia at two specific rates of delivery. The slow rate is 0.5ml/min and the fast rate is 1.8ml/min. An aspiration cycle can be activated at any time by simply pressing the pressure on the foot-rheostat starting a 4.5 second aspiration cycle. The wand permits both a precise rate of flow and a controlled pressure to be maintained irrespective of the type of tissue into which the local anaesthetic is being deposited. Therefore even tissues with low elasticity receive a constant pressure and rate of flow, resulting in a more favourable (comfortable, less tissue damage) outcome.

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.

Comfort control syringe (CCS) system was introduced several years after The Wand. The CCS has a two-stage delivery system; the injection begins at an extremely slow rate to prevent the pain associated with quick delivery. After 10 seconds, the CCS automatically increases speed to the pre-programmed injection rate for the technique selected. It has five different basic injection rate settings designed for specific injections: block, infiltration, PDL, IO, and palatal injection.

Fig 2

CompuFlo technology

In 2001, Hochman and colleagues advanced the science and understanding of subcutaneous injection fluid dynamics by identifying a predictable method for measuring the precise value of fluid exit pressure in situ (at the tip of the needle) during drug administration [7]. This approach to fluid injection dynamics is called dynamic pressure sensing technology, which was developed for the delivery and aspiration of medicaments [8]. In 2007,CompuFlo technology was applied in dentistry to address an important challenge: performing more predictable single tooth anesthesia(e.g., the PDL injection).With the decreasing trend of generalised dental caries and increasing trend towards site specific treatment of an individual tooth, the use of nerve block anesthesia has become less necessary [9].

Electronic Dental Anesthesia

Electronic dental anesthesia/transcutaneous electric nerve stimulation (TENS) is a technique that provides us a promising way to produce dental anesthesia by using a mild amount of electric current and is based on the much-established Gateway Theory of pain control given by Malzack and Wall in 196510. According to Allgood, 11 "TENS is the direct stimulation of the nerves by sho t-duration, small amplitude electricpulses." TENS units are grouped into three categories. High-frequency (25-150 Hz) is the mode used most frequently to manage chronic TMJ pain, acute postoperative pain, and to provide EDA. Low frequency (2-10 Hz) is used when high-frequency TENS becomes ineffective because of accommodation during treatment of chronic pain. Ultralow-frequency (0.5-2 Hz) is again useful for treating chronic TMJ pain and measuring accurate vertical dimension of rest.

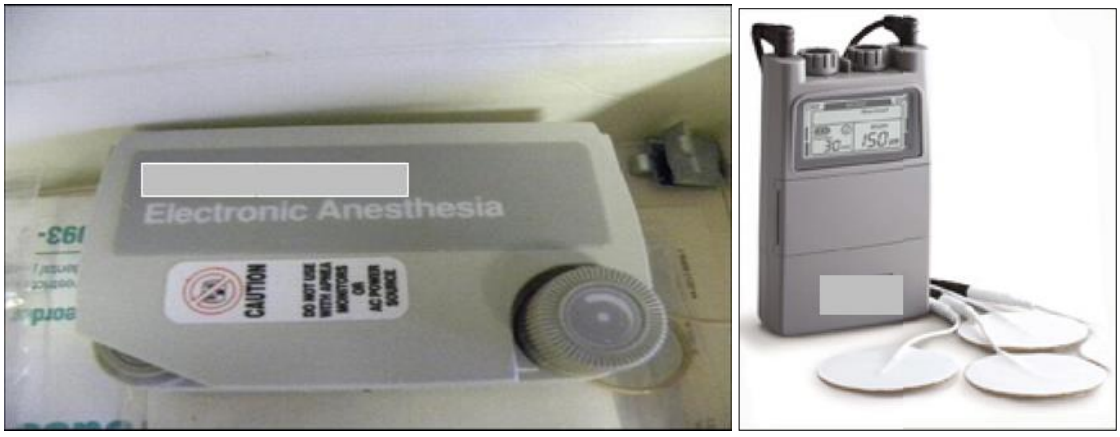

Fig 3

Pressure Syringes

First introduced in 1970, pressure syringes brought a renewed interest in periodontal/intraligamentary injection technique. It has made it possible to achieve consistently reliable pulpal anaesthesia of one isolated tooth. The original pressure devices, Peripress and Ligmajectwere modeled after a device that was available in dentistry in 1905 – The Wilcox Jewett Obtunder.

Fig 4

Jet Injections [14]

First use of jet injections in dentistry was in 1958 by Margetis and associates. It is based on the principle that liquids forced through very small openings called jets at very high pressure can penetrate intact skin or mucous membrane. The primary use of the jet injector is to obtain topical anaesthesia before the insertion of a needle. Regional nerve blocks or supraperiosteal injections still are necessary for complete anaesthesia.

The syrijet (Mizzy, precision instruments – New Jersey) and Madajet (Mada Medical products), developed in 2003 are the most used jet injectors in dentistry. The Syrijet holds any 1.8ml dental cartridge of local anaesthetic. It is calibrated to deliver 0.05 to 0.2ml of solution at 2000 psi. The Syrijet will provide subtopical anaesthesia to a depth of 1.5cm for painless needle insertion.

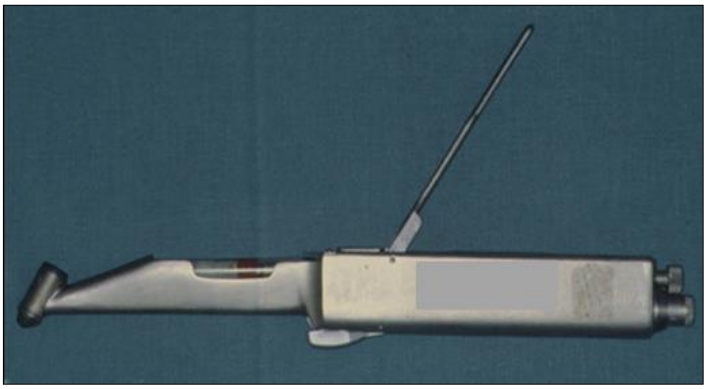

Fig 5

Advances in Anaesthetic Techniques

Lingual Infiltration

A relatively new concept, lingual infiltration of the mandible, theoretically and practically has merit but may also pose some disadvantages [19]. As with any other technique, patient (anatomical) selection is important. It should be reinforced that, although mandibular infiltration is generally regarded as not reliably successful, certain conditions may establish profound anesthesia via the combination of facial (buccal) and lingual injection.

Advantages

Thin cortical plate, Lingual foramina

Patient acceptance

Disadvantages
Ballooning of tissue

Periodontal Ligament Injection
The introduction of the intraligamentaryinjection techniques popularized by the Ligmaject in the 1970s is an actual intraosseous delivery of local anesthesia, provides a supplement to routine submucosal anesthesia [20]. For the route of administration commonly known as the periodontal ligament injection (PDL), it must be understood that the PDL space is simply the anatomical medium to deliver an intraosseous injection. Success rates with the intraligamentary technique are variable, depending on practitioner's experience, volume of solution injected, and the tooth being anesthetized.
Although intraligamentary injections appear to have a slightly lower success rate, their use for diagnostics in referred pain states, with uncontrolled hemophiliacs and as an adjunct following failed mandibular blocks, appears quite valuable. Initially, injection into the PDL tissue occurs by advancement of a 30 or 27 gauge short needle to the point of obtaining significant back pressure on injection, a criterion required for the local anesthesia successfully to penetrate the cribiform plate and circumferentially anesthetize even in an abscessed or ''hot'' tooth.
The volume of solution required is approximately 0.4–0.9 mL per administration, and recommendations for mandibular molars include a 2-site approach (mesial lingual and distal lingual). The duration will vary from 5 to 25 minutes, depending on volume, clearance, protein binding, and vasoconstrictor concentration [20].

Intra-Osseous Anesthesia
Although IO-induced local anesthesia has been used in clinical dentistry for overa century, the original technique was too invasive for widespread adoption, requiring a gingival flap to be raised to gain access to the buccal cortical bone for perforation with a small round bur. It became even less important with the discovery and marketing of lidocaine in the 1940s. Nevertheless, in 1975 Lilienthal described a technique in which a handpiece-driven root canal reamer was used to perforate the cortical plate. This use of a motor-driven perforator to penetrate the buccal gingiva and bone may be considered the first modern technique of IO anesthesia and the foundation upon which all current methods are based.
The intraosseous (IO) injection involves placement of a local anesthetic directly into the cancellous bone adjacent to the tooth to be anesthetized, and is used primarily in endodontic practice. One of the benefits of the IO injection is the reported immediate onset of anesthesia. The injection is recommended to be given distal to the tooth to be anesthetized. The exception to this rule would be the maxillary and mandibular second molars, for which a mesial site injection would be needed. The perforation site for the IO injection should be equidistant between the teeth and in the attached gingiva to allow for the perforation to be made through a minimal thickness of tissue and cortical bone and to prevent damage to the roots of the teeth. Clinical experience has shown that local anesthetics seem to be significantly less effective in endodontic pain patients who present with signs and symptoms of irreversible pulpitis and/or acute peri radicular inflammation, secondary to either an apical extension of pulpal inflammation or pulpal necrosis and bacterial invasion. Clinical studies have reported that a single inferior alveolar nerve (IAN) block injection of local anesthetic (1.8 mL) is ineffective in 30% to 80% of Patients with irreversible pulpitis [21]

Advances in Anaesthetic Agent
Articaine Hydrochloride
In 1969, carticaine hydrochloride, with a chemical code name of Hoe 40 45, was synthesized by H. Ruschin*get al*. as the first amide type drug with a lipophilic thiophene ring and additional ester side chain. It was originally known as "carticaine", the generic nomenclature of this local an aesthetic was changed in 1984 to Articaine.

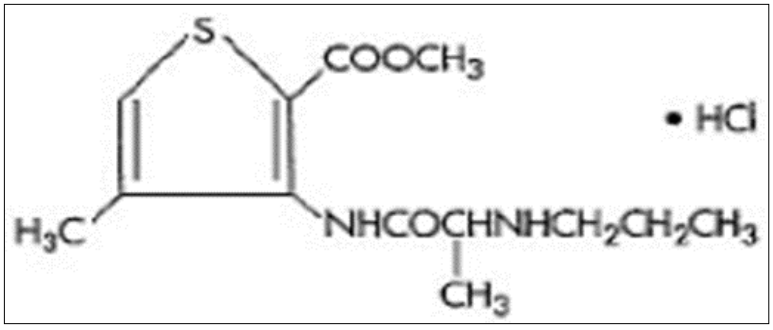

Fig 6

It was introduced in Switzerland and Germany in 1976, Canada in1983, USA in 2000. More recently, use of 4% Articaine with epinephrine 1:1, 00,000 and with epinephrine 1:2, 00,000 was approved in 2006 by the FDA. The amide structure of articaine is, in general, similar to that of other local anesthetics. It is unique, however, among the amide local anesthetics in that it does not contain a benzene ring like the others but instead contains a thiophene ring. Thethiophene ring increases its lip osolubility, making it more effective in crossing lipid barriers.

It also contains an additional ester group, which enables articaine to undergo biotransformation in the plasma (hydrolysis by plasma esterase) as well as in the liver (by hepatic microsomal enzymes) 2.

Articaine HCl does not possess any relevant systemic side effects or gross toxicity, and can be considered a safe local anesthetic [29].The safety and efficacy of articainehas been studied, and it has been found to be a well-tolerated, safe, and effective local anesthetic for use in clinical dentistry that will meet the clinical requirements for pain control of most dental procedures in most patients. Its lower systemic toxicity and wide therapeutic range permits the use of articaine in higher concentrations than other amide-type local anesthetics [30].

Articaine reaches its peak blood concentration in about 25 minutes following a single-dose dental injection by the sub mucosal route of a solution containing1:200,000 epinephrine. It diffuses better through soft tissue and bone than other local anesthetics. The concentration of articaine in the alveolus of a tooth in the upper jaw after extraction was about 100 times higher than that in systemic circulation [31]. Approximately 60%to80%of articaine HCl is bound to human serum albumin and gamma globulins, and is rapidly metabolized by plasma carboxyesterase to its primary metabolite articainicacid which is secreted by the kidneys as an inactive metabolite. The elimination half-life is 20 minutes. The onset of anesthesia is within 1 to 9 minutes after injection, and complete anesthesia lasts approximately1 hour for infiltrations and up to approximately [2] hours for nerve block.

Articaine is known to possess enhanced diffusion properties and better anaesthetic efficacy. It has described as having potency 1.5 times that of lidocaine and 1.9 times that of procaine, fast onset and increased success rate, with dentists reporting that they ‘don’t miss as often’. Articaine’s superiority was mainly founded on the notion that its thiophene ring bestows enhanced performance. This feature has been credited with providing increased lipid solubility and protein binding, two properties theoretically related to increased anaesthetic efficacy. Lipid solubility is an intrinsic quality of local anesthetic potency. This quality is essential for penetration of the anesthetic through the lipid nerve membrane and subsequent diffusion into surrounding tissues.

Sodium Bicarbonate with Local Anaesthesia

Chemically, amide local anaesthetics are weak bases. Commercial local anaesthetic cartridges are purposefully formulated as relatively acidic solutions (compared with the physiologic pH of 7.4) in order to enhance the solubility of the anaesthetic salts and to prolong shelf life. Typically, commercial lidocaine solutions have a pH of about 3.9. The pH of the solution is important because it affects the way anaesthetic works. Like most other injectable local anaesthetics, lidocaine with epinephrine solution contains two forms of the anaesthetic salt.

Fig 7

(i) The uncharged, de-ionized, or “active” free base form, which is lipid soluble; and charged or ionized cationic form, which is not lipid soluble. The de-ionized form more readily penetrates the nerve membrane to enter the nerve axon, where the anaesthetic attaches to receptors on the sodium channels, resulting in a blockade of nerve conduction. This biochemical process makes the relative availability of de-ionized anaesthetic important in creating clinical analgesia. According to the Henderson-Hassel balch equation, in any sample of local anaesthetic solution the ratio of the de-ionized species of the anaesthetic to the ionized species of the anaesthetic is based on the pH of the sample. At a more acidic pH, the ionized cationic form predominates. For instance, at a pH of 3.9, a typical cartridge of lidocaine with epinephrine contains only 1 molecule of de-ionized anaesthetic for every 10,000 molecules of ionized anaesthetic. On the other hand, closer to physiologic pH, more de-ionized anaesthetic is present. For instance, at the physiologic pH of 7.4 there is one moleculeof de-ionized lidocaine in solution for every 4 molecules of ionized lidocaine. At the physiologic pH, then, there is 2,500x more of the active form of the anaesthetic available than at pH 3.9. Normally, the body buffers the local anaesthetic after injection toward physiologic pH, which eventually increases the availability of de-ionized anaesthetic. Over time, as this *In vivo* buffering process continues, more and more of the de-ionized or active form of the anaesthetic is available. This ultimately leads to nerve blockade. After injection, tissue buffering raises the pH and a percentage of the drug dissociates to become free bases, the amount de ending upon the ‘dissociation

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