CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

Effectiveness of intraosseous anaesthesia in irreversible pulpitis

Systematic integrative review

Matthieu Hilaire Antoine Bédé

Dissertação conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

Gandra, 15 de maio de 2022

CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

Matthieu Hilaire Antoine Bédé

Dissertação conducente ao Grau de Mestre em Medicina Dentária (Ciclo Integrado)

Effectiveness of intraosseous anaesthesia in irreversible pulpitis

Systematic integrative review

Trabalho realizado sob a Orientação de Prof. Paulo Miller

CESPU
INSTITUTO UNIVERSITÁRIO
DE CIÊNCIAS DA SAÚDE

Declaração de Integridade

Eu, Matthieu Hilaire Antoine Bédé, declaro ter atuado com absoluta integridade na elaboração deste trabalho, confirmo que em todo o trabalho conducente à sua elaboração não recorri a qualquer forma de falsificação de resultados ou à prática de plágio (ato pelo qual um indivíduo, mesmo por omissão, assume a autoria do trabalho intelectual pertencente a outrem, na sua totalidade ou em partes dele). Mais declaro que todas as frases que retirei de trabalhos anteriores pertencentes a outros autores foram referenciadas ou redigidas com novas palavras, tendo neste caso colocado a citação da fonte bibliográfica.

ACKNOWLEDGMENTS

I would like to thank in particular my Professors António Ferraz and Paulo Miller, who accompanied and advised me throughout this work. You created the conditions for me to experiment with intraosseous anaesthesia. I would not have been able to do this work without your help, so thank you very much.

Thank you to all my clinical teachers. Thanks to Doctor Stéphane Diaz, who allowed me to perform the anaesthesia I am talking about in this work and guided me during its execution.

I dedicate this thesis to my parents Jocelyn and Béatrice, my sister Cécile and my brothers Jean and Joseph who have always been the first to support me and without whom I would never have managed to be here today. I love you all.

To the rest of my family, my grandparents, my aunt and uncle, Sidoine, Maïa and my sisters-in-law.

Thank you to Giulia, who made the last two years in Portugal beautiful, and who also accepted to be my guinea pig for the thesis, thank you for being there.

To Antoine, Quentin, July and Thomas and my other friends in France who will recognize themselves by reading this thesis, go ahead and have a look, it's fascinating.

To my partner Giv and my roommate Elias with whom I had some meulé time, without forgetting Zak, Moha, Abd, Soso and the others.

ABSTRACT

INTRODUCTION: In patients with irreversible pulpitis, pain management is a challenge due to the higher failure rate that occurs in healthy patients. Conventional techniques are sometimes not sufficient and other anaesthesia systems could be needed. Intraosseous anaesthesia (IOA) is a more efficient technique that delivers the anaesthetic solution into the cancellous bone directly in contact with the apex of the tooth.

OBJECTIVES: Primary is to evaluate the efficacy of IOA in root canal treatment of teeth with irreversible pulpitis.

Secondary are:

- To evaluate the precautions and the contraindications of IOA.
- To compare the side effects with conventional systems.

MATERIALS AND METHODS: A bibliographic search was conducted in PubMed from 2012 to 2022 of articles in English using the following keywords: "Anesthesia"; "Intraosseous"; "Dental"; "Irreversible Pulpitis"; "mandibular molar".

RESULTS: 14 articles were selected. Of the 14 articles, 6 evaluated the efficacy of IOA as a first injection, and 4 as a secondary injection. The remaining 4 articles evaluated other variables.

DISCUSSION: In the first injection, depending on the study, the effectiveness of IOA is either equal or superior to conventional techniques. In the reinforcement anaesthesia, IOA was more effective than conventional. Side effects were observed, the main one being an increase in heart rate. Other side effects are rare, and most can be avoided with precautions. In terms of comfort, IOA was preferred by patients.

CONCLUSION: IOA as supplementary anaesthesia is a good alternative to conventional anaesthesia in patients with IP. It is recommended for patient's comfort.

INDEX:

INDEX OF FIGURE

INDEX OF TABLES

INDEX OF ABBREVIATIONS

BI: Buccal Infiltration anesthesia

GGNB: Gow-Gates nerve block

IA: Infiltrative Anesthesia

IANb: Inferior Alveolar Nerve block

IOA: Intraosseous Anesthesia

IP: Irreversible Pulpitis

ISI: Intraseptal Injection

LI: Lingual Infiltration

MINb: Mental/Incisive Nerve block

PDL: Intraligamentary injection

rIANb: Second injection of IANb

VANB: Vazirani-Akinosi nerve block

1. INTRODUCTION

Achieving efficient pulpal anesthesia is the first step for a successful endodontic treatment. Inadequate depth of anesthesia prolongs the treatment time and creates stress in both clinician and patient. It can lower the quality of treatment and decrease patient cooperation as well (1). Successful administration of local anesthesia allows the dentist to establish a relationship with the patient, to continue the appointment and to complete the therapeutic procedure (2). Effective pain control during endodontic treatment is therefore necessary to allow patient comfort as well as to reduce operator stress (3).

Inferior dental nerve block and infiltrated local anesthesia are the most commonly used techniques to achieve the desired analgesia for endodontic treatment with a very good success rate (4). However, the condition and clinical signs of irreversible pulpitis can present a real challenge and difficulty for these anesthetic techniques (4). For example, inferior alveolar nerve block (IANb) is associated with a 15% failure rate in patients with normal tissue, whereas IANb fails in 44-81% of cases in patients with irreversible pulpitis. Similarly, it has been reported that the failure rate of a maxillary infiltration injection is as high as 30% in teeth with irreversible pulpitis (3).

It has been suggested that pulpal and periapical inflammation and infection can lower the tissue pH in the affected region limiting the ability of the local anesthetic to provide pain control; others have hypothesized that inflammation products enhance nerve conduction. Unusual vasodilation caused by inflammation may also lead to systemic uptake of anesthetic solution from the local site of infiltration, thus, reducing its local effectiveness (3). Clinically, a symptomatic irreversible pulpitis is a condition characterized by dental pulp inflammation, with sharp spontaneous or intermittent pain. When teeth are diagnosed with symptomatic irreversible pulpitis, based on symptoms and clinical signals, it is no longer expected for the dental pulp to heal (5).

Professionals are often obliged to adopt additional measures of anesthesia to control pain, such as intraligamentar injections (PDL), periapical infiltrative complementary (4), buccal infiltration (BI), lingual infiltration (LI), intraseptal injection (ISI), mental/incisive nerve block (MINB), Gow-Gates nerve block (GGNB), Vazirani-Akinosi nerve block (VANB), and intraosseous injection (6).

The use of intraosseous anesthesia (IOA) dates back to 1910, when *Masselink BH* published a technique for placing the solution inside the medullar bone through a perforation in the cortical bone made with a round carbide drill (7). Intraosseous injection refers to penetrating the cortical bone adjacent to the root of the respective tooth. After penetration, a short needle is inserted into the site and anesthetic agent is directly injected into the cancellous bone between the buccal and lingual cortices. Highly porous nature of the cancellous bone allows fast diffusion of the anesthetic agent, and a deep state of anesthesia is rapidly achieved as such (1).

As irreversible pulpitis is an area prone to anesthetic failure using conventional techniques, would IOA be an effective alternative and therefore a solution to this problem?

2. OBJECTIVES

The primary objective was to evaluate the efficacy of IOA in root canal treatment of teeth with irreversible pulpitis.

The secondary objectives were:

- To evaluate what are the precautions of use and contraindications of IOA systems.
- To compare the side effects of IOA (increased heart rate and blood pressure, reflux events and postoperative pain) with conventional systems.

3. MATERIALS AND METHODS

3.1. Protocol:

This study was realized in accord with the directives PRISMA (Preferred Reporting Items for Systematic and Meta-Analyses).

3.2. Eligibility Criteria:

This work was recommended according to Cochrane's recommendations responding to PICO (Population; Intervention; Comparison; Outcome).

Table 1: PICO	
Population	Patients with irreversible pulpitis
Intervention	Use of intraosseous anaesthesia technique
Comparison	With conventional methods of anaesthesia
Outcome	Analyzing the effectiveness of the intraosseous anaesthesia technique

The eligibility criteria were divided into two groups, the inclusion and exclusion criteria:

Table 2: Eligibility criteria	
Inclusion criteria	**Exclusion criteria**
• Articles published in the last 10 years • Articles in English, Portuguese, and French • Studies about intraosseous anaesthesia • Studies including mandibular molars • Clinical studies and randomized controlled trials.	• Articles without full text • Duplicates • Articles not related to intraosseous anaesthesia • In vitro studies • Books and documents • Reviews and Systematic reviews • Irrelevant articles

3.3. Searching for information

This literature search was conducted in the PubMed databases (via the National Library of Medicine) between January 2022 and March 2022 with the combination of the following scientific MeSH terms: "Anesthesia"; "Intraosseous"; "Dental"; "Irreversible Pulpitis"; "mandibular molar"; "Visual Analogue Scale"; "Electric Pulp Test" with the linking word "And". The combinations were "anesthesia and dental and intraosseous"; "anesthesia and dental and intraosseous and pulpitis"; "Anesthesia and dental and pulpitis and irreversible and mandibular molar"; "Visual Analogue Scale and dental"; "Electric Pulp test".

Other supporting articles for the introduction and discussion were obtained with a free manual search.

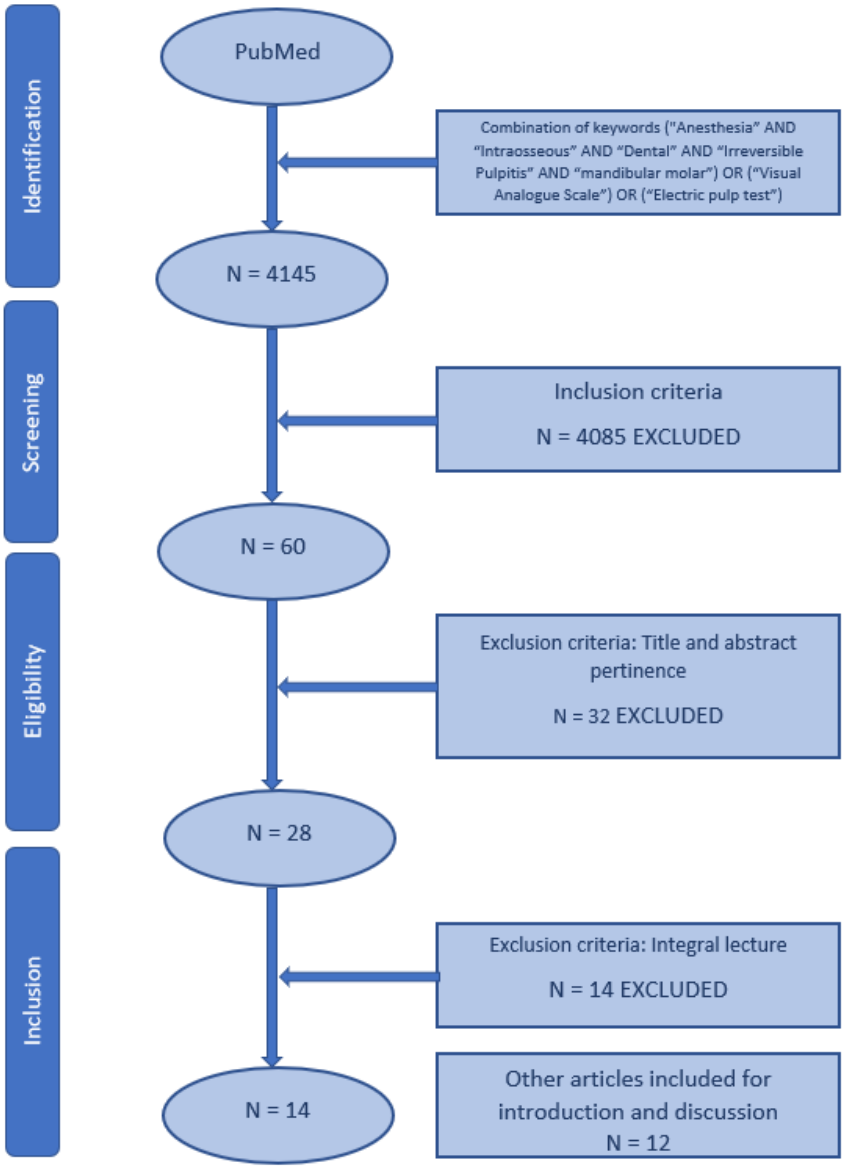

Figure 1:PRISMA Fluxogram

4. RESULTS

In the search for studies, PubMed was the only search engine used. A total of 4145 articles were found. After applying the exclusion criteria, reading the titles and contexts, 28 articles were selected. Then after reading these 28 articles, 14 were excluded. Of these 14 articles, 2 were in-vitro studies, 1 had no results, 4 were too old, and 7 had only a very minor focus on IOA.

Of the 14 articles selected, 6 articles evaluated the efficacy of IOA as a first injection, and 4 articles evaluated it as a secondary injection. The remaining 4 studies evaluated other variables such as duration of anaesthesia, increase in heart rate, pain and discomfort during anaesthesia, mean onset time of anaesthesia, pain at the injection site after surgery and other rarer side effects.

With the free manual search, 12 articles were found to support the introduction and discussion.

Table 3: Results

Title / Author / type of study / year	Objective	Materials and Methods				results	Conclusion
		Sample	Anesthetics / Type of anesthesia	Teeth evaluated	Variables evaluated		
(17) **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** / Mohammad D. Kanaa / randomized clinical trial / 04-04-2012	To compare the efficacy of supplementary repeat inferior alveolar nerve block with 2% lidocaine and epinephrine, buccal infiltration with 4% articaine with epinephrine, intraligamentary injection, or intraosseous injection (both with 2% lidocaine with epinephrine) after failed inferior alveolar nerve block (IANB) for securing pain-free treatment in patients experiencing irreversible pulpitis in mandibular permanent teeth.	182 patients: -Gender: 133 males / 49 females -Age: 18-66 years / mean 31.9 years	- **Inferior alveolar nerve block (IANb):** 2mL of lidocaine 2% with epinephrine 1:80,000 - **IANB Booster (rIANb):** 2mL lidocaine 2% with epinephrine 1:80,000 - **Buccal infiltration (ABI):** 2mL 4% articaine HCL with epinephrine 1:100,000 - **Intraligamentary injection (PDL):** 0.18 ml of 2% lidocaine with 1:80,000 epinephrine - **Intraosseous X-tip anesthesia (IOA):** 0.2 mL 2% lidocaine with epinephrine (1:80,000)	182 mandibular teeth: - 93 1st molars - 62 2nd molars - 7 3rd molars - 3 first premolars - 15 second premolars - 1 lateral incisor - 1 canine	- Effectiveness of the IANb - Mean time of onset of pulp anesthesia of IANb - Effectiveness of supplemental IANb - Effectiveness of supplemental buccal infiltration - Effectiveness of supplemental intraligamentary injection - Effectiveness of supplemental IOA	- Successful IANb: 122/182 (67.0%) - Mean time to onset of pulp anesthesia for rIANb: 5.58 min - Successful rIANb: 9/16 (53.6%) - Success of supplementary ABI: 10/12 (83.3%) - Success of supplementary PDL: 7/14 (50%) - Success of supplementary IOA: 14/18 (77.8%)	Buccal infiltration of 2 mL 4% articaine with epinephrine and intraosseous injections of 1 mL 2% lidocaine with epinephrine allowed more pain-free treatments than intraligamentary injections of 0.2 mL of 2% lidocaine with epinephrine or repeat IANB injections for patients experiencing irreversible pulpitis in mandibular permanent teeth.

(12) **Comparison of the anesthetic efficacy of and heart rate changes after periodontal ligament or intraosseous X-Tip injection in mandibular molars: a randomized controlled clinical trial** / M. Zarei / 2012	To compare the efficacy of supplemental anesthesia using periodontal ligament injections (PDL) and intraosseous injections with the X-Tip system in terms of the measured heart rate and patient reported pain level.	47 patients with symptomatic irreversible pulpitis - 47 in first IANb -20 in IOA supplemental injection - 20 in PLD supplemental injection Mean age: 27.9yo	**IANb:** 1.8 mL of 2% lidocaine and 1/100 000 epinephrine **IOA** X-tip: 1.8 mL of 2% lidocaine with 1:100 000 epinephrine **PDL** injection: 1.8 mL of 2% lidocaine with 1:100 000 epinephrine	mandibular posterior tooth - 15 first molars - 17 second molars - 8 second premolars	Efficacity of the supplemental IOA technique Efficacity of the supplemental PLD injection technique	Success of the supplemental IOA technique: 100% (20/20) Success of the supplemental PLD injection technique: 70% (14/20)	Supplemental injections are essential when pulpal anesthesia from the IANb is inadequate, which frequently occurs in patients diagnosed with irreversible pulpitis. According to the findings of this study, it can be concluded that supplemental Intraosseous anaesthesia by the X-Tip system is more effective than intraligamentar injection, although the X-Tip system elevated the patient heart rate more than intraligamentar injection.
(25) **Intraosseous anesthesia with solution injection controlled by a computerized system versus conventional oral anesthesia: A preliminary study** / Simple-blind	To compare a computerized intraosseous anesthesia system with the conventional oral anesthesia techniques and analyze the latency and duration of the anesthetic	30 patients: Age: 18-65years old Sex: - 12 female	**IANb**: 4% articaine with 1 :100 000 adrenalin **IOA** (QuickSleeper): 4% articaine with 1 :100 000 adrenalin		Discomfort during IANb Discomfort during IOA technique	Discomfort during IANb: 32.1% Discomfort during IOA technique: 46.3%	The described intraosseous anesthetic system is effective, with a much shorter latency than the conventional technique, sufficient duration of anesthesia to perform the

prospective study / Rut Beneito-Brotons / May 2012	effect and patient preference.	- 18 male			Latency of the IANb technique Latency of the IOA technique Duration of the IANb effect in soft tissues Duration of the IOA effect in soft tissues	Latency of the IANb technique: 7.1min Latency of the IOA technique: 0.48min Duration of the IANb effect in soft tissues: 199.3 min Duration of the IOA effect in soft tissues: 1.6 min Patients' preference: - IANb: 23.3% - IOA: 69.7%	required dental treatments, and with a much lesser soft tissue anesthetic effect. Most of the patients preferred intraosseous anesthesia.
(14) **Side effects and complications of intraosseous anesthesia and conventional oral anesthesia** / simple-blind, prospective clinical study / David	To analyze the side effects and complications following intraosseous anesthesia (IA), comparing them with those of the conventional oral anesthesia techniques.	100 patients Age: 10-55 years old Sex: - 47 male - 53 female	**Conventional**: 2% lidocaine with 1:100,000 adrenalin - local infiltration - IANb **IOA**: 3% mepivacaine without vasoconstrictor		Increase in heart rate Pain at injection site Trismus after injection	Increase in heart rate: - Conventional technique: 4.66 bpm - IOA technique: 1.61 bpm Pain at injection site: - Conventional technique: 4% - IOA technique: 11%	Both anesthetic techniques significantly increased heart rate, and IA caused comparatively more pain at the injection site, while limited oral aperture was more frequent with conventional anesthesia. Post-anesthetic biting

Peñarrocha-Oltra / May 2012					Post-anesthetic biting problems	Trismus: - Conventional technique: 5% - IOA technique: 0% Post anesthetic biting problems: - Conventional technique: 4% - IOA technique: 0%	showed no significant differences between the two techniques.
(24) **A comparative evaluation of pain and anxiety levels in 2 different anesthesia techniques: locoregional anesthesia using conventional syringe versus intraosseous anesthesia using a computer-controlled system (Quicksleeper)** / clinical study / Senem Özer / November 2012	To compare anxiety and pain levels during anesthesia and efficacy of Quicksleeper intraosseous (IO) injection system, which delivers computer-controlled IO anesthesia and conventional inferior alveolar nerve block (IANB) in impacted mandibular third molars.	40 adult subjects Gender: 15 men 25 women Age: 18-40years old	**IOA** (QuickSleeper system): 0.3 mL and 1.5 mL of a 4% articaine solution with 1:100,000 adrenaline **IANb**: 1.5 and 0.3mL of 4% articaine with 1:100 000	Impacted 3rd mandibular molars	Pain and discomfort during IANb technique (VAS) Pain and discomfort during the QuickSleeper IOA technique (VAS)	Pain and discomfort during IANB technique (VAS): - After anesthesia: 1.01 - After operation: 3.30 Pain and discomfort during the QuickSleeper IOA technique (VAS): - After anesthesia: 2.28 - After operation: 2.35	Although IOA is a useful technique commonly used during various treatments in dentistry, the duration of injection takes longer than conventional techniques, there is a possibility of obstruction at the needle tip, and, the duration of the anesthetic effect is inadequate for prolonged surgical procedures.

(9) **X-tip intraosseous injection system as a primary anesthesia for irreversible pulpitis of posterior mandibular teeth: A randomized clinical trail** / Hamid Razavian / mar-apr 2013	The aim of this study was to compare the efficacy of X-tip intraosseous injection and inferior alveolar nerve block (IANb) in primary anesthesia for mandibular posterior teeth with irreversible pulpitis.	40 patients with irreversible pulpitis - 20 in IOA group - 20 in IANB group Age: mean= 40 years old Gender: - 51% male - 49% female	- **IOA**: 1.8 ml of 2% lidocaine with 1:100,000 epinephrine	mandibular posterior teeth: - 63% 1st molar - 37% 2nd molar	Efficacy of the IOA technique Efficacity of the IANb technique Time duration for onset of IOA technique Time duration for onset of IANb technique	Success of the IOA technique: 85% (17/20) Success of the IANb technique: 70% (14/20) Time duration for onset of IOA technique: -Mean time: 7.4min Time duration for onset of IANb: -Mean time: 9.5min	Considering the relatively expensive armamentarium, probability of penetrator separation, temporary tachycardia, and possibility of damage to root during drilling, the authors do not suggest intraosseous injection as a suitable primary technique.
(10) **Anesthetic efficacity of X-tip intraosseous injection using 2% lidocaine with 1 :80,000 epinephrine in patients with irreversible pulpitis after inferior alveolar nerve block : A clinical**	To evaluate the anesthetic efficacity of X-tip intraosseous injection (2% lidocaine with 1:80,000 epinephrine) in patients with irreversible pulpitis in mandibular posterior teeth when conventional IAN block failed.	30 patients with irreversible pulpitis - 16 males - 14 females Age: 18-40 years old	**IANb**: 1.8 ml of 2% lidocaine with 1:80,000 epinephrine **IOA**: 1.8 ml of 2% lidocaine with 1:80,000 epinephrine	mandibular posterior tooth: - 1 second premolar - 25 first molars - 4 second molars	Efficacity of the IOA technique Perception of discomfort during IOA technique	Success of the IOA technique: 93% (26/28) None or mild pain during the IOA: 96.66%	Supplemental X-tip intraosseous injection using 2% lignocaine with 1:80,000 epinephrine has a statistically significant influence in achieving pulpal anesthesia in patients with irreversible pulpitis.

study / Pushpendra Kumar Verma / 2013							
(26) **Articaine (4%) with epinephrine (1:100,000 or 1:200,000) in Intraosseous injections in symptomatic irreversible pulpitis of mandibular molars: anesthetic efficacy and cardiovascular effects** / randomized double-blind study / Leandro Augusto Pinto Pereira / 02-08-2013	To compare the cardiovascular effects and the anesthetic efficacy of intraosseous injections of 4% articaine with 1:100,000 epinephrine (EPI100) or 4% articaine with 1:200,000 epinephrine (EPI200).	60 patients with symptomatic irreversible pulpitis Age: 18-55 years old	**IOA group 1:** 0.9 mL 4% articaine with 1:100,000 epinephrine **IOA group 2:** 0.9 mL of 4% articaine with 1:200,000 epinephrine	mandibular posterior tooth	Efficacity of the IOA technique with articaine with 1:100,000 epinephrine Efficacity of the IOA technique with articaine with 1:200,000 epinephrine	Success of the IOA technique with articaine with 1:100,000 epinephrine: 96.8% Success of the IOA technique with articaine with 1:200,000 epinephrine: 93.1%	The epinephrine concentration did not affect the efficacy of IO anesthesia with 4% articaine in mandibular molars with symptomatic irreversible pulpitis. Both anesthetic solutions tested promoted a high success level of pulpal anesthesia.
(3) **Intraosseous injection as an adjunct to conventional local anesthetic techniques: A clinical study** / Mohamed Idris / 09-10-2014	A clinical study was undertaken using intraosseous injection system by name X-tip to evaluate its effectiveness in cases where inferior alveolar nerve block has failed to provide pulpal anesthesia.	60 patients: - Gender: 34 male / 26 female - Age: 18-43 years	- **IANb**: 1.5mL of articaine 4% with 1:100,000 epinephrine - **IOA** (X-tip injection): 0.9mL of articaine 4% with epinephrine 1:100,000	Mandibular molars	- Effectiveness of the IANb - Effectiveness of the supplementary IOA	- IANb success: 60% (36/60) - Supplementary IOA success: 87.5% (21/24)	Within the limits of this study, we can conclude that supplemental intraosseous injection using 4% articaine with 1:100,000 epinephrine has a statistically significant influence in achieving pulpal anesthesia in patients with irreversible pulpitis.

(7) **Perception of discomfort during injection and the need for supplemental anesthesia in the intraosseous technique using 4% articaine**/ Adel Martínez / experimental study / 2016	To determine the perception of patient discomfort during injection and the need for supplemental anesthesia using the intraosseous technique with 4% articaine with 1:100,000 epinephrine in patients with symptomatic pulpitis in mandibular molars	70 patients with irreversible pulpitis 35 in IANb group: - 16 male - 19 female 35 in IOA group: - 19 male - 16 female	- **IAO:** 4% articaine with 1:100,000 epinephrine - **IANb**: 4% articaine with 1:100,000 epinephrine	mandibular molars	Efficacity of the IANb technique Efficacity of the IOA technique Perception of discomfort during IANb technique Perception of discomfort during IOA technique	Success of the IANb technique: 34.28% (12/35) of the sample required supplemental injection Success of the IOA technique: 37.15% (13/35) of the sample required supplemental injection The mean values on the visual analogue scale (VAS) were 0.94 (SD: 1.21) for IOA group and 2.6 (SD: 1.24) for IANb group	The intraosseous technique was found to be similar to the conventional technique with regard to the need for supplemental anesthesia: 13 (18.57%) and 12 patients (17.14 %) The intraosseous technique with the X Tip Kit is more comfortable than puncture using the conventional technique at the level of the inferior dental orifice.
(4) **Anesthesia in Dental Medicine with Local Infiltrative Anesthetic Technique *Versus* Diploe Anesthesia Delivery Systems: Efficacy and Behavior, an**	To compare the analgesic efficacy and the influence of local infiltrative anesthesia techniques, with diploe anesthesia, on the cardiac rhythm	32 healthy volunteers Age: 20-23years old	**periapical vestibular infiltrative anesthesia:** 0.45 mL of 2% lidocaine with 1:80 000 adrenaline **IOA**: 0.45 mL of 2% lidocaine with 1:80 000 adrenaline	Healthy teeth 1.4	Efficacity of IOA (QuickSleeper system) Efficacity of the periapical anesthesia	Success of the IOA (QuickSleeper system) with the electric test: - Before anesthesia: 47 - 1 min after: 80 - 15 min after: 80 - 30 min after: 80 - 60 min after: 60	the onset of analgesic action with diploe anesthesia was immediate and the duration effect is lower than with conventional anesthesia techniques.

Experimental Study / Manuel MARQUES-FERREIRA / 30-12-2017					Hearth rate: - Before anesthesia - 1 min after - 15 min after - 30 min after - 60 min after	Success of the periapical anesthesia with the electric test: - Before anesthesia: 41 - 1 min after: 45 - 15 min after: 75.5 - 30 min after: 66.5 - 60 min after: 50 Hearth rate with IOA (bpm) - Before anesthesia: 76 - 1 min after: 80 - 15 min after: 72 - 30 min after: 72 - 60 min after: 72 Hearth rate with the periapical anesthesia (bpm) - before anesthesia: 72 - 1 min after: 72 - 15 min after: 72 - 30 min after: 72 - 60 min after: 72	When compared with the t1 of periapical infiltrative anesthesia, there was an increase in the heart rate in the first minute with diploe anesthesia, which may be an alternative technique to infiltrative anesthesia.

(1) **Effect of intraosseous injection versus inferior alveolar nerve block as primary pulpal anesthesia of mandibular posterior teeth with symptomatic irreversible pulpitis: a prospective randomized clinical trial** / Alireza Farhad / 27-01-2018	To assess the success rate, effect on blood pressure, and pain of intraosseous injection (IO) and inferior alveolar nerve block (IANB) for pulpal anesthesia of mandibular posterior teeth with symptomatic irreversible pulpitis as the primary anesthetic technique.	60 patients with irreversible pulpitis 30 in IOA group - 13 male - 17 female 30 in IANB group - 11 male - 19 female Age: 18-65 years old	- **IOA**: 1.8 mL of 3% mepivacaine - **IANB**: 1.8mL of 3% mepivacaine	mandibular posterior teeth: - 8 second premolar - 44 first molar - 8 second molar	Efficacity of the IOA technique Efficacity of the IANb technique	Success of the IOA technique: 56.7% Success of the IANb technique: 23.3%	The results of the present study showed that IO had a higher success rate than IANB for pulpal anesthesia of mandibular posterior teeth with symptomatic irreversible pulpitis. Neither technique provided profound pulpal anesthesia. No significant difference was noted in pain during anesthetic injection or change in systolic and diastolic blood pressures following injection between the two techniques.
(6) **Intraosseous anesthesia in symptomatic irreversible pulpitis: Impact of bone thickness on perception and**	To evaluate the efficacy of intraosseous anesthesia (IO) using the Anesto® device supplementary to infiltration anesthesia (IA) and/or	33 patients - Age: 20-62 years old - Gender: 18 female / 15 male	- **IA and IANB** : 1.7 ml Ultracain forte (articaine hydrochloride with 1:100,000 epinephrine hydrochloride) - **IOA** (Anesto system): 1.7 ml Ultracain forte (articaine hydrochloride	- Lower molar region: 15 teeth 36.4% of the teeth that needed trepanation were located in the	- Efficacy of supplementary IOA - Duration of supplementary IOA	Success of the supplementary IOA: 95.76% - Male: 94.00% - Female: 97.22%	IO with the Anesto® device as an extension and deepening of local pain elimination is recommended for the treatment of hot teeth.

duration of pain / Manfred Nilius / Clinical trial / 2020-20-6	inferior alveolar nerve block anesthesia (IANB) in symptomatic irreversible pulpitis (IP).		with 1:100,000 epinephrine hydrochloride)	posterior area of the mandible		Duration of supplementary IOA: 13.03 min - Male: 12.33 min - Female: 13.61 min	
(23) **EFFECTIVENESS OF PRIMARY INTRAOSSEOUS ANESTHESIA IN THE ENDODONTIC TREATMENT OF MANDIBULAR MOLARS WITH IRREVERSIBLE PULPITIS** / Clinical study / Emiliya Simeonova / 26-06-2020	To investigate the effectiveness of primary intraosseous anesthesia (IO) in the endodontic treatment of lower molars with irreversible pulpitis.	30 patients with irreversible pulpitis Mean age: 28yo	**IOA** (QuickSleeper): 0.9 mL of 4% articaine hydrochloride with 1:100 000 adrenaline	mandibular posterior tooth - 16 first molars - 14 second molars	Efficacity of the IOA technique during 1st part of endodontic treatment Efficacity of the IOA technique during 2nd part of endodontic treatment Efficacity of the IOA technique during 3rd part of endodontic treatment	Success of the IOA technique during 1st part of endodontic treatment: 100% (28/28) Success of the IOA technique during 2nd part of endodontic treatment: 100% (28/28) Success of the IOA technique during 3rd part of endodontic treatment: 75% (21/28)	The IO can be use as primary method of analgesia that provides reliable pulp anesthesia for routine endodontic treatment.

5. DISCUSSION

Pain control of the mandibular molars with irreversible pulpal pain is one of the greatest challenges during pulp extirpation for root canal preparation (6). However, conventional anesthesia may sometimes be unsuccessful in irreversible pulpitis, especially in the posterior mandibular teeth, where the bone is denser and less porous (4). The success rate of IANb for pulpal anesthesia of mandibular posterior teeth has been reported to be 55–70%. This success rate decreases noticeably in acutely inflamed mandibular posterior teeth. Reisman et al. (8) reported the success rate of IANb for anesthesia of mandibular posterior teeth with irreversible pulpitis to be 25% and emphasized the need for administration of supplemental anesthetic injections (1).

Many authors have speculated on the reasons for the failures of the IANb: Razavian et al (9) and Verma et al (10) have hypothesized that the reasons of IANb failure in such cases may be accessory innervations, accuracy of needle placement, anesthetic solution migration along the path of least resistance and psychological factors. Their second assumption for this issue is that nerves arising from inflamed tissue have altered resting potentials and decreased excitability thresholds. Goodis et al (11) hypothesized that in inflamed periapical tissues there is a release of inflammatory mediators that reduce the sensitivity threshold of nociceptive neurons, to the point where any minor stimulus activates it. Then, they demonstrated that by lowering the pH from 7.4 to 6.5 the sensitivity of nociceptor neurons is increased. They also showed that by reducing the temperature from 37°C to 26°C the signal from these neurons would be blocked or drastically attenuated. In addition, Farhad et al. (1) hypothesized that cytokines and chemokines induce the inflammatory activation and sensitization of nociceptive neurons; resistance of tetrodotoxin-resistant sodium channels to the action of local anaesthetics; and anxious, apprehensive patients often have lowered pain threshold. Supplementary injections are therefore essential when the pulp anesthesia obtained by the IANb is insufficient and the pain is too great for the endodontist to proceed (10).

Therefore, alternatives to conventional nerve blocks need to be considered for in-depth anesthesia of the lower molars (6). The combination of anesthetic techniques such as lower dental nerve block, periapical infiltrative anesthesia and intra-ligament injections increase

efficacy, but are not always sufficient to obtain acceptable levels (4). Intraosseous injection is reported to be successful as a supplemental technique after failure of an IANb (12).

5.1. Description and characteristics of the IOA

The use of intraosseous anesthesia dates to 1910, when *Masselink BH* published a technique for a drilling system that penetrates the corticalis to inject the anesthetic solution directly into the cancellous bone. A rotating needle on the dental handpiece enters the corticalis minimally at a predetermined speed of approximately 1s. Then, the anesthetic solution is injected right into the cancellous bone with no pressure. Before penetrating the corticalis, a surface anesthesia is recommended. (6); (7). Today, the IOA system is usually computer-controlled, which gives it many advantages, such as a minimal lingering numbness of lips, does not cause anaesthesia of the tongue or tissue hematoma, a fast-acting and atraumatic anesthesia (1), a smaller doses anesthetic than regional block method, a good acceptance by the patients (13), it allows to perform a bilateral mandibular anesthesia due to the absence of anesthesia of the lip and tongue (14). Despite these advantages, some precautions are necessary to avoid complications and to have the best efficiency. To prevent these complications and have the best efficiency, the authors propose a set of preventive measures. The dentist should have a thorough knowledge of the root anatomy, perform a careful clinical examination of all protrusions of the cortical bone, and perform a periapical radiograph to determine exactly where the root is located, which is the most appropriate place to drill and administer the anesthetic solution (4). A conclusion is that better pulpal anesthesia was achieved if the intraosseous injection site was distal to the second premolar (12).

5.2. Efficacity of the IOA in comparison with conventional

The main criterion evaluated in this systemic review is the effectiveness of IOA in the case of IP compared to conventional systems (IANb and IA). In participants with IP, the effectiveness of IOA could be recorded by measuring the pain experienced during treatment following anaesthesia. This pain was measured here with the Visual Analogue Scale (VAS). The visual analog scale (VAS) is a pain rating scale first used by Hayes and Patterson in

1921. Scores are based on self-reported measures of symptoms that are recorded with a single handwritten mark placed at one point along the length of a 10-cm line that represents a continuum between the two ends of the scale "no pain" on the left end (0 cm) of the scale and the "worst pain" on the right end of the scale (10 cm). Measurements from the starting point (left end) of the scale to the patients' marks are recorded in centimeters and are interpreted as their pain (15). In patients without necessity for treatment, the efficacy of the IOA was measured with the electric pulp tester. An EPT is a system that passes an electrical current through the tooth via the pulp where the electrons excite the myelin sheaths and cause a reaction in the patient (16).

In all comparative studies, whether as a first injection strategy or as a reinforcement, the efficacy of IOA was either equal to conventional techniques (which means that there were no significant differences) (7);(9) either superior to them (17); (1); (12). In the study by Martinez et al (7), IOA and IANb are proposed as primary anaesthetic techniques, their results were 81.43% and 82.86% respectively. These results did not differ significantly. Razavian, et al. (9) observed that the success rate of the IOA using X-tip system was 85% (17/20) and the success rate of traditional IANb was 70% which does not represent a significant difference. Kanaa et al. (17) demonstrated that the success of IANb first injection in irreversible pulpitis was 67.0%. They then tried four reinforcement strategies including different types of anesthesia: IANb reinforcement (rIANb); buccal infiltration (BI); intraligamentary anesthesia (PDL) and finally intraosseous anesthesia (IOA). Of these techniques, the most effective were additional BI (83.3% success rate) and additional IOA (77.8% success rate). The rIANb and PDL techniques achieved 53.6% and 50% success respectively. Farhad et al. (1) observed that the success rate of IOA of 3% mepivacaine was 56.7%, which was significantly more than IANb (23.3%). Zarei et al. (12) experimented 2 systems of supplemental anesthesia, the IOA with X-tip and the PDL injection with a result of 100% for the IOA and 70% for the PDL. In their reports, the authors cite other older studies, but with interesting results: For primary IOA in patients with IP, Remmers et al. (18) found 87% efficacy versus 60% with IANb; Reisman et al. (8) found 80% efficacy; Jensen et al. (19) found 100% efficacy.

For additional AIO in patients with IP; Nusstein et al. (20) found 90% efficacy; Parente et al. (21) found 91% efficacy; Prohic' et al (22) 94.9% efficacy.

Some authors explain that several mechanisms are responsible for the failure rate with IOA: A first phenomenon is that in some patients, the very dense and compact cancellous bone prevents good distribution of the anaesthetic around the apices (3). Another phenomenon is backflow, which may be due to wrong selection of needle size in the perforator hole by the clinician or closure of the perforator hole with bone debris during the perforation process which leads to extrusion of the anaesthetic solution (9). The choice of site could impact on the efficacy of IOA, Verma et al. (10) explain that the choice of injection site, mesial to the tooth to be anaesthetised, may have lowered the success rate (10).

Differences in effectiveness between studies are explained by use of different systems for IOA, differences in type and volume of anaesthetic agents used, variable pain threshold of patients, differences in the severity of inflammation, anatomical variations and inter-individual and interracial differences (1).

Among the selected studies, the best results obtained with IOA in first line are those of Razavian et al. (9) with a success rate of 85%, and Simeonova et al. (23) who obtained a success rate of 100%. Razavian et al. used the X-tip system with 1.8mL of 2% lidocaine with 1:100,000 epinephrine. They first assessed the roots by radiography and then determined the site of perforation in the alveolar mucosa, between the mandibular n°6 and n°7 molars. They then injected 0.1mL of 2% lidocaine with 1:100,000 epinephrine at the perforation site. The perforator drill was positioned at a 90° angle to the cortical bone and the slow-speed hand piece was activated in a series of short bursts, using light pressure until 2-5 sec had passed. The anesthetic solution was slowly injected for 60 seconds. Before inserting the 27-gauge ultrashort X-tip needle into the guide sleeve, the needle was bent at a 60-80° angle to allow easy insertion. The perforator was pushed through the alveolar mucosa until the X-tip faced bone (9). Simeonova et al. used the computer assisted system Quicksleeper with 0.9 mL of 4% articaine hydrochloride with 1:100 000 adrenaline. Before perforation, they proceed an infiltrative anesthesia of soft tissue with 0.3 mL of 4% articaine hydrochloride with 1:100 000 adrenaline at an angle of 15° to the bone at the target point (23).

Other variables investigated in the selected studies showed that IOA was faster acting than conventional techniques (4) and was less painful and preferred by patients (24).

5.3. Comparison of other criteria

The effectiveness of IOA in terms of pain reduction is not the only variable evaluated in this study, other variables are also considered such as discomfort during the application of the anaesthetic, onset of action of the anaesthetic, duration of anaesthesia, increased heart rate, blood pressure and other possible complications.

5.3.1. Discomfort during procedure

Regarding discomfort during anaesthetic application, according to Farhad et al. (1); (6), there are no significant differences between the AIO and the IANb. Their study considered the injection process as a single phase instead of dividing it to separate steps. This may be the reason for different injection pain values obtained in this study compared to previous studies.

For Martínez et al. (7) as reported on the Visual Analog Scale (VAS), 18 patients (25.79%) reported no pain during the intraosseous technique, in contrast to the mandibular technique group, in which only 2 (2.85%) reported no pain. They therefore conclude by saying that the intraosseous technique with the X-Tip Kit is more comfortable than puncture using the conventional technique at the level of the inferior dental orifice. In the study of Verma et al. with the IOA technique, (36), 96.66% (29/30) of patients reported none or mild pain, whereas 3.34% (1/30) patients reported moderate pain. No severe pain was reported by any of the patients.

5.3.2. Onset of action

The next variable to be considered was the onset of action of the anaesthetic. All studies that measured this variable found that the onset of action of IOA was either immediate or lasted less than one minute. The onset of action of the IANb was longer. Nilius, et al. (6), talk about an IOA onset time of 2.40 minutes. Idris et al. (3) observed that the onset of anesthesia was immediate for those patients receiving successful X-tip injections. Endodontic access was begun as soon as the rubber dam was placed, and the patients experienced none or mild pain. The results of Ferreira et al. (4) demonstrate that between t0 and t1, there is a statistically significant improvement with diploe anaesthesia, which

does not occur with periapical infiltrative anaesthesia. In all volunteers, the onset of analgesic action with QuickSleeper® was immediate.

Brotons et al. (25) in their study found a mean onset of action of 7.1 minutes for IANb and 0.48 minutes for AIO. They quote more ancient studies which compared the onset of action of IOA with IANb. They found onset times of 36 seconds and 10-120 seconds for IOA and 7 minutes and 8-17 minutes for IANb.

5.3.3.Average anesthesia time

Of the selected papers, those that analyzed anaesthesia time all found that IOA lasted less time than IANb, the only study that did not find a significant difference between the two techniques was that of Brotons et al (25), however, the procedures performed in their study did not last long enough to note any difference between the two techniques. Nilius, et al. (6), using 1.7 ml Ultracain forte (articaine hydrochloride with 1:100,000 epinephrine hydrochloride), observed that the duration of IOA was on average less than a quarter of an hour (13.03 min). Idris et al (3) and Verma et al. (10) found the same results: IOA provide a shorter duration of anesthesia than IANb or IA. However, pulpal anesthesia has duration of less than 60 min with vasoconstrictor and approximately 15-30 min without vasoconstrictor. Razavian, et al. (9) noted that the average duration of IOA with 1.8 ml of 2% lidocaine with 1:100,000 epinephrine for normal mandibular teeth has been reported to be 60 min, whereas the IANb has longer duration of anesthesia which is more than 140 min. Ferreira et al (4), who divided the times into several parts, found a significant difference between t1 and t60, indicating that from this moment, the anaesthesia loses its efficacity. The fact that the IOA lasts less time than the IANb can be explained by the fact that the spongy bone of both the jawbone and the jaw has a good blood supply, which causes the anaesthetic deposited there to be metabolized more quickly. As a result, the duration of the anaesthetic effect of this method in the tooth is lower than in conventional anaesthesia techniques. (4)

5.3.4.Heart rate

The main adverse effect described in almost all the selected studies was increased heart rate.

Nilius et al. (6) observed in their study a variation between 77.3 heartbeats/min at T0 and a pulse of 101.18 after 15 minutes. Ferreira et al. (4) observed too an increase in heart rate, but only at t1, up to 2 minutes after injection. At t15, t30 and t60, there is no significant difference between IOA and IANb. Pereira et al. (26) compared the effects of IOA of 4% articaine with 1:100,000 and 1:200,000 epinephrine on the cardiovascular system and indicated that both had minimal cardiovascular complications. They showed no significant changes in the heart rate after a slow IO injection (1.4 mL 2% lidocaine with 1:100,000 epinephrine injected over 4.75 minutes). Verma et al. (10) observed an increase in heart rate in 96% (27/28) of patients receiving an IOA. The increase was 18.93bpm during the injection and then decreased to 9.21bpm after 3 minutes. The reason for this might be due to an increase in the concentration of adrenaline (1:80,000) in local anesthetic solution used for primary as well as intraosseous anesthesia. Oltra et al. (14) observed an increase in heart rate despite the absence of the vasoconstrictor and therefore conclude that the effect on heart rate may not be due to the vasoconstrictor but to the anaesthetic substance itself. To explain this increase Ferreira et al. (4) talk about a greater absorption of adrenaline into the bloodstream with greater vascularity of cancellous bone. They then warn against using adrenaline in patients with heart problems with this technique, and propose 3% mepivacaine as an alternative, even if the anaesthetic time is reduced. Farhad et al. (1) observed a smaller increase in heart rate by injecting the anaesthetic more slowly. They concluded that slow injection of anaesthetic agents decreased their adverse effects on the cardiovascular parameters including the heart rate and systolic and diastolic blood pressures.

Here the authors contradict each other and therefore do not reach a consensus, further studies are needed.

5.3.5.Other side effects

Other complications and side effects have been observed and studied across the selected articles.

Farhad et al. (1) observed that the mean change in systolic and diastolic blood pressures was positive for both IOA and IANb groups, which indicated that both groups had a net increase in systolic and diastolic blood pressures after the injections. Pereira et al. (26) have noted increases in blood pressure after administration of 2% lidocaine with 1:80,000 epinephrine during both blocks or infiltrations. Rapid intraosseous injections (0.9 mL) with 2% lidocaine with 1:80,000 epinephrine have been shown to increase blood pressure.

5.4. Contraindications

Regarding contraindications, the IOA cannot be administered in case of infection of the perforation site, close to vital structures such as the chin nerve for example, close to developing teeth, in case of aggressive periodontitis (9), acute periapical infection, root fusion, difficult perforation of cortex due to high thickness, and presence of inadequate volume of cancellous bone in the area (1).

5.5. Preventive measures

To summarize the adverse effects, the IOA can cause increase in blood pression and heart rate; acute periodontitis and temporary tachycardia (9); backflow phenomenon; pain at the injection site (14); locking and subsequent fracture of device in bone (1); overheating due to the rotation of the needle; root perforation (4); perforation of the maxillary sinus (7) and osteonecrosis in rare cases (4). To prevent these iatrogenic lesions, the authors propose a set of preventive measures. The dentist should have a thorough knowledge of the root anatomy, perform a careful clinical examination of all protrusions of the cortical bone, and perform a periapical radiograph to determine exactly where the root is located, which is the most appropriate place to drill and administer the anaesthetic solution. In order to avoid overheating the periradicular structures, the needle should perforate the bone at the speed of predefined rotation (11 000 rpm) in order to increase the safety of the procedure (4). To

prevent locking and subsequent fracture of device in bone, the handpiece had to be operating during the entire bone perforation procedure in order. To prevent the backflow phenomenon, if resistance was sensed during injection, the needle was rotated a quarter turn and injection was attempted again (1).

5.6. Advantages and inconvenient

The list of adverse effects of this technique can be very inconvenient, although some effects are rare. In view of the list of adverse effects that can be caused by IOA, a formation seems necessary for the proper realization of this technique. In addition, this technology has a high price tag, which can represent a large investment for the dentist.

Its effectiveness in terms of duration of anaesthesia can be a disadvantage for the dentist as it limits the duration of care and prevents the correct performance of treatments that take longer, however, it could be an advantage to the patient because a shorter anaesthetic is more comfortable in the postoperative period.

Despite the list of adverse effects and disadvantages, the IOA has many advantages over the IANb. IOA is more effective than conventional techniques for anaesthetic reinforcement in teeth with IP, requires less anaesthetic than conventional techniques, is more appreciated by patients because it is more comfortable than conventional anaesthesia, does not anaesthetise soft tissues, and takes less time to anesthetize which is better for the patient.

6. CONCLUSION

The IOA is an anaesthesia system that has many advantages compared to conventional anesthesia, mainly better patient comfort and better efficacy in reinforcement anaesthesia. For mandibular molars with IP, in the first injection, the different studies either showed a superiority of IOA or did not observe significant differences between IOA and IANb. However, in the second injection, all studies showed the superiority of the AIO over the IANb.

All studies did not achieve the same success rates when using IOA, these differences can be explained by the skills of the different operators, the variability of bone density, the duration of the operation and the shortening of the anaesthetic effect due to bleeding. The most common side effect was increased heart rate, however, this decreased after only a few minutes. Other side effects have been observed but most of them can be avoided with precautions and a good use protocol.

In terms of comfort during anesthesia, all the patients preferred the IOA technique. IOA as a supplemental anesthesia could therefore be a good alternative to conventional anesthesia, more efficient and comfortable, however, its high cost and the need for training in its use make access to this technology more difficult. Moreover, the differences in efficacy between studies are still very large, studies with larger numbers of participants would therefore be necessary.

7. BIBLIOGRAPHY REFERENCES

1. Farhad A, Razavian H, Shafiee M. Effect of intraosseous injection versus inferior alveolar nerve block as primary pulpal anaesthesia of mandibular posterior teeth with symptomatic irreversible pulpitis: a prospective randomized clinical trial. Acta Odontol Scand. 2018 Aug;76(6):442-447.

2. Lasemi E, Sezavar M, Habibi L, Hemmat S, Sarkarat F, Nematollahi Z. Articaine (4%) with epinephrine (1:100,000 or 1:200,000) in inferior alveolar nerve block: Effects on the vital signs and onset, and duration of anesthesia. J Dent Anesth Pain Med. déc 2015;15(4):201-5.

3. Idris M, Sakkir N, Naik KG, Jayaram NK. Intraosseous injection as an adjunct to conventional local anesthetic techniques: A clinical study. J Conserv Dent JCD. sept 2014;17(5):432-5.

4. Marques-Ferreira M, Carrilho E, Paulo S, Carrilho T, Pedro Figueiredo J, Macedo R. Anaesthesia in Dental Medicine with Local Infiltrative Anaesthetic Technique Versus Diploe Anaesthesia Delivery Systems: Efficacy and Behaviour, an Experimental Study. Acta Med Port. 29 déc 2017;30(12):848-53.

5. Dias-Junior LC de L, Bezerra AP, Schuldt DPV, Kuntze MM, de Luca Canto G, da Fonseca Roberti Garcia L, et al. Effectiveness of different anesthetic methods for mandibular posterior teeth with symptomatic irreversible pulpitis: a systematic review and meta-analysis. Clin Oral Investig. déc 2021;25(12):6477-500.

6. Nilius M, Mueller C, Nilius MH, Haim D, Leonhardt H, Lauer G. Intraosseous anesthesia in symptomatic irreversible pulpitis: Impact of bone thickness on perception and duration of pain. J Dent Anesth Pain Med. déc 2020;20(6):367-75.

7. Martínez Martínez A, Lujan Pardo MD, Harris Ricardo J. Perception of discomfort during injection and the need for supplemental anesthesia in the intraosseous technique using 4% articaine. Acta Odontol Latinoam. 2016 Dec;29(3):214-218.

8. Reisman D, Reader A, Nist R, Beck M, Weaver J. Anesthetic efficacy of the supplemental intraosseous injection of 3% mepivacaine in irreversible pulpitis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. déc 1997;84(6):676-82.

9. Razavian H, Kazemi S, Khazaei S, Jahromi MZ. X-tip intraosseous injection system as a primary anesthesia for irreversible pulpitis of posterior mandibular teeth: A randomized clinical trail. Dent Res J. mars 2013;10(2):210-3.

10. Verma PK, Srivastava R, Ramesh KM. Anesthetic efficacy of X-tip intraosseous injection using 2% lidocaine with 1:80,000 epinephrine in patients with irreversible pulpitis after inferior alveolar nerve block: A clinical study. J Conserv Dent JCD. mars 2013;16(2):162-6.

11. Goodis HE, Poon A, Hargreaves KM. Tissue pH and temperature regulate pulpal nociceptors. J Dent Res. nov 2006;85(11):1046-9.

12. Zarei M, Ghoddusi J, Sharifi E, Forghani M, Afkhami F, Marouzi P. Comparison of the anaesthetic efficacy of and heart rate changes after periodontal ligament or intraosseous X-Tip injection in mandibular molars: a randomized controlled clinical trial. Int Endod J. oct 2012;45(10):921-6.

13. Gazal G, Bahabri R, Alolayan AB, Alkayyal M, Al-Ghamdi R, Salamah R. How Successful is Supplemental Intraseptal and Buccal Infiltration Anaesthesia in the Mandibular Molars of Patients Undergoing Root Canal Treatment or Tooth Extraction? J Oral Maxillofac Res. mars 2020;11(1):e5.

14. Peñarrocha-Oltra D, Ata-Ali J, Oltra-Moscardó MJ, Peñarrocha-Diago M, Peñarrocha M. Side effects and complications of intraosseous anesthesia and conventional oral anesthesia. Med Oral Patol Oral Cirugia Bucal. 1 mai 2012;17(3):e430-434.

15. Delgado DA, Lambert BS, Boutris N, McCulloch PC, Robbins AB, Moreno MR, et al. Validation of Digital Visual Analog Scale Pain Scoring With a Traditional Paper-based Visual Analog Scale in Adults. J Am Acad Orthop Surg Glob Res Rev. mars 2018;2(3):e088.

16. Jafarzadeh H, Abbott PV. Review of pulp sensibility tests. Part II: electric pulp tests and test cavities. Int Endod J. nov 2010;43(11):945-58.

17. 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. avr 2012;38(4):421-5.

18. Remmers T, Glickman G, Spears R, He J. The Efficacy of IntraFlow Intraosseous Injection as a Primary Anesthesia Technique. J Endod. mars 2008;34(3):280-3.

19. Jensen J, Nusstein J, Drum M, Reader A, Beck M. Anesthetic Efficacy of a Repeated Intraosseous Injection Following a Primary Intraosseous Injection. J Endod. févr 2008;34(2):126-30.

20. Nusstein J, Reader A, Nist R, Beck M, Meyers WJ. Anesthetic efficacy of the supplemental intraosseous injection of 2% lidocaine with 1:100,000 epinephrine in irreversible pulpitis. J Endod. juill 1998;24(7):487-91.

21. Parente SA, Anderson RW, Herman WW, Kimbrough WF, Weller RN. Anesthetic efficacy of the supplemental intraosseous injection for teeth with irreversible pulpitis. J Endod. déc 1998;24(12):826-8.

22. Prohić S, Sulejmanagić H, Šečić S. The efficacy of supplemental intraosseous anesthesia after insufficient mandibular block. Bosn J Basic Med Sci. 20 févr 2005;5(1):57-60.

23. Simeonova E, Tsanova S, Zagorchev P. Effectiveness of primary intraosseous anesthesia in the endodontic treatment of mandibular molars with irreversible pulpitis. J IMAB – Annu Proceeding Sci Pap. 8 avr 2020;26(2):3063-7.

24. Özer S, Yaltirik M, Kirli I, Yargic I. A comparative evaluation of pain and anxiety levels in 2 different anesthesia techniques: locoregional anesthesia using conventional syringe versus intraosseous anesthesia using a computer-controlled system (Quicksleeper). Oral Surg Oral Med Oral Pathol Oral Radiol. nov 2012;114(5 Suppl):S132-139.

25. Beneito-Brotons R, Peñarrocha-Oltra D, Ata-Ali J, Peñarrocha M. Intraosseous anesthesia with solution injection controlled by a computerized system versus conventional oral anesthesia: A preliminary study. Med Oral Patol Oral Cir Bucal. mai 2012;17(3):e426-9.

26. Pereira LAP, Groppo FC, Bergamaschi C de C, Meechan JG, Ramacciato JC, Motta RHL, et al. Articaine (4%) with epinephrine (1:100,000 or 1:200,000) in intraosseous injections in symptomatic irreversible pulpitis of mandibular molars: anesthetic efficacy and cardiovascular effects. Oral Surg Oral Med Oral Pathol Oral Radiol. août 2013;116(2):e85-91.