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ORIGINAL ARTICLE

Extraction of mandibular premolars and molars: comparison between local infiltration via pressure syringe and inferior alveolar nerve block anesthesia

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Abstract

Objectives The purpose of this study was to evaluate the anesthetic efficiency of local infiltration anesthesia administered with a pressure syringe (P-INF) via a special technique versus direct block anesthesia of the inferior alveolar nerve (IANB) for tooth extraction in the posterior mandible.

Materials and methods In a prospective randomized study, 101 teeth in 101 patients were extracted in the posterior mandible under local anesthesia whereby two different administration techniques were used (P-INF $n = 48$; IANB $n = 53$). Primary objectives were comparisons of anesthetic success rate (yes/no) and efficacy (full/sufficient vs. insufficient). Secondary objectives were patients' pain perception during treatment, pain of injection (numerical rating scale), need for second injections (always IANB), time until onset of anesthetic action (min), and duration of local numbness (min).

Results IANB was successful in all cases, whereas initial P-INF achieved 35% of success only. Furthermore, IANB reached significant higher values of anesthetic efficacy compared to P-INF ($P < 0.001$). Concerning pain of injection, patients rated IANB to be more painful ($P = 0.039$). Second injections were significantly more often necessary for P-INF ($P = 0.006$) whereas duration until onset of action as well as the duration of local numbness were found to be equal.

Conclusions For anesthetic efficacy as well as anesthetic success, block anesthesia of the inferior alveolar nerve (IANB) turned out to be more proficient to local infiltration via special delivering system with a special technique.

Clinical relevance Infiltration, even when performed with 4% articaine and a pressure syringe system, is not a suitable method of anesthesia in the posterior mandible.

Keywords Anesthetic success · IANB · Mandibular molar tooth extraction · Molar region of the mandible · Local anesthesia · Pressure syringe system

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Introduction

Local anesthesia plays a pivotal role in modern dentistry and anesthetic agents rank among the most frequently used drugs both in medicine [1] and dentistry [2, 3]. It is known that a patients' anticipation of pain may compromise dental treatment [1, 4] and that administration of local anesthetic drugs typically triggers anxiety [5].

Inferior alveolar nerve block (IANB) still is the most frequently used anesthetic technique for surgical and restorative treatments in the posterior mandible [6, 7]. When administered successfully, IANB provides enough anesthesia to perform surgical and restorative procedures in a large area of the posterior mandible [8, 9]. However, it is associated with

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relatively high failure rates of 7 to 75% [10–15]. Additionally, major intra- and postoperative complications may occur such as systemic toxicity from iatrogenic intravascular injections, severe bleeding from adjacent blood vessels injury, prolonged mandibular anesthesia, as well as transient, or even permanent paresthesia of the inferior alveolar and the lingual nerves [16–19]. To avoid these disadvantages, investigators have looked for alternative techniques such as periodontal intraligamentary injection anesthesia (PDL). Compared to IANB, PDL is considered as a sufficient alternative method for single tooth anesthesia [20] providing a less painful method of injection without the risk for nerve damage [20] with a circumscribed effect on the adjacent soft tissue only [21]. PDL is commonly performed with specialized high-pressure syringe systems [22, 23] or computer-controlled local anesthesia devices [4, 24] with special 30-gauge short needles. Advantages are single tooth anesthesia, minimal anesthetic dosage, rapid onset, and safety in patients with bleeding problems as well as in medically compromised patients [22, 25]. Further, commensurability of anesthesia and selected treatment should be assessed since a shorter and controllable duration of ILA would be inadequate for extended dental and alveolar surgery of the mandible. However, damages to the periodontal tissue and root resorption [26] as well as severe bacteremia up to 100% [27] are reported. Hence, an alternative technique which is simple in its application in combination with modern instruments and anesthetic agents would be beneficial. In adults, local infiltration anesthesia (INF) has shown to be successful for surgical and restorative treatments in the maxillary as well as the frontal mandibular region, though INF has not been used commonly in the mandibular posterior region due to the dense bony architecture at this site [28]. However, recent studies showed that when using 4% articaine with epinephrine 1:200,000, successful anesthesia could be achieved even in the posterior mandible region. Corbett et al. reported no statistical difference between INF (1.8 mL of 4% articaine with 1:100,000 epinephrine) and IANB (2.0 mL of 2% lidocaine with 1:80.000 epinephrine) when performing electronic pulp testing of mandibular first molars without dental treatment [29]. Another recent study using INF with a high dose of 1.8–3.6 mL of 4% articaine in the posterior mandible found its anesthetic success to be mainly dependent on the mandibular cortical bone thickness and described onset durations of up to 5 min [30]. In the literature, INF success rates in the posterior mandible ranged from 54 to 94% [29, 31].

It is beneficial that local infiltration provides a shorter duration of anesthesia as well as decreases the patients' discomfort of a painful injection when compared to IANB. Even though the incidence of adverse effects using local infiltration anesthesia is lower, numbness of the lip and tongue cannot be entirely avoided with buccal and lingual infiltration. A novel pressure syringe system (Biofeedject®; P-INF) has been developed with the aim of providing successful anesthesia, while avoiding lip and tongue numbness. Therefore, P-INF uses a pressure-guided injection technique to administer the anesthetic solution.

The aim of this study was to evaluate the anesthetic efficiency of infiltration anesthesia using Biofeedject® (P-INF), as compared to the routinely used direct IANB regarding success of anesthesia on patients undergoing tooth extraction in posterior regions of the mandible.

Materials and methods

Patients

In this prospective, randomized study, 101 patients received either inferior alveolar nerve block (IANB) or a special form of infiltration anesthesia (P-INF) for tooth extractions (simple or surgical) of mandibular premolars or molars. The study was conducted after the approval of the local ethics committee of Rhineland Palate [No. 837.192.13 (8877-F)] and in accordance with the Declaration of Helsinki. Inclusion criteria were at least 18 years of age (or younger with approval of parental authority) with clinical indication for tooth extraction in the posterior mandible (premolars and molars) under dental local anesthesia (4% articaine with 1:200,000 epinephrine). Exclusion criteria were contraindications for components of the anesthetic solution (articaine, epinephrine, sulfite), physical and mental retardation, inability to open the mouth for injection of the local anesthetic, chronic or occasional abuse of psychotropic drugs, lacking compliance, patients with American Society of Anesthesiologists (ASA) classification level > 2, as well as infection in and around the area of injection. An oral questioning and a written health history were used to ensure the subjects were in good health and that they were not taking any medication which could possibly affect pain sensation. Prior to dental treatment, all patients signed an informed consent. The study was performed in a private dental practice specializing in oral surgery in cooperation with the Department of Oral and Maxillofacial Surgery, at the University Medical Center of Johannes Gutenberg University, Mainz, Germany. All treatments were conducted by one single experienced surgeon (FS). Each participant in this study received dental treatment of one tooth only.

Equipment and performed technique

For local anesthesia, a solution of 4% articaine with epinephrine 1:200,000 (Ultracain DS®; Sanofi-Aventis GmbH, Berlin Germany) was used. Local anesthesia was either administered as P-INF (4 × 0.3–0.5 mL) with a pressure syringe (Biofeedject®; SMJM Inject GmbH; Aachen, Germany) or with a conventional syringe (IANB; 1 × 1.2 mL) in a direct technique as described before [9]. The Biofeedject® system consists of a syringe and a standardized 1.8 mL single-use glass cartridge, containing the anesthetic solution. For injection, a 25-gauge short needle (Septoject®, Septodont GmbH, Germany) was used. To initiate the Biofeedject®'s injection process, a dosage button needed to be activated, which in turn moves a dispensing piston toward the anesthetic solution in the glass cartridge (Fig. 1). The duration and intensity of the applied pressure determine the flow rate and velocity of the anesthetic solution. For precise pressure control, multiple feedback mechanisms, such as three different rings colored in red, green, and blue are integrated to display the current changes in infusion velocity. Submucosal injections (n = 4/ 0.3 to 0.5 mL) were performed directly around the treatment area at the mesial and distal (lingual and vestibular) sites, respectively, as advocated by the manufacturer. Each injection was set in the labial and lingual regions at an angle of 45° to the tooth's axis without bone contact.

Treatment protocol

Patients were randomly assigned to either P-INF or IANB by a computerized random generator. Preoperative radiographs were obtained. The treatment procedure and the use of the pain scale (numeric rating scale (NRS) 0–10), in which the respondents had to select a whole number from a horizontal bar (0–10; 0 = no pain, 10 = extreme pain) that best reflected the intensity of their pain level, were explained to the patients.

1. Prior to treatment, a questionnaire (Suppl.) was given to all patients. The participants had to document their personal data first, and afterwards they were instructed to mark their current pain level.
2. IANB was conventionally performed [3], whereas P-INF was administered by Biofeedject®.
3. Patients were asked to quantify the pain of injection (NRS).
4. The onset of anesthetic action (min) was timed with a stopwatch. Prior the treatment, numbness was tested with a probe on the soft tissue around the tooth each 30 s after injection whereas treatment did not start before subjective symptoms of numbness were reported by the patient.
5. Patients subjectively rated (NRS) local anesthesia for its anesthetic efficacy, prior, during, and after the treatment. Anesthesia was fully sufficient when local numbness occurred.
6. Patients continuously noted their pain level before and during the treatment (NRS).
7. Local anesthesia was denoted successful when the procedure could be completed without pain. Pain during the procedure led to a second injection or if still not controllable, then to a change of the anesthetic method (IANB instead of P-INF) or even a termination of the treatment.
8. The following day, the patients were contacted via phone call and asked for the duration of anesthesia and adverse effects whereby the time period from the onset of complete numbness to its complete fading was measured.

Other parameters such as the amount of used anesthetic solutions as well as the frequency of required additional injections were also assessed.

Statistics

Prior to the statistical analyses, questionnaires were numbered and data were automatically randomized. Continuous variables were summarized as median, maximum, minimum, and mean with standard deviation (mean ± SD) as well as categorical variables were summarized as frequencies and percentages. All analyses were carried out using the statistics software SPSS version 22.0 for Macintosh (SPSS, Chicago, IL, USA) whereby P values of ≤ 0.05 were termed significant for descriptive reasons only. Anesthetic efficacy was categorized into full/sufficient and non-sufficient. Normal distribution was tested using the Kolmogorov-Smirnov test as well as non-parametric Mann-Whitney U tests were performed for independent testing (IANB vs. P-INF). Pearson's chi-square statistic was used to test the mutual influence of two categorical variables. Graphics were created using the statistical software GraphPad PRISM® v. 6.0d (GraphPad Software, Inc., CA, USA).

Results

Patients

In total, 101 patients (male n = 43, female n = 58; mean age 33.3 years (± 15.9)) with 101 teeth were included in the study. Twenty-four simple and 77 surgical extractions were performed. Table 1 shows the exact distribution of treatment procedures.

Primary objectives

Anesthetic success rate

Only when patients experienced no pain during the treatment was the anesthetic technique assessed to be successful. Figure 2 shows the anesthetic success rate, which was a 100% (53/53) in the case of IANB, whereas successful P-INF was only achieved in 35% (17/48).

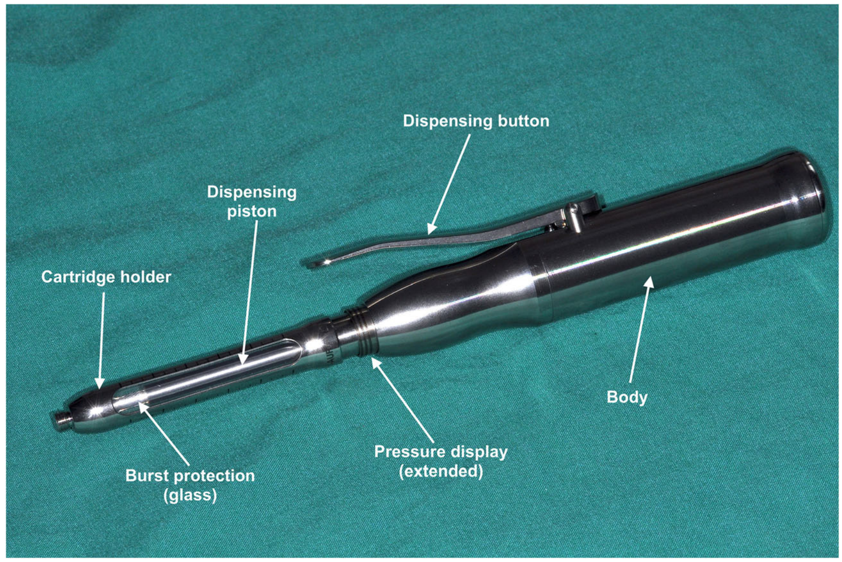

Fig. 1 Pressure syringe (Biofeedject®) (SMJM Inject GmbH, Aachen, Germany). Components marked by white arrows

Anesthetic efficacy and subjective experience of pain

All patients rated the respective anesthetic technique for its efficacy when full local numbness subjectively occurred after the injection using a NRS (Fig. 3). For P-INF, 27/48 patients (56%) rated the anesthetic efficacy as non-sufficient whereas only 11/53 patients (20%) did in the case of IANB. Based on the patients' ratings, it revealed that IANB was the favored technique as it provided full/sufficient anesthesia more often than P-INF (80 vs. 44%; $P < 0.001$).

Once adequate numbness was achieved, no significant differences in the patients' subjective rating of pain during the treatment or unpleasant treatment were revealed, whereas significantly more patients [53/101 (52%)] experienced greater pain of injection when getting treated with IANB ($P = 0.039$; Fig. 4). For pain of injection, the mean NRS score of P-INF was 1.85 ± 1.59 and for IANB a mean of 2.62 ± 2.08 was evaluated.

Secondary objectives

Amount of used solution and number of second injections

Concerning the amount of used volume (mL) of the local anesthetic solution (Ultracain DS®) during the procedures, it turned out that significantly less volume was needed in cases of successful P-INF when compared with that of IANB (1.379 mL ± 0.15 vs. 1.747 mL ± 0.132; $P < 0.001$). Second injections were always performed with IANB and were significantly more often required when using P-INF ($n = 33/48$ vs. $n = 22/53$; $P = 0.006$). Hence, second injections were not included in the total amount of used anesthetic solution.

Duration of local numbness

A follow-up at the first day after surgery showed a mean duration of local numbness up to 3.57 ± 1.72 h for P-INF

Table 1 The allocation of the removed teeth and all analyzed parameters

Tooth	Treated number (n)	Procedure		Method	
		Extraction (n)	Surgical extraction (n)	P-INF	IANB
35	3	3	0	1	2
36	7	6	1	3	4
37	2	1	1	0	2
38	36	1	35	17	19
45	2	2	0	1	1
46	6	5	1	3	3
47	4	3	1	3	1
48	41	3	38	20	21
Total	101	24	77	48	53

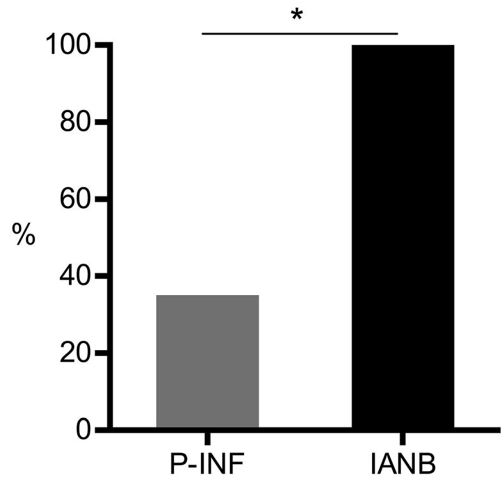

Fig. 2 Bar chart indicating the success rates (%) of block anesthesia of the inferior alveolar nerve (IANB) and local pressure infiltration anesthesia (P-INF) administered with Biofeedject® pressure syringe system. The asterisk indicates statistical significance

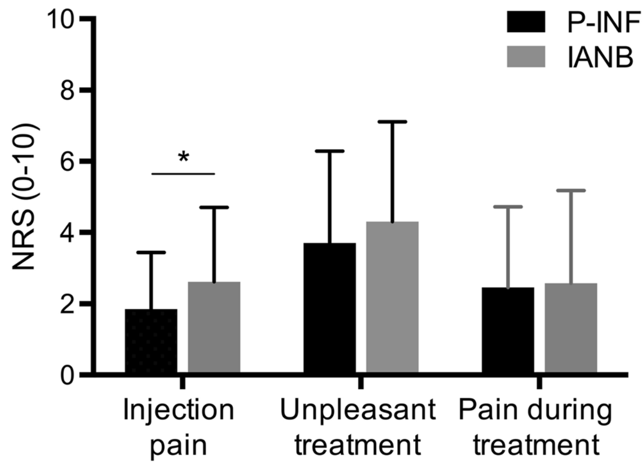

Fig. 4 Pain during treatment, unpleasant treatment, and injection pain rated with a numeric rating scale (NRS) for inferior alveolar nerve block anesthesia (IANB) and local infiltration anesthesia with a pressure syringe system [Biofeedject® (P-INF)]. The asterisk indicates statistical significance

(Biofeedject®) and 3.59 ± 1.51 h for IANB. Hence, no relevant difference could be observed.

Onset of action

Regarding the duration until onset of anesthetic action (min), the findings at hand revealed that both methods performed equally (P-INF mean = 8.65 min ± 3.84 vs. IANB mean 8.62 min ± 4.27, respectively).

Discussion

A common clinical problem faced by different professional groups (dentists, oral surgeons, and maxillofacial surgeons) is the difficulty of achieving profound local anesthesia in patients undergoing dental treatments such as a simple or surgical tooth extraction in the posterior region of the mandible [32–34]. It is well known that the patients' satisfaction as well as their anticipation of pain may compromise the dental treatment [1, 4, 34]; hence, adequate anesthesia is essential to develop a more positive attitude of the patient toward dental procedures. The main difficulty in the posterior mandible is related to the thickness of the cortical bone [30, 35]. In this context, IANB is considered as the standard anesthetic technique [6] regardless of its higher risk for complications. PDL seems to be a viable alternative to IANB in cases of circumscribed treatments without involvement of the surrounding soft tissue. Nevertheless, PDL has some inherent disadvantages such as bacteremia and the technique itself needing considerable experience. Therefore, the aim of this study was to compare IANB with a special infiltration technique (P-INF) for extraction of teeth in the posterior mandibular with regard to the patients' individual pain perceptions.

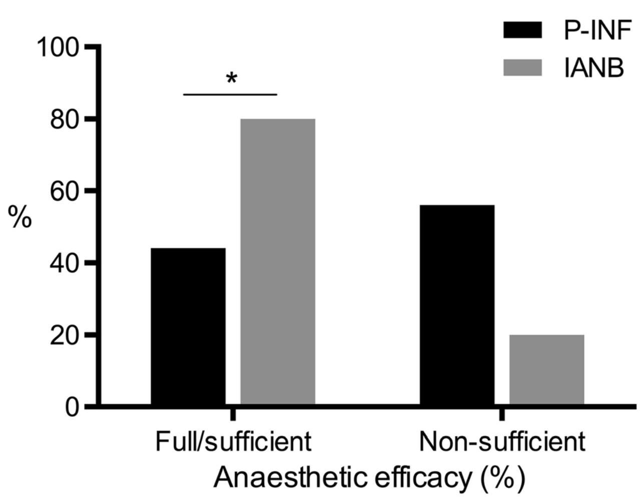

Fig. 3 Bar chart indicating the rating of anesthetic efficacy of P-INF and IANB. The asterisk indicates statistical significance

Although IANB is described as the standard method for local anesthesia, it is associated with complications including vessel and nerve damages as well as a significant failure rate [30, 36]. This outcome is typically attributed to its susceptibility to anatomical variations in the mandibular foramen beside the fact that the numbers of accessory innervations have to be anesthetized [37, 38]. Hence, practitioners and scientists have been searching for safer alternatives for IANB over the past few years. In this context, infiltration anesthesia (INF) was often described to meet the requirements of easier and safer administration together with equal qualities of anesthetic effects [31, 37, 39]. The successful use of primary infiltration anesthesia for treatments in the mandibular deciduous and permanent dentition was reported in several studies [28, 37, 40]. The study of Corbett et al. showed significant benefits in adding buccal and lingual infiltration extra to the inferior alveolar nerve block [29], whereas that of Foster et al. did not [6].

However, to our knowledge, no clinical trial compared the anesthetic efficiency of this particular type of pressure-controlled INF administration with that of the IANB. According to the manufacturers' home page, the used pressure syringe system provides adequate local anesthesia for simple tooth extraction, surgical tooth extraction, implantation, and other procedures in the posterior mandible. Its application is claimed to reduce the required volume of anesthetic solution and perform faster onset of action relating to a faster treatment. In accordance with others, the present study showed that significant less volume of anesthetic solution was required when performing P-INF compared to IANB ($P < 0.001$) [37].

In contrast to other studies [37] addressing the patients' subjective pain perceptions, the present study demonstrated that applying P-INF was significant less painful than IANB ($P = 0.039$; Fig. 4). Regarding unpleasant as well as painful treatment, the results at hand indicated that both techniques were equal (Fig. 4). Concerning the onset of anesthetic action, P-INF and IANB seemed to act similar which is not surprising since the probing technique only tests for surface sensitivity. For complete pulpal anesthesia, a time-delayed onset can be expected for P-INF since the anesthetic agent has to diffuse to its neural target whereas a faster onset, most likely caused by the anesthetic agent placed near its neural target structure at the mandibular foramen, in the case of IANB was demonstrated [37, 41]. Moreover, high inter- and intra-individual differences of response to articaine in the time of onset have been documented [42].

In order to ensure comparable conditions, a solution of 4% articaine and epinephrine (1:200,000) was used in both techniques. Articaine is frequently used and its allergic and toxic potential is low [42, 43]. In comparison to other local anesthetic agents, articaine excels at its ability to penetrate bone more easily due to its chemical structure [17, 44]. It is also possible for the anesthetic agent to diffuse through the accessory foramina of the mandible, into the medullary bone [19, 45–47].

Evaluating the anesthetic efficacy (full/sufficient) as the primary objective, the study at hand revealed that 80% of the patients treated by IANB rated the method to be fully sufficient, in contrast to only 44% of patients treated by P-INF (Biofeedject®) (Fig. 3) which is in accordance to a study performing INF with a conventional syringe [48]. The greater need for second injections in the case of P-INF is consistent with the patients' rating of the anesthetic efficacy. Regarding complete pulpal anesthesia, the idea of an advanced anesthetic effect by respective mesial and distal administration each into the lingual and vestibular sites of the adjacent gingiva only (Biofeedject®) is questionable.

Although Yang et al. found IANB to be successful in up to 96% of treatments in the molar region of the mandible [49, 50], several authors have reported less success rates (24%) [51], with failure rates between 44 and 81% [48, 52, 53]. Hence, there is an increasing demand for comparable alternative anesthetic methods.

In the study at hand, P-INF (Biofeedject®) was significantly less successful in patients undergoing tooth extraction in the posterior mandible when compared to the IANB anesthesia. This would be in accordance with the national survey of Devine M. et al. since it was shown that the majority of the respondents (oral surgeons) uses block anesthesia for tooth extraction in the mandibular molar region [54]. This is in contrast with other studies in which INF and IANB were found to be equal concerning anesthetic efficacy in cases of tooth extraction in the mandibular molar region using 4% articaine with 1:100,000 epinephrine [17, 37].

The literature clearly indicates that INF can provide profound anesthesia in cases of dental treatment in the posterior mandible when administered properly and in addition with the use of 4% articaine and 1:100,000 epinephrine [17, 55–57]. This would be in accordance with the present results revealing no significant difference between the two techniques in the perception of pain during the treatment, once complete pulpal numbness has occurred. Similar results were described by Bataineh et al. in a recent study [58].

There are some limitations to this study. One of the drawbacks using P-INF as the main anesthetic technique in comparison to IANB anesthesia is the fact that lip numbness cannot serve as a reliable sign of infiltration anesthesia technique's success due to the anatomical situation. Prior to the treatment, local numbness was tested with a probe on the tooth itself and the surrounding soft tissue only. The use of an electric pulp tester would have provided more objective findings. Thus, a longer latency time between administration and therapy start in addition to the use of a higher concentrated anesthetic solution (1:100,000) could potentially increase the success rate of P-INF since the anesthetic agent would have had more time penetrating the bone to its neural target. This would underline the CBCT-based findings of Flanagan who determined a cortical bone wall thickness of 2–3 mm as threshold to achieve sufficient anesthesia in the posterior mandible region [30]. Higher success rates of P-INF also could potentially be achieved by using larger volumes of anesthetic solution. In this context, El-Kohley et al. found INF to achieve profound anesthesia in up to 93% of cases by using 3.6 mL of 4% articaine solution (1:100,000) for extraction of the mandibular molars [31].

Conclusion

Taken together, even if Biofeedject® represents an innovative technique of local infiltration anesthesia, the results at hand clearly suggest that the IANB should be favored over P-INF as the suitable anesthetic technique to achieve profound local anesthesia in simple or surgical tooth extraction in the mandibular molar region.

Author Contributions All the authors of this manuscript had substantial contribution to the conception and design or acquisition, analysis, and interpretation of data; all revised it critically for important intellectual content and did the final approval of the version to be published. All authors read and approved the final manuscript. D.G.E. Thiem (daniel.thiem@med.uni-rostock.de) takes responsibility for the integrity of the work as a whole, from inception to finished article.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study.

References

1. Thomson WM, Dixon GS, Kruger E (1999) The West Coast Study. II: Dental anxiety and satisfaction with dental services. N Z Dent J 95(420):44–48
2. Kaufman E, Epstein JB, Naveh E, Gorsky M, Gross A, Cohen G (2005) A survey of pain, pressure, and discomfort induced by commonly used oral local anesthesia injections. Anesth Prog 52(4): 122–127. https://doi.org/10.2344/0003-3006(2005)52[122:ASP]2.0.CO;2
3. Malamed SF (1997) Handbook of local anesthesia, vol 4. Mosby, St. Louis
4. Kämmerer PW, Schiegnitz E, von Haussen T, Shabazfar N, Kammerer P, Willershausen B, Al-Nawas B, Daublander M (2015) Clinical efficacy of a computerised device (STA) and a pressure syringe (VarioJect INTRA) for intraligamentary anaesthesia. Eur J Dent Educ 19(1):16–22. https://doi.org/10.1111/eje.12096
5. Kaakko T, Milgrom P, Coldwell SE, Getz T, Weinstein P, Ramsay DS (1998) Dental fear among university students: implications for pharmacological research. Anesth Prog 45(2):62–67
6. Foster W, Drum M, Reader A, Beck M (2007) Anesthetic efficacy of buccal and lingual infiltrations of lidocaine following an inferior alveolar nerve block in mandibular posterior teeth. Anesth Prog 54(4):163–169. https://doi.org/10.2344/0003-3006(2007)54[163:AEOBAL]2.0.CO;2
7. Shabazfar N, Daublander M, Al-Nawas B, Kämmerer PW (2014) Periodontal intraligament injection as alternative to inferior alveolar nerve block—meta-analysis of the literature from 1979 to 2012. Clin Oral Investig 18(2):351–358. https://doi.org/10.1007/s00784-013-1113-1
8. Davis MJ, Vogel LD (1996) Local anesthetic safety in pediatric patients. N Y State Dent J 62(2):32–35
9. Kämmerer PW, Palarie V, Daublander M, Bicer C, Shabazfar N, Brullmann D, Al-Nawas B (2012) Comparison of 4% articaine with epinephrine (1:100,000) and without epinephrine in inferior alveolar block for tooth extraction: double-blind randomized clinical trial of anesthetic efficacy. Oral Surg Oral Med Oral Pathol Oral Radiol 113(4):495–499. https://doi.org/10.1016/j.tripleo.2011.04.037
10. Hinkley SA, Reader A, Beck M, Meyers WJ (1991) An evaluation of 4% prilocaine with 1:200,000 epinephrine and 2% mepivacaine with 1:20,000 levonordefrin compared with 2% lidocaine with:100,000 epinephrine for inferior alveolar nerve block. Anesth Prog 38(3):84–89
11. Vreeland DL, Reader A, Beck M, Meyers W, Weaver J (1989) An evaluation of volumes and concentrations of lidocaine in human inferior alveolar nerve block. J Endod 15(1):6–12. https://doi.org/10.1016/S0099-2399(89)80091-3
12. Nist RA, Reader A, Beck M, Meyers WJ (1992) An evaluation of the incisive nerve block and combination inferior alveolar and incisive nerve blocks in mandibular anesthesia. J Endod 18(9):455–459. https://doi.org/10.1016/S0099-2399(06)80849-6
13. Nusstein J, Reader A, Beck FM (2002) Anesthetic efficacy of different volumes of lidocaine with epinephrine for inferior alveolar nerve blocks. Gen Dent 50(4):372–375 quiz 376-377
14. Yonchak T, Reader A, Beck M, Meyers WJ (2001) Anesthetic efficacy of unilateral and bilateral inferior alveolar nerve blocks to determine cross innervation in anterior teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 92(2):132–135. https://doi.org/10.1067/moe.2001.115720
15. Steinkruger G, Nusstein J, Reader A, Beck M, Weaver J (2006) The significance of needle bevel orientation in achieving a successful inferior alveolar nerve block. J Am Dent Assoc 137(12):1685–1691
16. SF. M (2004) Handbook of local anesthesia, vol 4, 4th edn. Esevier Mosby, St Louis
17. Jung IY, Kim JH, Kim ES, Lee CY, Lee SJ (2008) An evaluation of buccal infiltrations and inferior alveolar nerve blocks in pulpal anesthesia for mandibular first molars. J Endod 34(1):11–13. https://doi.org/10.1016/j.joen.2007.09.006
18. Choi EH, Seo JY, Jung BY, Park W (2009) Diplopia after inferior alveolar nerve block anesthesia: report of 2 cases and literature review. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 107(6):e21–e24. https://doi.org/10.1016/j.tripleo.2009.02.009
19. Hussein R, Muhammad D, Omar O (2015) Comparison between infiltration and inferior alveolar nerve block anesthesia in extraction of non-vital mandibular posterior teeth (prospective clinical study). Zanco Journal of Medical Sciences 18(3):822–825. 10.15218/zjms.2014.00340
20. Shabazfar N, Daublander M, Al-Nawas B, Kämmerer PW (2014) Periodontal intraligament injection as alternative to inferior alveolar nerve block-meta-analysis of the literature from 1979 to 2012. Clin Oral Invest 18(2):351–358. https://doi.org/10.1007/s00784-013-1113-1
21. Berlin J, Nusstein J, Reader A, Beck M, Weaver J (2005) Efficacy of articaine and lidocaine in a primary intraligamentary injection administered with a computer-controlled local anesthetic delivery system. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 99(3): 361–366. https://doi.org/10.1016/j.tripleo.2004.11.009
22. Kämmerer PW (2012) Clinical and histological comparison of pulp anaesthesia and local diffusion after periodontal ligament injection and intrapapillary infiltration anaesthesia. Journal of Pain & Relief 01(05). https://doi.org/10.4172/2167-0846.1000108
23. Meechan JG (1992) Intraligamentary anaesthesia. J Dent 20(6): 325–332
24. Hochman MN (2007) Single-tooth anesthesia: pressure-sensing technology provides innovative advancement in the field of dental local anesthesia. Compend Contin Educ Dent 28 (4):186–188, 190, 192–183

25. Stoll P, Buhrmann K (1983) Intraligamental anesthesia for tooth extraction in patients with hemorrhagic diathesis. ZWR 92(11):545
26. Roahen JO, Marshall FJ (1990) The effects of periodontal ligament injection on pulpal and periodontal tissues. J Endod 16(1):28–33
27. Roberts GJ, Simmons NB, Longhurst P, Hewitt PB (1998) Bacteraemia following local anaesthetic injections in children. Br Dent J 185(6):295–298
28. Oulis CJ, Vadiakas GP, Vasilopoulou A (1996) The effectiveness of mandibular infiltration compared to mandibular block anesthesia in treating primary molars in children. Pediatr Dent 18(4):301–305
29. Corbett IP, Kanaa MD, Whitworth JM, Meechan JG (2008) Articaine infiltration for anesthesia of mandibular first molars. J Endod 34(5):514–518. https://doi.org/10.1016/j.joen.2008.02.042
30. Flanagan DF (2016) The effectiveness of articaine in mandibular facial infiltrations. Local Reg Anesth 9:1–6. https://doi.org/10.2147/LRA.S94647
31. El-Kholey KE (2013) Infiltration anesthesia for extraction of the mandibular molars. J Oral Maxillofac Surg 71 (10):1658 e1651–1655. doi:https://doi.org/10.1016/j.joms.2013.06.203
32. Fagade OO, Oginni FO (2005) Intra-operative pain perception in tooth extraction—possible causes. Int Dent J 55(4):242–246
33. Mehlisch DR (2002) The efficacy of combination analgesic therapy in relieving dental pain. J Am Dent Assoc 133(7):861–871
34. Vassend O (1993) Anxiety, pain and discomfort associated with dental treatment. Behav Res Ther 31(7):659–666
35. Reed KL, Malamed SF, Fonner AM (2012) Local anesthesia part 2: technical considerations. Anesth Prog 59(3):127–136; quiz 137. https://doi.org/10.2344/0003-3006-59.3.127
36. Takasugi Y, Furuya H, Moriya K, Okamoto Y (2000) Clinical evaluation of inferior alveolar nerve block by injection into the pterygomandibular space anterior to the mandibular foramen. Anesth Prog 47(4):125–129
37. Bataineh AB, Alwarafi MA (2016) Patient's pain perception during mandibular molar extraction with articaine: a comparison study between infiltration and inferior alveolar nerve block. Clin Oral Investig. https://doi.org/10.1007/s00784-016-1712-8
38. Briggs M, Closs JS (1999) A descriptive study of the use of visual analogue scales and verbal rating scales for the assessment of postoperative pain in orthopedic patients. J Pain Symptom Manag 18(6):438–446. https://doi.org/10.1016/s0885-3924(99)00092-5
39. Wright GZ, Weinberger SJ, Marti R, Plotzke O (1991) The effectiveness of infiltration anesthesia in the mandibular primary molar region. Pediatr Dent 13(5):278–283
40. Sharaf AA (1997) Evaluation of mandibular infiltration versus block anesthesia in pediatric dentistry. ASDC J Dent Child 64(4):276–281
41. Lima-Junior JL, Dias-Ribeiro E, de Araujo TN, Ferreira-Rocha J, Honfi-Junior ES, Sarmento CF, Seabra FR, de Sousa Mdo S (2009) Evaluation of the buccal vestibule-palatal diffusion of 4% articaine hydrochloride in impacted maxillary third molar extractions. Med Oral Patol Oral Cir Bucal 14(3):E129–E132
42. Kämmerer PW, Seeling J, Alshihri A, Daublander M (2014) Comparative clinical evaluation of different epinephrine concentrations in 4% articaine for dental local infiltration anesthesia. Clin Oral Investig 18(2):415–421. https://doi.org/10.1007/s00784-013-1010-7
43. Santos CF, Modena KC, Giglio FP, Sakai VT, Calvo AM, Colombini BL, Sipert CR, Dionisio TJ, Faria FA, Trindade AS Jr, Lauris JR (2007) Epinephrine concentration (1:100,000 or 1:200,000) does not affect the clinical efficacy of 4% articaine for lower third molar removal: a double-blind, randomized, crossover study. J Oral Maxillofac Surg 65(12):2445–2452. https://doi.org/10.1016/j.joms.2007.04.020
44. Isen D (2000) Articaine: pharmacology and clinical use of a recently approved local anesthetic. Dentistry today 19:72–77
45. Etoz OA, Er N, Demirbas AE (2011) Is supraperiosteal infiltration anesthesia safe enough to prevent inferior alveolar nerve during posterior mandibular implant surgery? Med Oral Patol Oral Cir Bucal 16(3):e386–e389
46. Madeira MC, Percinoto C, das Gracas MSM (1978) Clinical significance of supplementary innervation of the lower incisor teeth: a dissection study of the mylohyoid nerve. Oral Surg Oral Med Oral Pathol 46(5):608–614
47. Stein P, Brueckner J, Milliner M (2007) Sensory innervation of mandibular teeth by the nerve to the mylohyoid: implications in local anesthesia. Clin Anat 20(6):591–595. https://doi.org/10.1002/ca.20479
48. Yadav S (2015) Anesthetic success of supplemental infiltration in mandibular molars with irreversible pulpitis: a systematic review. J Conserv Dent 18(3):182–186. https://doi.org/10.4103/0972-0707.157238
49. Rogers BS, Botero TM, McDonald NJ, Gardner RJ, Peters MC (2014) Efficacy of articaine versus lidocaine as a supplemental buccal infiltration in mandibular molars with irreversible pulpitis: a prospective, randomized, double-blind study. J Endod 40(6):753–758. https://doi.org/10.1016/j.joen.2013.12.022
50. Yang J, Liu W, Gao Q (2013) The anesthetic effects of Gow-Gates technique of inferior alveolar nerve block in impacted mandibular third molar extraction. Hua Xi Kou Qiang Yi Xue Za Zhi 31(4):381–384
51. Claffey E, Reader A, Nusstein J, Beck M, Weaver J (2004) Anesthetic efficacy of articaine for inferior alveolar nerve blocks in patients with irreversible pulpitis. J Endod 30(8):568–571
52. Nusstein J, Reader A, Nist R, Beck M, Meyers WJ (1998) Anesthetic efficacy of the supplemental intraosseous injection of 2% lidocaine with 1:100,000 epinephrine in irreversible pulpitis. J Endod 24(7):487–491. https://doi.org/10.1016/S0099-2399(98)80053-8
53. Cohen HP, Cha BY, Spangberg LS (1993) Endodontic anesthesia in mandibular molars: a clinical study. J Endod 19(7):370–373. https://doi.org/10.1016/S0099-2399(06)81366-X
54. Devine M, Gerrard G, Renton T (2016) Current practice in mandibular third molar surgery. A national survey of British Association of Oral Surgeons membership. Oral Surgery:n/a-n/a. https://doi.org/10.1111/ors.12211
55. Kanaa MD, Whitworth JM, Meechan JG (2012) 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 38(4):421–425. https://doi.org/10.1016/j.joen.2011.12.006
56. Abdullah WA (2014) Articaine (4%) buccal infiltration versus lidocaine (2%) inferior alveolar nerve block for mandibular teeth extraction in patients on warfarin treatment. Journal of Anesthesia & Clinical Research 05(08). https://doi.org/10.4172/2155-6148.1000434
57. Zain M, Khattak SuR, Shah SA, Sikandar H, Khattak Y (2015) Comparison of effectiveness of 4% articaine buccal infiltration versus inferior alveolar nerve block in symptomatic mandibular 1st molar tooth 29(2015)
58. Bataineh AB, Alwarafi MA (2016) Patient's pain perception during mandibular molar extraction with articaine: a comparison study between infiltration and inferior alveolar nerve block. Clin Oral Investig 20(8):2241–2250. https://doi.org/10.1007/s00784-016-1712-8