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Inferior Dental Blocks Versus Infiltration Dentistry: Is it time for change?

Abstract: Dentistry is unique in that high volume surgery is undertaken efficiently on conscious patients, an anathema to most other surgical specialties who predominantly operate on unconscious patients. Local anaesthesia provides an efficient block to nociceptive pain (the first stage of the pain pathway) but only addresses one small part of the pain experience. Currently the inferior dental block (IDB) is the 'go to' standard for dental LA for mandibular dentistry despite its significant shortcomings. Unfortunately, as creatures of habit clinicians continue to practise what is taught at dental school, namely IDBs, when evolving more patient-safe practice takes time to be taken up by the workforce.

Local anaesthesia blocks are inefficient in providing swift pulpal anaesthesia. Malamed stated that the rate of inadequate anaesthesia ranged from 31% to 81%. When expressed as success rates, this indicates a range of 19% to 69%. These numbers are so wide ranging as to make selection of a standard for rate of success for IDB seemingly impossible. LA blocks also increase the risk of systemic complications and they may be associated with nerve injury. Though LA-related permanent nerve injury is rare (approximately 1in 52–57K IDBs), once the injury occurs approximately 75% may resolve but the remaining 25% are untreatable. Most patients with trigeminal nerve injuries experience chronic pain in their lip, teeth and gums or tongue and gums, depending on which nerve is damaged. This is a lifelong burden that these patients find difficult to accommodate, especially when they were never warned about the possible risk.

The risk of nerve injury can be mitigated by altering the block technique or by avoiding block anaesthesia altogether. With novel development in pharmacology of LA and equipment, block anaesthesia is likely to become rarely needed in dentistry.

CPD/Clinical Relevance: Dentistry is a profession predicated upon causing and/or managing pain in patients. Providing effective pain control during surgery is essential but using techniques with the minimum risks is imperative.

Dent Update 2019; 46: 204–218

How can we improve our local anaesthetic practice?

There are five questions that we should first address in critiquing existing LA practice and assess if there is need for improvement.

1. What is the role of LA in managing analgesia for dental patients?
- An update on pain
- The patients' perspective

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2. How do we minimize systemic complications of dental LA?
- Systemic issues for LA

3. What are the medical modifiers for dental LA?

4. How do we minimize regional complications of LA?
- Avoiding failed LA
- Avoiding local complications including LA nerve injuries

5. How can we do better?

Proposed tailored smart LA practice:
- What technique?
- What agent?
- What LA volume?

What is the role of LA in managing analgesia for dental patients?

Patients want two main outcomes when they visit a dental practice, first, pain free injections and second painless procedures.[1] However, needles and tablets are but a small part of the holistic pain management of dental patients.[2] The definition of pain is that it is '*an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage*'.[3] The brain overlays the pain sensation on the part of the body that is getting hurt to

protect it from harm. There are four types of pain:[4] two healthy and two pathological. Healthy protective pain includes firstly; nociceptive pain, which is the conversion of tissue injury and release of algogenic factors (intracellular components released due to cell damage) which act as 'foreign bodies' exciting pain receptors on nociceptive nerve fibres (C, A delta and A beta fibres). These cause transduction from chemical inflammation into an action potential and the progression of an action potential advancing up to the tertiary order neurones to the somatosensory cortex; once reached, the 'ouch' results in reflex withdrawal of the 'digit' from danger. Inflammatory pain follows nociceptive pain, if tissue damage occurs promoting tissue healing. This process should usually resolve in days or weeks, depending on the degree of damage and persistence of infection.

Local anaesthesia blocks nociceptive pain very successfully but, due to the multiple components of pain there is increasing evidence supporting the education of patients in expected pain levels (managing their expectations), being caring, empathetic, providing appropriate anxiolysis and distraction. Some patients may be stoic types ('rugby player') able to cope with the anticipated and actual surgical discomfort, whereas others may be more susceptible to lack of coping and catastrophizing ('football player patients') needing a lot more attention. Holistic patient management is all important in pain management, with alternative techniques (hypnosis and acupuncture).

Patients' expectations are paramount and it is known that all patients expect pain when visiting their dentist.[5] It is important for clinicians to point out to patients that they are not magicians but surgeons and it is impossible to do complex surgery on patients without causing some minor discomfort intra-operatively and, occasionally, moderate pain post-operatively. Perioperative dental pain is not managed well in dentistry and is the most common adverse event reported by dentists[6,7] and by patients.[8] Regarding the dental experience involving pain, 60% of a representative sample of the general population aged 15 years or more has reported pain at least once during a dental visit.[9]

Local anaesthetic injection plus analgesic tablets are NOT enough! Local anaesthesia is only a small part of operative pain management.[2] Pain and its management is complex as the individual's pain experience is unique and based upon his/her gender, beliefs, religion, ethnicity, prior pain experience, psychological factors, nocebo and placebo effects etc.[5] There are many psychological factors driving the response to acute pain related to surgery and in relation to the development of chronic post-surgical pain.

The key aspects for operative pain management include:

- Patient factors including:
  - Managing the patients' expectations and anxiety. Education about pre- and post-operative events with clear and frank two-stage consent allowing patients some control of their treatment decisions;
  - Appropriate anxiolysis (assessment and management) will elevate pain thresholds and improve pain management.
- Medical aspects including:
  - Optimal local anaesthetic practise;
  - Appropriately prescribed analgesics.
- Surgical factors: It is also acknowledged that good surgical practice minimizes pain for the patient, including minimal access technique.
- Post-op advice with accessibility for patient contacting the practice and/or surgeon with clear post-operative advice on mouthcare maintenance and analgesics use.

How do we minimize systemic complications of dental LA?

Over one billion dental local anaesthetic injections are given annually worldwide (personal communication: Malamed S, FDI lecture 2017). The reported adverse reaction rate is 1:1,000,000 and the mortality (death) rate from dental local anaesthetic injections has been stated at 0.000002%. Allergies are very rare and can often be psychosomatic.[10]

The definition of the term 'adverse reaction' covers noxious and unintended effects resulting not only from the authorized use of a medicinal product at normal doses, but also from medication errors and uses outside the terms of the marketing authorization, including the misuse and abuse of the medicinal product. The range of pharmaceuticals used in dental practice is relatively small, consisting primarily of sedatives, local anaesthetics, analgesics and antibiotics. Adverse drug reactions are categorized as type A or type B.

- Type A reactions are more common and and are generally attributable to known pharmacological or toxic effects of the drug.
- Type B reactions are idiosyncratic, unpredictable, acute/sub-acute, not related to a known mechanism

The most common adverse reactions to LA include:

- **Vasovagal** attack or faint: nearly all patient-related collapses during dental LA are faints. A study carried out at Dundee Dental School showed that, of 27 cases of 'local anaesthetic allergies', only one was caused by the anaesthetic injection (and this was a sulphite allergy, not a drug allergy).[11] This can be overcome by good chairside manner and observation of the patient. If a prolonged procedure is anticipated, the patient should have eaten prior to the procedure or be provided with a glucose drink. Any patient who is anxious must be provided with suitable anxiolysis.
- **Allergy** to local anaesthetic agents is very rare and usually related to adjunctive agents including the bung (Latex),[12] the preservative (sodium metabisulphites), antiseptic, vasoconstrictor or, very rarely, the local anaesthetic agent. Most LA agents are now latex free. Esters are highly allergenic and there is no documented allergy to amides. The patient is more likely to be allergic to bisulphate preservative (needed for vaso-constricture). The least allergenic LAs are mepivicaine or plain prilocaine. Allergy is not dose dependent unlike toxicity.[13] The signs of allergy include breathlessness, disorientation and distress, urticaria hypotension and collapse. Immediate action is required including; Call for help, 1:1000 Units epinephrine IM and provision of oxygen.
- **Adverse effects** (Table 1) usually caused by high plasma concentration of LA drug resulting from:
  - Inadvertent intravascular injection related to block injections;

Vasoactive adjunctive agents are added to:
• Delay absorption of LA
• Reduce the systemic plasma levels of the LA
• Prolong the duration of action of the LA
• Reinforce the intensity of the LA's effects
• Reduce local blood perfusion

Table 1. Adverse effects are usually caused by high plasma concentration of either LA drug or adjunctive content resulting from the above.

Drug	Maximum Dose (mg/kg)	1/10th Cartridge (mg)
2% Lidocaine	4.4	3.6–4.4
2% Mepivacaine	4.4	4.0
3% Mepivacaine	4.4	6.0
3% Prilocaine	6.0	6.6
4% Prilocaine	6.0	8.0
4% Articaine	7.0	6.8–8.0

Table 2. Maximum doses of local anaesthetic agents.

- Excessive dose or rate of injection;
- Medically compromised patients:
  - Delayed drug clearance;
  - Drug interactions.

Adverse events happen in relation to the concentration and dose of LA, the size and health of your patient and intravascular injections. This is more likely with block, intraosseous and periodontal injections. Minimizing risk of overdose includes avoiding:

- All 4 quadrant treatment (staged treatment for elderly patients);
- Plain LA (no vasoconstrictor);
- Full cartridge injections (should Commonwealth move to 1.7 ml cartridges?);
- Exceeding maximum recommended dose (Table 2)

Young and elderly patients must be suitably assessed for their weight. A child of 5 years weighs 18–20 kg therefore maximum dose 88 mg (2 x 2.2 ml lidocaine cartridges). Due to their size, children are at high risk of toxicity. Goodson and Moore have documented catastrophic consequences of this drug interaction in paediatric patients receiving procedural sedation, along with excessive dosages of local anesthetics.[14,15]

• **Medical issues:** Any health aspects that include metabolizing or excreting. The main medical risks are:

- Patients with cardiovascular diseases;
- Patients with endocrine diseases;
- Patients with CNS disorders;
- Patients with lung diseases.

Aspiration during dental LA is a legal requirement in the UK. Avoiding intravascular LA is possible by using aspiration and avoiding intraosseous injections and being aware of the increased vascularity of inflamed tissue whilst always observing clinical reactions by:

- Talking to patients during the injection and monitoring their ECG/blood pressure to realize early symptoms of central-nervous and cardiovascular toxicity if they are at risk;
- Stop injection immediately when early symptoms are realized;
- Considering the time course for development of toxic signs (5–10 min)
- Avoiding long-acting and potent substances (bupivacaine is the most neurotoxic agent).

A recent survey of 2731 patients undergoing LA for dental treatment reported that 45.6% patients had medical risk factors (mostly cardiovascular). The overall LA complication rate was 4.5% complications (5.7% in risk patients/ 3.5% non-risk patients), which were, most commonly, dizziness, tachycardia, agitation and bronchospasm. Severe complications, including seizures and bronchospasm, occurred rarely (0.07%). Overall, there were fewer complications with articaine 4% I:100K epinephrine compared with articaine 4% I:200K epinephrine.[16] Articaine is less toxic than lidocaine at the same concentration as it has high binding plasma rate thereby reducing crossing the placenta or blood brain barrier. Metabolism of articaine occurs in tissue and plasma (rather than in the liver for lidocaine or bupivacaine) and lidocaine only 50% is degraded after 1.5–3 hours, which is much slower than articaine of which 50% is eliminated after 20 minutes (Table 3).

All suspected adverse events to local anaesthesia should be reported and this can be done online via the MHRA Yellow Card website (**at www.mhra.gov.uk/yellowcard**) or by calling the National Yellow Card Information Service on 0808 100 3352 (10am to 2pm Monday–Friday). In addition, dental practices should sign up to receive MHRA alerts. Subscribe using the following link: **https://www.gov.uk/drug-device-alerts/email-signup**

What are the medical modifiers for dental LA?

There are few absolute medical contra-indications to local anaesthetic and these are listed in Table 4. There are some relative but not absolute contra-indications for adrenaline use including:

- Hypertension, angina pectoris, heart failure;
- Diabetes mellitus;
- Bronchial asthma;
- Regularly taken medication (TCAs, MAO inhibitors, beta-blockers);
- Pregnancy;
- Narrow-angle glaucoma.

However, prudent avoidance of blocks, or aspirating when using blocks and slow injection, low dosage and staged

At the following serum levels patients may complain of:
• 1–5 mcg/mL
– Tinnitus
– Lightheadedness
– Circumoral numbness
– Diplopia
– Metallic taste
– May complain of nausea and/or vomiting, or they may become more talkative
• 5–8 mcg/mL
– Nystagmus, slurred speech, localized muscle twitching, or fine tremors may be noticed. Patients also have been noted to have hallucinations at these levels
• 8–12 mcg/mL
– Focal seizure activity occurs; this can progress to generalized tonic-clonic seizures. Respiratory depression occurs at extremely high blood levels (20–25 mcg/mL) and can progress to coma

Table 3. Lidocaine toxicity.

• Pheochromocytoma	Adrenaline producing tumour of the adrenal gland
• Hyperthyroidism	Elevated levels of thyroxine which lead to sensitization of adrenaline receptors
• Tachycardic arrhythmias	Unstable ventricular fibrillation
• Sulphite allergy	Anaphylactic reaction

Table 4. Absolute medical contra-indications for LA include the above.

Articaine 4% with adrenaline 1: 400,000	12.5 ml
Articaine 4% with adrenaline 1: 200,000	8 ml
Articaine 4% with adrenaline 1: 100,000	4 ml
Articaine 4% without adrenaline	7 ml
Mepivacaine 3% without adrenaline	10 ml
Mepivacaine 2% without adrenaline	15 ml

Table 5. Low dose adrenaline LA agents may be used in these cases.

treatments allows the use of adrenaline in patients with these conditions. Use of low dose adrenaline LA agents may be used in these cases (Table 5).[16]

■ Specific systemic complications have been reported with dental local anaesthetics including methaemoglobinemia. Benzocaine should no longer be used. Prilocaine should not be used in children younger than 6 months old, in pregnant women, or in patients taking other oxidizing drugs. The dose should be limited to 2.5 mg/kg. At low levels (1–3%), methaemoglobinemia can be asymptomatic, but higher levels (10–40%) may be accompanied by any of the following complaints: cyanosis, breathlessness, tachycardia, fatigue and weakness.[17]

■ Drug interactions:

– Lidocaine can interact with CNS depressants and with H2 Blocker (PPIs)

– Epinephrine

• Propranolol is the only non-selective beta-blocker reported to have the potential to cause severe hypertension and reflex bradycardia in the presence of epinephrine.

• A significant risk does not appear to be associated with the use of epinephrine and cardio selective beta-blockers.

Many complications or adverse events arise during dental local anaesthetics due to the patient being overly anxious or not well informed. Thus, the LA technique used must address several aspects including:

■ Care to recheck medical history at every visit:

• Check patient's recent prescription chart (<2 weeks);

• Check patient's blood pressure;

• Care with small patients:

– Children;

– The elderly (sacropenia is the loss of muscle mass which reduces body mass significantly after 60 years).

■ Good pre-operative assessment of medical history and anxiety levels;

■ Reassurance/warnings (avoid showing patient the syringe);

■ Give the patient feelings of control;

■ Distraction;

■ Topical LA;

■ Place fingertip near region where the needle is about to inject;

■ Warm LA cartridges;

■ Slow injections are less painful and more effective.[10]

A key factor in patient satisfaction is a sense that the care-giver is doing his/her best and is genuinely concerned that therapy is adequate.[18]

How do we minimize regional complications of LA?/Avoiding failed LA

There are many myths regarding failed LA in dentistry.[19] Local anaesthesia failure is often assumed to be the fault of the clinician due to the general

overestimation of the effectivity of block anaesthesia providing pulpal anaesthesia in the mandible. The onset of lip numbness usually occurs within 5–9 minutes of injection and pulpal anaesthesia follows 15–16 minutes later.[20-22] Slow onset of pulpal anesthesia (after 15 minutes) occurs approximately 19–27% in mandibular teeth and approximately 8% of patients have onset after 30 minutes.[23] Lip numbness does not guarantee pulpal anaesthesia and failure to achieve lip numbness occurs about 5% of the time with experienced clinicians.[24,25]

Inferior dental blocks are remarkably inefficient at providing pulpal anaesthesia for dental procedures.[26-28] Malamed stated that the rate of inadequate anaesthesia ranged from 31% to 81%. When expressed as success rates, this indicates a range of 19% to 69%. These numbers are so wide ranging as to make selection of a standard for rate of success for IDB seemingly impossible.[10] There are many other possible components contributing to LA failure including:

- Anatomical variation – flared or broad mandibular rami may require a modified IDB technique;[29]
- Patients who have a poor history to responding to LA;[30]
- Speed of IDB injection – a slow inferior alveolar nerve block injection (60 seconds) results in a higher success rate of pulpal anaesthesia and less pain than a rapid injection (15 seconds);[31]
- Pathological (infection)[32,33] – pulpitis is a challenging clinical problem, and can only be overcome by increasing the dose of anaesthetic in the area, with increased accuracy of the placement of the anaesthetic solution.[34]
- Choice of technique, insufficient dose, poor technique, damaged LA due to poor storage.[35]

How do we manage failed IDB?

- Giving another inferior alveolar nerve block does not help patients if they feel pain during operative procedures. The second injection does not provide additional anaesthesia – the first injection is just 'catching up'.[36]
- Increasing the volume to two cartridges of lidocaine or increasing the epinephrine concentration from 1:100,000 to 1:50,000[20,21] will not provide better pulpal anesthesia.[37,38]
- Using higher concentration agents for block injections is not evidenced to improve efficacy.[39-41]
- Specifically articaine compared with lidocaine IDBs has no or limited additional efficacy.[42,43]
- Computed techniques do not add advantage for IDB efficacy.[44]
- There is increasing evidence that additional injections (buccal infiltration, intraseptal, intraligamental, intra-osseous) can enhance and even replace IDBs. Supplemental injections can improve mandibular pupal anaesthesia.[33]
- Recent studies report that giving a buccal infiltration of a cartridge of 4% articaine with 1:100,000 epinephrine after an inferior alveolar nerve block significantly increased success (88%) when compared to a lidocaine formulation (71% success).[45,46] In a study of 182 patients, 122 achieved successful pulpal anaesthesia within 10 minutes after initial IDB injection and only 82 experienced pain-free treatment. Additional articaine buccal infiltration (ABI) and Intra-osseous (IO) allowed more successful (pain-free) treatment as follows:[47]
  - IDB + ABI 84% pain free Rx
  - IDB + IO 68% pain free Rx
  - IDB + PDL 48% pain free Rx
  - IDB alone 32% pain free Rx
- The addition of intraligamental injections may assist in extractions.[48,49,50] However, intraligamental injections are unlikely to be as effective at IDB alone for other dental procedures.
- The addition of the intra-osseous injection after an inferior alveolar nerve block, in the first molar, will provide a quick onset and a high incidence of pulpal anaesthesia (approximately 90%) for 60 minutes. Clinically, the supplemental intra-osseous injection works very well but systemic cardiac effects are related to the 'intravenous' nature of this injection.[51-53]

There is no evidence supporting using direct or indirect Halstead IDB technique or the improved efficacy of using Gow Gates or Akinosi techniques. The main issues appear to be the overestimation of the efficacy of IDBs in general, impatience and lack of awareness that one must wait over 15 minutes for maximum efficacy of a lidocaine block, in addition to the lack of use of alternative techniques that provide improved pulpal anaesthetic rates for anterior teeth.

How do we minimize regional complications of LA?

Most of these complications can be avoided by careful technique and avoidance of intravascular injections, but even when clinicians use the utmost care, by aspirating before the injection and noting anatomical landmarks, intra-arterial injections can occur during inferior alveolar nerve blocks.[54] Fortunately, permanent damage to nerves, facial and oral tissues, and eyes is rare. Possible regional complications related to IDBs include:

- Facial palsy likely due to poor IDB technique with too deep or superior injection through the coronoid process into the sheaths of the parotid gland through which the facial nerve travels.[55]
- Tissue trauma-haematoma trismus. In patients who have coagulopathies or platelet malfunction, avoidance of block injections is advisable but occasionally unavoidable.
- Fracture of the needle is more likely to occur with 30 gauge needles, using needles too short leaving no additional space between the Hub and tissues, and pre-bending of the needle prior to injection.[56,57]
- Ophthalmic complications.[58]
- Nerve injury related to IDB injections may cause permanent neuropathy in lingual and inferior alveolar nerves often associated with combined numbness, paraesthesia and neuropathic pain. Though LA-related permanent nerve injury is rare (approximately 1 in 52–57K IDBs), once the injury occurs approximately 75% may resolve but the remaining 25% are untreatable. Most patients with trigeminal nerve injuries experience chronic pain in their lip teeth and gums or tongue and gums, depending on which nerve is damaged. This is a lifelong burden that these patients find difficult to accommodate, especially when they were never warned about the possible risk. The risk of nerve injury can be mitigated by altering the block technique or by avoiding block anaesthesia altogether. The risk factors for nerve injury related to dental anaesthesia are listed in Table 6.

The incidence of persistent neuropathy related to dental IDBs is rare, estimated to be between 1 in 14K temporary and 1 in 52K permanent (25% permanent),[59] 1:26,762 and 1:160,571,[63]

Risk Factors for Nerve Injury	Evidence
Block anaesthesia	59
Lingual nerve >IAN	60
Blind block injections There is criticism of teaching the use of blind injections in dentistry	61–63
• Technique or Anatomy?	No evidence that direct Halstead causes more lingual nerve injuries than indirect technique
Concentration of LA agent	59, 60, 64–71
Speed of injection	
Multiple injections	59
Severe pain on injection	60% more likely to experience persistent neuropathy[59]
LA Agent toxicity	Increasing toxicity at same concentration Bupivicaine>Mepivacaine>Prilocaine>Lidocaine>Articaine
• Type of vasoconstrictor? • Sedated GA • Lack LA aspiration	No evidence No evidence No evidence

Table 6. Risk factors for nerve injury related to dental local anaesthesia.[32,59-79]

respectively, 1 in 27.415 cases,[74] 1 in 785,000 injections, *to* 1 in 13,800.[66] The majority of nerve injuries are painful in patients seeking care, consistent with other surgical sensory neuropathies, leading to a condition known as chronic post-surgical pain. Unfortunately for these patients, the unforeseen complication of routine dental care leads to life-changing orofacial pain with subsequent significant functional and psychological sequelae.

Management

There is no evidenced-based treatment for these nerve injuries, so it is a 'sit and wait' game whilst caring for patients. If pain is caused during an IDB, arrange to contact the patient the next day to exclude persistent neuropathy (pain, numbness and/or altered sensation), reassure him/her that 75% recover, medical intervention including NSAIDs, Vitamin B and steroids are used for spinal iatrogenic nerve injuries and may be effective in reducing neural inflammation and irritation, but there is no evidence to support this aside from patients being reassured that their clinician is trying to help them.

Should patients be warned of possible rare nerve injuries related to dental LA?

Clinicians must now ensure that patients are aware of any material risks involved in a proposed treatment, and of reasonable alternatives, following the judgment in the case *Montgomery v Lanarkshire Health Board*.[80] This is a marked change to the previous 'Bolam test', which asks whether a doctor's conduct would be supported by a responsible body of medical opinion.[81] This test will no longer apply to the issue of consent, although it will continue to be used more widely in cases involving other alleged acts of negligence. Thus one has to question when would a permanent burning tongue or elicited neuralgic pain of the face caused whenever a patient has to eat, kiss, speak or go out in the cold is not material to a patient? Suggested routine consent was suggested in the US in 1939.[72] In Germany, there is already a legal precedent to warn all patients undergoing dental LA of possible nerve injury and any patient undergoing spinal or epidural injections in the UK must warn patients of possible permanent motor or sensory nerve injuries in 1 in 57K.[73]

Thus, prevention of LA nerve injuries is paramount and most effectively achieved by avoiding block anaesthesia. Dentistry is the ONLY healthcare profession taught to aim for nerves blindly during block injections! There is increasing pressure to use ultrasound neural location to minimize systemic toxicity and nerve injuries as practised in regional block anaesthesia elsewhere in the body. Other strategies would include avoiding risk factors (Table 6[59-79]) but mainly avoiding block anaesthesia and using infiltration techniques instead.

What is wrong with our current practice and how can we do better?

Proposed tailored smart LA practice asks the questions:

- What technique?
- What agent?
- What LA volume?

The limitations of IDB in providing swift mandibular pulpal anaesthesia is recognized and recent evidence supports the use of infiltration mandibular dentistry. Interestingly, for decades dentists have routinely undertaken maxillary dentistry with infiltrations, accepting that nerves within bone are accessible to submucosal local anaesthetic techniques. With respect to maxillary infiltration anaesthesia, some studies have found 4% articaine to be more effective than 2% lidocaine for lateral incisors but not molars,[74] while others reported no clinical superiority for this injection.[75,76] A recent randomized controlled trial found a statistically significant difference supporting the use of 4% articaine in place of 2% lidocaine for buccal infiltration in patients experiencing irreversible pulpitis in maxillary posterior teeth.[77]

As mentioned previously, nerve blocks are related to nerve injury and there are no indications for the use of palatal, incisal or infra-orbital nerve blocks for dentistry, except in very rare exceptions. An example of this is spreading infection from canines or premolars, when the use of block anaesthesia will prevent the need for GA

Technique	Volume (ml)
Supraperiosteal (infiltration)	0.6
Posterior superior alveolar (PSA)	0.9 to 1.8
Middle superior alveolar (MSA)	0.9 to 1.2
Anterior superior alveolar (ASA)	0.9 to 1.2
Anterior middle superior alveolar (AMSA)	1.4 to 1.8
Palatal approach-anterior superior alveolar (P-ASA)	1.4 to 1.8
Greater (anterior) palatine	0.45 to 0.6
Nasopalatine	0.45 (max)
Palatal infiltration	0.2 to 0.3
Maxillary (V_2) nerve block	1.8

Table 7. Volume recommendation for maxillary local anaesthesia in dentistry taken from Malamed SF. [106]

Technique	Volume (ml)
Inferior alveolar (IDB)	1.5
Buccal	0.3
Gow-Gates (kind of IDB)	1.8
Vazirani-Akinosi (kind of IDB)	1.5 to 1.8
Mental	0.6
Incisive	0.6 to 0.9

Table 8. Volume recommendation for mandibular local anaesthesia in dentistry taken from Malamed SF.[106]

drainage and extractions. Several studies report the lack of indications for palatal block injections.[78,79] There is increasing evidence that additional injections (buccal infiltration, intraseptal, intraligamental, intra osseous) can enhance and even replace IDBs.[32,35,47,77] Lidocaine infiltration is likely to be as effective as articaine for maxillary dentistry.[82] A recent systematic review highlighted that there is no benefit in using articaine infiltration for maxillary dentistry but articaine is 3.6 more times effective than lidocaine for mandibular infiltration dentistry.[83]

Can articaine 4% infiltration replace lidocaine 2% IDBs for routine dentistry?

Using infiltration and not IDBs improves patient comfort as patients prefer having full lingual sensation and shorter duration LA anaesthesia after dental treatment.[32] Not only are buccal infiltration techniques proving to be more effective than IDBs, but intraligamental injections can also be used effectively for exodontia as they are effectively intravascular with more likely systemic effects but, in addition, there are reported higher post-restorative pain levels.[84,85]

IDBs are unnecessary to treat

- Pulpitic mandibular molars in adults.[86,87]
- For exodontia in adults and children.[88,89]
- IDBs are unnecessary to treat implant surgery.[90] A total of 120 patients requiring the placement of a single implant in order to replace a missing first mandibular was randomly allocated to two groups comparing crestal with infiltration. No nerve damage occurred using either anaesthesia types, therefore the choice of type of anaesthesia is a subjective clinical decision. However, it may be preferable to use a low dose (0.9 ml) of subperiosteal anaesthesia, since it is unnecessary to deliver 7.2 ml of articaine to anaesthetize a single mandibular molar implant site.[91]
- IDBs are unnecessary for restorative mandibular care in children.[92] However, in a recent study of 57 paediatric patients undergoing restorative mandibular treatment, a higher success and less painful treatment with IDB was reported. There was no statistically significant difference in local analgesia success between articaine and lignocaine when delivered via buccal infiltration.[93]

Benefit of computerized systems for infiltration techniques

There is limited evidence to support that computerized infiltration systems are more effective, but those regularly using these systems empirically report better patient acceptance and comfort during injections.[94]

What is the best agent?

Articaine (4-methyl-3-[2-(propylamino)-propionamido]-2-thiophene-carboxylic acid, methyl ester hydrochloride) is a unique amide LA in that it contains a thiophene, instead of a benzene, ring. The thiophene ring allows greater lipid solubility and potency as a greater portion of an administered dose can enter neurons. It is the only amide anaesthetic containing an ester group, allowing hydrolysation in unspecific blood esterases. About 90% of articaine metabolizes quickly via hydrolysis in the blood into its inactive metabolite articainic acid, which is excreted by the kidney in the form articainic acid glucuronide. Its metabolism is age dependent, where clearance and volume of distribution decreases with increasing age. The elimination serum half-life of articaine is 20 minutes and of articainic acid is 64 minutes.[95-97] Articaine at three different comparative lidocaine concentrations provides more effective mandibular pulpal anaesthesia.[98] However, articaine is 3.6 times more effective for mandibular infiltration

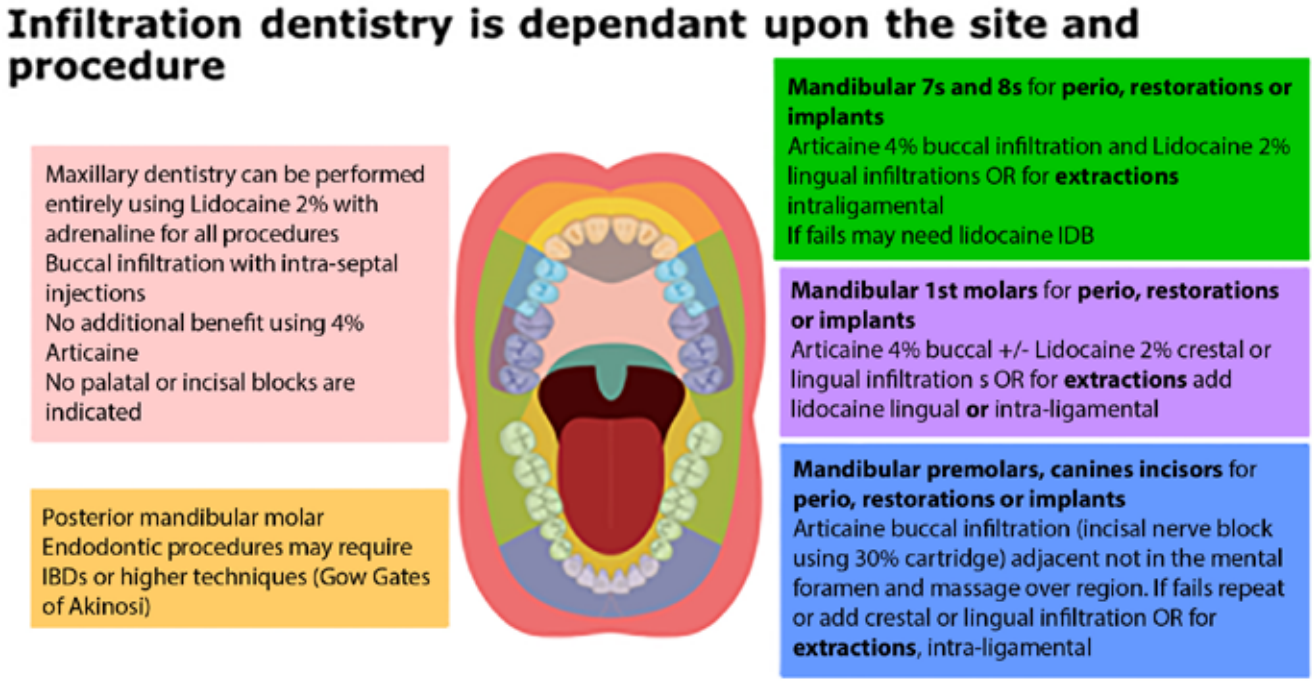

Figure 1. Summarizing mandibular LA infiltration techniques. Illustration modified from figure courtesy of Andrew Mason of Unversity of Dundee.

dentistry[99] and a recent study demonstrated that 2% articaine is as effective as 4% articaine using IDB for mandibular dental extraction in adults.[100,101] In summary, more research is needed before recommending replacing 4% with 2% articaine for all dental procedures.

The concentration of epinephrine may be reduced from 1 in 100 to 1in 200 and is equally effective for third molar extraction.[102] An epinephrine concentration of 1 in 400 may only be required for paediatric extractions using 4% articaine.[103]

So, is the future agent for dental anaesthesia 2% articaine with 1: 200–400K epinephrine for all LA techniques and dental procedures in adults? Could we use epinephrine-free LA for paedodontic dentistry? Further research is needed

What LA volumes should we be using?

The most common LA cartridge volume used worldwide is 1.8 ml.[104] Dentists in France and Japan use only 1 ml cartridges and the Commonwealth 2.2 ml cartridges. Dictation of LA volume should be related to diameter of nerve and accuracy of technique. For buccal Infiltration, average LA volume of 0.59 ml with 97.5% provided effective pain control.[105]

Infiltration techniques require significantly less LA volume compared with block techniques: Gow Gates only block anaesthesia technique recommends full cartridge 1.8–2.2 ml; and infra-orbital LA block requires 1.8–2.2 ml[106] (Tables 7 and 8).

Thus the continued use of 2.2 ml cartridges should be questioned and changed to 1.8 ml cartridges, which would improve patient safety and likely impact minimally on repeated injections.

The future interest is the possibility of development of newer improved agents (sensory blocking agents only) and devices and techniques for achieving profound sensory anaesthesia. A nasal spray (**http://clinicaltrials.gov/ct2/show/NCT01302483**) which has been shown to anaesthetize maxillary anterior six teeth is set to be tested in an FDA Phase 3 trial, which will assess the spray's effectiveness compared to the current 'gold standard' treatment – painful anaesthesia injections. Buffering of acidic local anaesthetics to more neutral physiological pH allows for speedier LA onset and is already in use in the US. Another development is a syringe micro vibrator (SMV),[107] a new device being introduced in dentistry to alleviate pain and anxiety of intra-oral injections.

Summary

A radical change in LA practice is required with regard to many aspects of patient safety based upon current evidence, whilst acknowledging further research would be ideal. With the current research legislation, undertaking simple efficacy studies of existing commonly used LA agents is prohibitively expensive and unlikely to be funded by pharmaceutical companies, limiting the provision of future robust supportive research. Infiltration LA for implantology is a good example where common sense and application of optimal technique has occurred without a robust evidence base providing safer more effective patient care. The following are guidelines for the possible way forward:

- A tailored approach to dental local anaesthesia should be recommended to prevent the continued unnecessary use of IDBs when infiltration anaesthesia is

likely to be more effective for most dental procedures. Tailored LA is dictated by the site and procedure, Figure 1 summarizing the optimal anaesthetic techniques.

- The lack of safety when giving blind block injections with likely systemic and local complications (especially nerve injury) may be considered 'indefensible'.
- IDBs should be prescribed in limited cases when indicated.
- Consent for LA – in the light of Montgomery consent recommendations, all patients should be routinely warned of a risk of nerve injury when routinely undergoing dental local anaesthesia, as they are already in Germany and in the UK in relation to epidural or spinal injections.
- Reduction of epinephrine levels is likely possible for most dental procedures, also improving patient safety and minimizing systemic effects and reducing problems in medically compromised patients.
- Revisitation of the required cartridge volume is necessary and recommendation for the use of 1.8 ml versus 2.2 ml cartridges will improve patient safety.

Compliance with Ethical Standards

Conflict of Interest: The author declares that she has no conflict of interest.

References

1. de St Georges J. How dentists are judged by patients. *Dent Today* 2004; **23**: 96–99.
2. Renton T. Prevention and optimal management of peri-surgical pain in dentistry. *Dent Update* 2018; **45**: 935–946.
3. International Association for the Study of Pain (IASP) 1994. Available from: **https://www.iasp-pain.org/SearchResults.aspx**
4. Woolf CJ. What is this thing called pain? *J Clin Invest* 2010; **120**: 3742–3744.
5. Tracey I. Getting the pain you expect: mechanisms of placebo, nocebo and reappraisal effects in humans. *Nat Med* 2010; **16**: 1277–1283.
6. Kalenderian E, Obadan-Udoh E, Maramaldi P, Etolue J, Yansane A, Stewart D *et al*. Classifying adverse events in the dental office. *J Patient Saf* 2017; doi: 10.1097/PTS.0000000000000407. (Epub ahead of print).
7. Maramaldi P, Walji MF, White J, Etolue J, Kahn M, Vaderhobli R *et al*. How dental team members describe adverse events. *J Am Dent Assoc* 2016; **147**: 803–811. doi: 10.1016/j.adaj.2016.04.015. Epub 2016 Jun 3.
8. Hiivala N, Mussalo-Rauhamaa H, Tefke HL, Murtomaa H. An analysis of dental patient safety incidents in a patient complaint and healthcare supervisory database in Finland. *Acta Odontol Scand* 2016; **74**: 81–89. doi: 10.3109/00016357.2015.1042040. Epub 2015 May 13.
9. Locker D, Shapiro D, Liddell A. Negative dental experiences and their relationship to dental anxiety. *Community Dent Health* 1996; **63**: 86–92.
10. Malamed SF. *Handbook of Local Anesthesia* 6th edn. St Louis: Mosby Elsevier, 2013. eBook ISBN: 9780323242028; Paperback ISBN: 9780323074131.
11. Harris SC. Aspiration before injection of dental local anaesthetics. *J Oral Surg* 1957; **15**: 299–303.
12. Shojaei AR, Haas DA. Local anesthetic cartridges and latex allergy: a literature review. *J Can Dent Assoc* 2002; **68**: 622–626.
13. Syed M, Chopra R, Sachdev V. Allergic reactions to dental materials – a systematic review. *J Clin Diagn Res* 2015; **9**: ZE04–9.
14. Goodson JM, Moore PA. Life-threatening reactions after pedodontic sedation: an assessment of narcotic, local anesthetic and antiemetic drug interactions. *J Am Dent Assoc* 1983; **107**: 239–245.
15. Daublander M, Mauller R, Lipp MD. The incidence of complications associated with local anaesthesia in dentistry. *Anes Prog* 1997; **44**: 132–141.
16. Niwa H, Tanimoto A, Sugimura M, Morimoto Y, Hanamoto H. Cardiovascular effects of epinephrine under sedation with nitrous oxide, propofol, or midazolam. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2006; **102**: e1–9. Epub 2006 Sep 25.
17. Guay J. Methemoglobinemia related to local anesthetics: a summary of 242 episodes. *Anesth Analg* 2009; **108**: 837–845. doi: 10.1213/ane.0b013e318187c4b1.
18. Bucknall T, Manias E, Botti M. Acute pain management: implications of scientific evidence for nursing practice in the postoperative context. *Int J Nurs Pract* 2001; **7**: 266–273.
19. American Association of Endodontics. *Endodontics Colleagues for Excellence*. **https://www.aae.org/uploadedfiles/publications_and_research/endodontics_colleagues_for_excellence_newsletter/winter09ecfe.pdf** AAE, 2009.
20. Vreeland D, Reader A, Beck M, Meyers W, Weaver J. An evaluation of volumes and concentrations of lidocaine in human inferior alveolar nerve block. *J Endod* 1989; **15**: 6–12.
21. McLean C, Reader A, Beck M, Meyers WJ. An evaluation of 4% prilocaine and 3% mepivacaine compared to 2% lidocaine (1:100,000 epinephrine) for inferior alveolar nerve block. *J Endod* 1993; **19**: 146–150.
22. Hinkley S, Reader A, Beck M, Meyers W. An evaluation of 4% prilocaine with 1:200,000 epinephrine and 2% mepivacaine with levonordefrin compared to 2% lidocaine with 1:100,000 epinephrine for inferior alveolar nerve block. *Anesth Prog* 1991; **38**: 84–89.
23. Nusstein J, Reader A, Beck M. Anesthetic efficacy of different volumes of lidocaine with epinephrine for inferior alveolar nerve blocks. *Gen Dent* 2002; **50**: 372–375.
24. Mikesell P, Nusstein J, Reader A, Beck M, Weaver J. A comparison of articaine and lidocaine for inferior alveolar nerve blocks. *J Endod* 2005; **31**: 265–270.
25. Claffey E, Reader A, Nusstein J, Beck M, Weaver J. Anesthetic efficacy of articaine for inferior alveolar nerve blocks in patients with irreversible pulpitis. *J Endod* 2004; **30**: 568–571.
26. Fernandez C, Reader A, Beck M, Nusstein J. A prospective, randomized, double-blind comparison of bupivacaine and lidocaine for inferior alveolar nerve blocks. *J Endod* 2005; **31**: 499–503.
27. Nusstein J, Reader A, Beck M. Anesthetic efficacy of different volumes of lidocaine with epinephrine for inferior alveolar nerve blocks. *Gen Dent* 2002; **50**: 372–375.
28. Hinkley S, Reader A, Beck M, Meyers W. An evaluation of 4% prilocaine with 1:200,000 epinephrine and 2% mepivacaine with levonordefrin compared to 2% lidocaine with 1:100,000 epinephrine for inferior alveolar nerve block. *Anesth Prog* 1991; **38**: 84–89.
29. Tae Min You, Kee-Deog Kim, Jisun Huh, Eun-Jung Woo, Wonse Park. The influence of mandibular skeletal characteristics on inferior alveolar nerve block anesthesia. *J Dent Anesth Pain Med* 2015; **15**: 113–119.
30. Kaufman E, Weinstein P, Milgrom P. Difficulties in achieving local anesthesia. *J Am Dent Assoc* 1984; **108**: 205–208.
31. Kanaa MD, Meechan JG, Corbett IP, Whitworth JM. Speed of injection influences efficacy of inferior alveolar nerve blocks: a double-blind randomized controlled trial in volunteers. *J Endod* 2006; **32**: 919–923.
32. Meechan JG. The use of the mandibular infiltration anesthetic technique in adults. *J Am Dent Assoc* 2011; **142** (Suppl 3): 19S–24S.
33. Yadav S. Anesthetic success of supplemental infiltration in mandibular molars with irreversible pulpitis: a systematic review. *J Conserv Dent* 2015; **18**: 182–186.
34. TN Lai, CP Lin, SH Kok. Evaluation of mandibular block using a standardized method. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2006; **102**: 462–468.
35. Meechan JG. How to overcome failed local anaesthesia. *Br Dent J* 1999; **186**: 15–20.
36. Nusstein J, Reader A, Beck M. Anesthetic efficacy

of different volumes of lidocaine with epinephrine for inferior alveolar nerve blocks. *Gen Dent* 2002; **50**: 372–375.
37. Wali M, Reader A, Beck M, Meyers W. Anesthetic efficacy of lidocaine and epinephrine in human inferior alveolar nerve blocks. *J Endod* 1988; **14**: 193 (abstract).
38. Dagher BF, Yared GM, Machtou P. An evaluation of 2% lidocaine with different concentrations of epinephrine for inferior alveolar nerve blocks. *J Endod* 1997; **23**: 178–180.
39. Claffey E, Reader A, Nusstein J, Beck M, Weaver J. Anesthetic efficacy of articaine for inferior alveolar nerve blocks in patients with irreversible pulpitis. *J Endod* 2004; **30**: 568–571.
40. Malamed SF, Gagnon S, Leblanc D. Efficacy of articaine: a new amide local anesthetic. *J Am Dent Assoc* 2000; **131**: 635–642.
41. Moore PA, Boynes SG, Hersh EV, DeRossi SS, Sollecito TP, Goodson JM *et al.* Dental anesthesia using 4% articaine 1:200,000 epinephrine: two clinical trials. *J Am Dent Assoc* 2006; **137**: 1572–1581.
42. Sierra Rebolledo A, Delgado Molina E, Berini Aytís L, Gay Escoda C. Comparative study of the anesthetic efficacy of 4% articaine versus 2% lidocaine in inferior alveolar nerve block during surgical extraction of impacted lower third molars. *Med Oral Patol Oral Cir Bucal* 2007; **12**: E139–44.
43. Isabel Peixoto Tortamano, Marcelo Siviero, Carina Gisele Costa, Inês Aparecida Buscariolo and Paschoal Laércio Armonia. A comparison of the anesthetic efficacy of articaine and lidocaine in patients with irreversible pulpitis. *J Endodont* 2009; **35**: 165–168.
44. Araújo GM, Barbalho JC, Dias TG, Santos Tde S, Vasconcellos RJ, de Morais HH. Comparative analysis between computed and conventional inferior alveolar nerve block techniques. *J Craniofac Surg* 2015; **26**: e733–736.
45. Haase A, Reader A, Nusstein J, Beck M, Drum M. Comparing anesthetic efficacy of articaine versus lidocaine as a supplemental buccal infiltration of the mandibular first molar after an inferior alveolar nerve block. *J Am Dent Assoc* 2008; **139**: 1228–1235.
46. Matthews R, Drum M, Reader A, Nusstein J, Beck M. Articaine for supplemental, buccal mandibular infiltration anesthesia in patients with irreversible pulpitis when the inferior alveolar nerve block fails. *J Endod* 2009; **35**: 343–346.
47. Kanaa MD, Whitworth JM, Meechan JG. A prospective randomized trial of different supplementary local anesthetic techniques after failure of inferior alveolar nerve block in patients with irreversible pulpitis in mandibular teeth. *J Endod* 2012; **38**: 421–425. doi: 10.1016/j.joen.2011.12.006. Epub 2012 Feb 2.
48. Dumbrigue HB, Lim MV, Rudman RA, Serraon A. A comparative study of anesthetic techniques for mandibular dental extraction. *Am J Dent* 1997; **10**: 275–278.
49. Shabazfar N, Daubländer M, Al-Nawas B, Kämmerer PW. Periodontal intraligament injection as alternative to inferior alveolar nerve block – meta-analysis of the literature from 1979 to 2012. *Clin Oral Investig* 2014; **18**: 351–358
50. Dumbrigue HB, Lim MV, Rudman RA, Serraon A. A comparative study of anesthetic techniques for mandibular dental extraction. *Am J Dent* 1997; **10**: 275–278.
51. Dunbar D, Reader A, Nist R, Beck M, Meyers W. Anesthetic efficacy of the intraosseous injection after an inferior alveolar nerve block. *J Endod* 1996; **22**: 481–486.
52. Guglielmo A, Reader A, Nist R, Beck M, Weaver J. Anesthetic efficacy and heart rate effects of the supplemental intraosseous injection of 2% mepivacaine with 1:20,000 levonordefrin. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999; **8**7: 284–293.
53. Stabile P, Reader A, Gallatin E, Beck M, Weaver J. Anesthetic efficacy and heart rate effects of the intraosseous injection of 1.5% etidocaine (1:200,000 epinephrine) after an inferior alveolar nerve block. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2000; **89**: 407–411.
54. Webber B, Orlansky H, Lipton C, Stevens M. Complications of an intra-arterial injection from an inferior alveolar nerve block. *J Am Dent Assoc* 2001; **132**: 1702–1704.
55. Tzermpos FH, Cocos A, Kleftogiannis M, Zarakas M, Iatrou I. Transient delayed facial nerve palsy after inferior alveolar nerve block anesthesia. *Anesth Prog* 2012; **59**: 22–27.
56. Cummings DR, Yamashita DD, McAndrews JP. Complications of local anesthesia used in oral and maxillofacial surgery. *Oral Maxillofac Surg Clin North Am* 2011; **23**: 369–377. doi: 10.1016/j.coms.2011.04.009.
57. Catelani C, Valente A, Rossi A, Bertolai R. Broken anesthetic needle in the pterygomandibular space. Four case reports. *Minerva Stomatol* 2013; **62**: 455–463.
58. von Arx T, Lozanoff S, Zinkernagel M. Ophthalmologic complications after intraoral local anesthesia. *Swiss Dent J* 2014; **124**: 784–806.
59. Renton T, Adey-Viscuso D, Meechan JG, Yilmaz Z. Trigeminal nerve injuries in relation to the local anaesthesia in mandibular injections. *Br Dent J* 2010; **209**: E15.
60. Pogrel MA, Thamby S. Permanent nerve involvement resulting from inferior alveolar nerve blocks. *J Am Dent Assoc* 2000; **131**: 901–907. Erratum in: *J Am Dent Assoc* 2000; **131**: 1418.
61. Hannan L, Reader A, Nist R, Beck M, Meyers WJ. The use of ultrasound for guiding needle placement for inferior alveolar nerve blocks. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 1999; **87**: 658–665.
62. Neal JM. Ultrasound-guided regional anesthesia and patient safety: update of an evidence-based analysis. *Reg Anesth Pain Med* 2016; **41**: 195–204.
63. Baldi C, Bettinelli S, Grossi P, Fausto A, Sardanelli F, Cavalloro F *et al.* Ultrasound guidance for locoregional anesthesia: a review. *Minerva Anestesiol* 2007; **73**: 587–593.
64. Hillerup S, Jensen R. Nerve injury caused by mandibular block analgesia. *Int J Oral Maxillofac Surg* 2006; **35**: 437–443. Epub 2005 Dec 15.
65. Haas DA, Lennon D. A 21 year retrospective study of reports of paresthesia following local anesthetic administration. *J Can Dent Assoc* 1995; **61**: 319–330.
66. Garisto GA, Gaffen AS, Lawrence HP, Tenenbaum HC, Haas DA. Occurrence of paresthesia after dental local anesthetic administration in the United States. *J Am Dent Assoc* 2010; **141**: 836–844. Erratum in: *J Am Dent Assoc* 2010; **141**: 944.
67. Haas DA. Articaine and paresthesia: epidemiological studies. *J Am Coll Dent* 2006; **73**: 5–10.
68. Hillerup S, Jensen RH, Ersbøll BK. Trigeminal nerve injury associated with injection of local anesthetics: needle lesion or neurotoxicity? *J Am Dent Assoc* 2011; **142**: 531–539.
69. Pogrel MA. Permanent nerve damage from inferior alveolar nerve blocks: a current update. *J Calif Dent Assoc* 2012; **40**: 795–797.
70. Gaffen AS, Haas DA. Retrospective review of voluntary reports of nonsurgical paresthesia in dentistry. *J Can Dent Assoc* 2009; **75**: 579.
71. Kingon A, Sambrook P, Goss A. Higher concentration local anaesthetics causing prolonged anaesthesia. Do they? A literature review and case reports. *Aust Dent J* 2011; **56**: 348–351. doi: 10.1111/j.1834-7819.2011.01358.x. Epub 2011 Oct 3.
72. Orr DL, Curtis WJ. Oral and maxillofacial surgery, anesthesiology for dentistry, University of Nevada School of Medicine, Las Vegas 89102–2287, USA. *J Am Dent Assoc* 2005; **136**: 1568–1571.
73. National Royal College of Anaesthetists Audit 2012.
74. Evans G, Nusstein J, Drum M, Reader A, Beck M. A prospective, randomized, double-blind comparison of articaine and lidocaine for maxillary infiltrations. *J Endod* 2008; **34**: 389–393. doi: 10.1016/j.joen.2008.01.004. Epub 2008 Feb 7.
75. Oliveira PC, Volpato MC, Ramacciato JC, Ranali J. Articaine and lignocaine efficiency in infiltration

anaesthesia: a pilot study. *Br Dent J* 2004; **197**: 45–46; discussion 33.
76. Vähätalo K, Antila H, Lehtinen R. Articaine and lidocaine for maxillary infiltration anesthesia. *Anesth Prog* 1993; **40**: 114–116.
77. Srinivasan N, Kavitha M, Loganathan CS, Padmini G. Comparison of anesthetic efficacy of 4% articaine and 2% lidocaine for maxillary buccal infiltration in patients with irreversible pulpitis. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2009; **107**: 133–136.
78. da Silva-Junior GP, de Almeida Souza LM, Groppo FC. Comparison of articaine and lidocaine for buccal infiltration after inferior alveolar nerve block for intraoperative pain control during impacted mandibular third molar surgery. *Anesth Prog Summer* 2017; **64**: 80–84. doi: 10.2344/anpr-64-02-06.
79. Lima JL Jr, Dias-Ribeiro E, Ferreira-Rocha J, Soares R, Costa FW, Fan S, Sant'ana E. Comparison of buccal infiltration of 4% articaine with 1 : 100,000 and 1 : 200,000 epinephrine for extraction of maxillary third molars with pericoronitis: a pilot study. *Anesth Prog* 2013; **60**: 42–45. doi: 10.2344/0003-3006-60.2.42.
80. Montgomery V Lanarkshire Health Board (2015) UK SC 11. Available from: **https://en.m.wikipedia.org/wiki/Montgomery_v_Lanarkshire_Health_Board**
81. Bolam V Friern Hospital Management Committee (1957) 1 WLR 582. Available from: **https://en.m.wikipedia.org/wiki/Bolam_v_Friern_Hospital_Management_Committee**
82. Bartlett G, Mansoor J. Articaine buccal infiltration vs lidocaine inferior dental block – a review of the literature. *Br Dent J* 2016; **220**: 117–120. doi: 10.1038/sj.bdj.2016.93.
83. Peters MC, Botero TM. In patients with symptomatic irreversible pulpitis, articaine is 3.6 times more efficacious than lidocaine in achieving anesthetic success when used for supplementary infiltration after mandibular block anesthesia. *J Evid Based Dent Pract* 2017; **17**: 99–101.
84. Shabazfar N, Daubländer M, Al-Nawas B, Kämmerer PW. Periodontal intraligament injection as alternative to inferior alveolar nerve block – meta-analysis of the literature from 1979 to 2012. *Clin Oral Investig* 2014; **18**: 351–358.
85. Kämmerer PW, Palarie V, Schiegnitz E, Ziebart T, Al-Nawas B, Daubländer M. Clinical and histological comparison of pulp anesthesia and local diffusion after periodontal ligament injection and intrapapillary infiltration anaesthesia. *J Pain Relief* 2012; **1**: 108. doi:10.4172/2167- 0846.1000108- 0846.1000108.
86. Zain M, Rehman Khattak SU, Sikandar H, Shah SA, Fayyaz. Comparison of anaesthetic efficacy of 4% articaine primary buccal infiltration versus 2% lidocaine inferior alveolar nerve block in symptomatic mandibular first molar teeth. *J Coll Physicians Surg Pak* 2016; **26**: 4–8.
87. Poorni S, Veniashok B, Senthikumar AD, Indira R, Ramamchandran S. Anesthetic efficacy of four percent articaine for pulpal anesthesia by using inferior alveolar nerve block and buccal infiltration techniques in patients with irreversible pulpitis: a prospective randomized double-blind clinical trial. *J Endod* 2011; **37**: 1603–1607.
88. Thakare A, Bhate K, Kathariya R. Comparison of 4% articaine and 0.5% bupivacaine anesthetic efficacy in orthodontic extractions: prospective, randomized crossover study. *Acta Anaesthesiol Taiwan* 2014; **52**: 59–63.
89. Dumbrigue HB, Lim MV, Rudman RA, Serraon A. A comparative study of anesthetic techniques for mandibular dental extraction. *Am J Dent* 1997; **10**: 275–278.
90. Etoz OA, Er N, Demirbas AE. Supraperiosteal infiltration anesthesia safe enough to prevent inferior alveolar nerve during posterior mandibular implant surgery? *Med Oral Patol Oral Cir Bucal* 2011; **16**: e386–389
91. Sánchez-Siles M, Camacho-Alonso F, Salazar-Sánchez N, Aguinaga-Ontoso E, Muñoz JG, Calvo-Guirado JL. A low dose of subperiosteal anaesthesia injection versus a high dose of infiltration anaesthesia to minimise the risk of nerve damage at implant placement: a randomised controlled trial. *Eur J Oral Implantol* 2016; **9**: 59–66.
92. Smith T, Urquiola R, Oueis H, Stenger J. Comparison of articaine and lidocaine in the pediatric population. *J Mich Dent Assoc* 2014; **96**: 34–37.
93. Arrow P. A comparison of articaine 4% and lignocaine 2% in block and infiltration analgesia in children. *Aust Dent J* 2012; **57**: 325–333.
94. Kämmerer PW, Schiegnitz E, von Haussen T, Shabazfar N, Kämmerer P, Willershausen B, Al-Nawas B, Daubländer M. Clinical efficacy of a computerised device (STA™) and a pressure syringe (VarioJect INTRA™) for intraligamentary anaesthesia. *Eur J Dent Educ* 2015; **19**: 16–22.
95. Becker DE, Reed KL. Essentials of local anesthetic pharmacology. *Anesth Prog* 2006; **53**: 98–109.
96. Oertel R, Rahn R, Kirch W. Clinical pharmacokinetics of articaine. *Clin Pharmacokinet* 1997; **33**: 417–425.
97. Vree TB, Gielen MJ. Clinical pharmacology and the use of articaine for local and regional anaesthesia. *Best Pract Res Clin Anaesthesiol* 2005; **19**: 293–308.
98. Abdulwahab M, Boynes S, Moore P, Seifikar S, Al-Jazzaf A, Alshuraidah A, Zovko J, Close J. The efficacy of six local anesthetic formulations used for posterior mandibular buccal infiltration anesthesia. *J Am Dent Assoc* 2009; **140**: 1018–1024.
99. Peters MC, Botero TM. In patients with symptomatic irreversible pulpitis, articaine is 3.6 times more efficacious than lidocaine in achieving anesthetic success when used for supplementary infiltration after mandibular block anesthesia. *J Evid Based Dent Pract* 2017; **17**: 99–101.
100. Kämmerer PW, Schneider D, Palarie V, Schiegnitz E, Daubländer M. Comparison of anesthetic efficacy of 2 and 4% articaine in inferior alveolar nerve block for tooth extraction – a double-blinded randomized clinical trial. *Clin Oral Investig* 2017; **21**: 397–403.
101. Senes AM, Calvo AM, Colombini-Ishikiriama BL, Gonçalves PZ, Dionísio TJ, Sant'ana E *et al*. Efficacy and safety of 2% and 4% articaine for lower third molar surgery. *J Dent Res* 2015; **94**(Suppl 9): 166S–173S. doi: 10.1177/0022034515596313. Epub 2015 Jul 22.
102. Moore PA, Boynes SG, Hersh EV, DeRossi SS, Sollecito TP, Goodson JM *et al*. The anesthetic efficacy of 4 percent articaine 1:200,000 epinephrine: two controlled clinical trials. *J Am Dent Assoc* 2006; **137**: 1572–1581.
103. Zurfluh MA, Daubländer M, van Waes HJ. Comparison of two epinephrine concentrations in an articaine solution for local anesthesia in children. *Swiss Dent J* 2015; **125**: 698–709.
104. Malamed S. 1.8 or 2.2 ml? How much anaesthetic is enough? Personal communication.
105. Makoto S, Atsushi K, Kenichi I, Hironori H, Kazuo K, Akira K, Toshikazu A, Shuji M. A study on the dosage of dental local anaesthetics – the clinical use of the ORA inj Cartridge 1.0ml. *Oral Therap Pharmacol* 1999; **8**: 97–103.
106. Malamed SF. Techniques of maxillary anaesthesia. In *Handbook of Local anaesthesia* 6th edn. St Louis: Mosby Elsevier, 2013: p223.
107. Shahidi Bonjar AH. Syringe micro vibrator (SMV) a new device being introduced in dentistry to alleviate pain and anxiety of intraoral injections, and a comparative study with a similar device. *Ann Surg Innov Res* 2011; **5**: 1–5.